Climate Change Management

Walter Leal Filho *Editor*

Climate Change and Disaster Risk Management

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Editor

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Editor
Prof. Walter Leal Filho
Research and Transfer Centre
"Applications of Life Sciences",
Faculty of Life Sciences
Hamburg University of Applied Sciences
Hamburg
Germany

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Preface

There has been some degree of reluctance in the past to consider disaster risk management within the mainstream of adaptation to climate variability and climate change; however, there is now wide recognition of the need to incorporate disaster risk management concerns in dealing with such phenomena. There is also a growing awareness of the necessity for a multisectoral approach in managing the effects of climate variability and climate change, since this can lead to a significant reduction of risk.

With storms, hurricanes, forest fires, floods, or droughts, matters related to “risk management”, “vulnerability”, or “risk analysis”—among others—always need to be duly considered. Knowledge about these inter-relations is needed in order to better integrate climate change mitigation and adaptation considerations into planning processes, as well as into implementation on the ground. This is exemplified in the UNFCCC Compendium on impacts, vulnerability, and adaptation methods, where a number of measures are outlined.

The fourth online climate conference, CLIMATE 2011, which draws from the success of the previous online events (CLIMATE 2008, CLIMATE 2009, and CLIMATE 2010), has filled a research gap and discussed many emerging issues related to climate variation, climate change, and disaster risk management. The event also introduced a variety of projects, initiatives, and strategies currently being undertaken and implemented in the five continents, which showcased concrete examples of how to ensure that matters related to climate variability and climate change are duly considered in disaster risk management.

I am therefore very pleased to introduce the book “Climate Change and Disaster Risk Management”, which is one of the outcomes of CLIMATE 2011. This publication is important for three main reasons:

1. It presents the latest findings from scientific research on climate variation, climate change, and their links with disaster risk management;
2. It showcases projects and other initiatives in this field that are being undertaken in both industrialized and developing countries, by universities and scientific institutions, government bodies, national and international agencies, NGOs and other stakeholders;

3. It discusses current and future challenges, identifying opportunities and highlighting the still unrealized potential for promoting better understanding of the connections between climate variation, climate change, and disaster risk management worldwide.

My thanks are due to all authors for their willingness to share their knowledge and for the time they have spent in writing and documenting their projects and their experiences. Thanks are also due to the CLIMATE 2011 team—Jelena Babir, Natalie Fischer, Olaf Gramkow, Franziska Mannke, Kathrin Rath, Josep de la Trincheria, and Johanne Vogt—for all their hard work. Finally, sincere thanks go to the International Development Research Centre (IDRC) for the support they provided, which has enabled the dissemination of this book to a worldwide audience, especially to people and organizations in developing countries.

I hope this book will provide valuable knowledge and information for international and regional disaster risk management specialists and climate change and planning experts, as well as for all those interested in the connections between climate change and disaster risk management. Enjoy your reading!

Spring 2012 Prof. Walter Leal Filho

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Chapter 1
Addressing Interpretive Uncertainty in Flood Risk Management

Roisin A. Bradford and John J. O'Sullivan

Abstract Extreme floods are the most common type of natural disaster in Europe. It is projected that future floods may be exacerbated by the effects of climate change. The concept of managing rather than preventing floods is now being recognised as an effective approach and is engrained in both national and European policy. The use of effective flood warnings and communication is an essential cornerstone of flood risk management. Uncertainty is also a key aspect of effective flood risk management. The concept of "interpretive uncertainty", defined as the differences in how people understand and interpret information, is emerging as a significant component in flood risk management and is the focus of this paper. The study involved extensive quantitative research of at-risk communities in four case study areas across Ireland, exposed to pluvial, fluvial and coastal risks as part of the ERA-Net CRUE UR-*flood* project. Approximately 2,200 postal questionnaires were administered across the four case study areas, with 436 returns; a response rate of 20 %. From an analysis of these results, the paper identifies barriers and obstacles to effective flood risk communication, focusing on before and during flood experiences such as risk perception, flood preparedness, information and warnings, communication methods and reacting to warnings. From these findings, recommendations are made on how these obstacles can be overcome.

Keywords Flood risk management · Flood warnings · Interpretive uncertainty

R. A. Bradford (✉) · J. J. O'Sullivan
School of Civil, Structural and Environmental Engineering, Newstead, Belfield, Dublin 4, Ireland
e-mail: roisin.bradford@ucd.ie

J. J. O'Sullivan
e-mail: jj.osullivan@ucd.ie

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Introduction

It is anticipated that future flood events will become more frequent and severe due to increased urbanisation of watersheds combined with the effects of climate change. As a consequence of this, the more traditional, structural approaches to dealing with flood risk are being recognised as unsustainable, resulting in a move towards flood risk management as a form of flood defence. This concept of managing rather than preventing floods is engrained in national policies such as the Report of the Flood Policy Review Group in Ireland (OPW 2004) and the Making Space for Water policy in the UK, and is underpinned by the EU Floods Directive (European Parliament and the Council of the European Union, 2007). Effective flood warnings and communication are essential to successful flood risk management; however, uncertainty can have a negative effect in this regard. This paper focuses on the emerging concept of "interpretive uncertainty", defined as the differences in how people understand and interpret information. The theory behind issuing flood warnings to reduce the negative impacts of flooding is based on the assumption that people will behave in a prescribed way when presented with certain information. In practice, however, this is rarely the case as a result of interpretive uncertainty. The objective of this paper is therefore to identify barriers and obstacles to effective flood risk communication based on an analysis of extensive quantitative data obtained from the public at risk of flooding in four Irish case study areas. Recommendations are made based on this analysis for improving flood risk communications. These recommendations will be useful to those responsible for developing or improving existing flood risk management communication plans.

Background

Warning dissemination and public response are known to be weak links in many current communication plans (Penning-Rowsell et al. 2000). Methods of warning and information dissemination vary from country to country. England and Wales have arguably the most direct method of issuing flood warnings through Floodline Warnings Direct (FWD). FWD sends text messages, emails, faxes or phone calls to those at risk (Twigger-Ross et al. 2009; Environment Agency 2011). FWD uses different warning messages depending on the level of risk. However, this system is not without its limitations. Currently, approximately 70 % of those who can sign up for FWD have not done so (Environment Agency 2011). In addition to this, not every property at risk is covered and non-English speakers and vulnerable, disconnected members of the public are not catered for. The system is one-way, with little room for questions to be asked. It also relies on people having and using the technology associated (mobile phones, Internet, etc.), and this technology being resilient to flooding (Twigger-Ross et al. 2009). The majority of current communication plans use the Internet for disseminating information and warnings, for example Ireland, Scotland, England, Wales, Australia, Norway and Germany (SEPA 2011; Environment Agency 2011; BOM 2011; NVE 2011). Radio and television announcements are also popular, for example in the USA, Australia and Germany (FEMA 2011; BOM 2011). Some countries use recorded messaging services that the public can call to listen to further information regarding a potential flood, for example Floodline in Scotland, England and Wales and Weathercall in Australia (SEPA 2011; Environment Agency 2011; BOM 2011). Other methods of warning include sirens (DEMA 2011), flood wardens (Twigger-Ross et al. 2009), and self-warning (Parker et al. 2009). Many studies agree that using multiple methods of communication is vital in case one fails, to ensure everyone is reached and to reinforce the message (Penning-Rowsell et al. 2000; Shaw et al. 2005; United Nations 2006). However, it is important that the message is consistent across all sources (United Nations 2006; Shaw et al. 2005). Regardless of the methods used, information provided is useless if the recipients do not understand it (Twigger-Ross et al. 2009). Lack of understanding of flood information is often due to a lack of participation of the community in the flood warning system (United Nations 2006). Furthermore, the public at risk may interpret information in unintended ways, leading to ineffective responses due to interpretive uncertainty. Therefore, addressing interpretive uncertainty in flood risk communication has the potential to improve flood current communication plans.

Methodology

Extensive quantitative research of the public at risk to fluvial, pluvial, coastal, residual and "new" risks was carried out in four case study areas across Ireland including Ballinasloe, Co. Galway; Wexford Town, Co. Wexford; Clonmel, Co. Tipperary and areas within the flood contour of the River Dodder in Dublin (Fig. 1.1). The research, as part of the ERA-Net CRUE UR-*flood* project, involved approximately 2,200 self-completion postal questionnaires being disseminated, with 436 completed returns; a response rate of 20 %. Details of questionnaire dissemination and type of risk within each case study area are shown in Table 1.1. Residents and small business owners within each area were targeted using a spatial database of addresses represented on a GIS platform combined with the 100 and 200-year flood extent envelopes for fluvial and coastal risks respectively. Respondents were therefore at risk to various types of flooding; however, they may not necessarily have experienced flooding in their current home. Questionnaires adhered to the key principles of questionnaire design, with the majority of questions being short and simple and of a pre-coded and prompted nature, and with both open-ended and closed questions being included. Questionnaires focused on themes including perception of risk, previous flood experience, flood preparedness, flood warnings, flood information, and uncertainty and risk. Questionnaires were

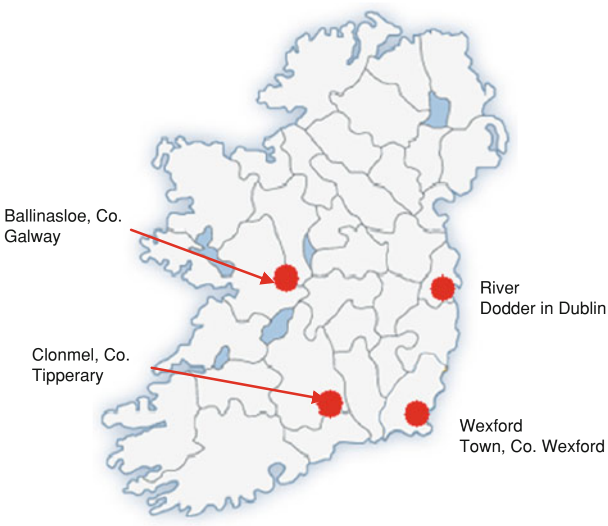

Fig. 1.1 Case study locations

posted along with a cover letter from the Office of Public Works (OPW), the lead agency for managing flood risks in Ireland, and a "freepost" self-addressed return envelope, following a notice in the local newspaper as well as an OPW press release a week prior. Reminder letters were sent to those who had not responded after approximately 2 weeks in order to boost return rates. Data were analysed using the computer program SPSS, with Chi-square tests, independent samples *t* tests, as well as one-way analysis of variance.

Results

The analysed sample in this study was representative of the Irish population in terms of gender, ownership of residence, education level, employment status, and age, comparing these factors with 2006 census data (CSO Ireland 2006). The non-response rate was therefore unlikely to have any effect on the representativeness of the sample. Due to the method of sampling within this study, whereby respondents were chosen from within the 100 or 200-year flood extent envelopes for fluvial and coastal risks respectively, each respondent within the sample was at risk to flooding. However, results showed that just 76 % of respondents perceived themselves to be at risk, with 14 % responding that they were "probably" at risk. 7 % of those surveyed responded that they did not live in a flood risk area, while the remaining 3 % did not know. A Chi-square test showed that perception of risk was directly related to having previous flood experience (Chi-square $= 41$, $df = 1$, $p < 0.001$). These results indicate a barrier to effective flood risk

Table 1.1 Flood risk type and questionnaire dissemination details in case study areas

Case study site	Type of risk	Total sent	Total returned	% returned
Ballinasloe	Fluvial, new	353	84	23.8
Wexford	Coastal	494	78	15.8
Clonmel	Fluvial, residual	649	126	19.4
Dublin	Fluvial, pluvial, coastal, residual	676	148	21.9
Total		2,172	436	20.1

management: those without previous flood experience have lower awareness levels than those who have been flooded previously. A recommendation therefore from this study is that efforts to increase community awareness should be focused on those living in flood risk areas with no previous flood experience. Residents new to the community should be particularly targeted, as 56 % of those with no flood experience in their current home had been living in that residence for 5 years or less ($t = 7.7$, $df = 269$, $p < 0.001$). While previous flood experience was found to be directly related to risk perception, a small portion of the sample (4 %) did not consider themselves to be at risk, despite having been previously flooded in that same residence. On further investigation it was found that 10 out of these 12 respondents lived in the same housing estate in Dublin. This area is close to the Irish Sea, rivers and canals; however, major flood protection works have been carried out since these respondents were last flooded in 2002. These results indicate that respondents living in areas protected by structural defences are unaware of the remaining residual risk that still exists, which may lead to their ability to respond to future flooding being compromised by this false sense of security. This finding highlights the importance of continuously educating those living close to structural defences of the residual risk that remains.

Levels of preparedness for flooding were low within the sample, with almost half of all respondents admitting to not being at all prepared or not very prepared. Twenty-eight percentage of those surveyed considered themselves slightly prepared; however, just 11 % stated they were very well prepared for flooding. An independent samples *t*-test proved that preparedness levels were directly related to previous flood experience within this sample, with those who had been flooded previously having significantly higher levels of preparedness than those with no experience ($t = 7$, $df = 180$, $p < 0.001$). Additionally, a one-way analysis of variance showed that preparedness levels increased with increasing frequency of floods affecting the home (1-way Anova, $F = 3.6$, $p = 0.028$). Surprisingly, no significant correlation was found between awareness of risk and levels of preparedness. This result is not consistent with suggestions found in scientific literature, that increasing risk perception will result in better community preparedness (Johnson et al. 2007; Shaw et al. 2005; Shidawara 1999). From these findings, it is clear that low levels of preparedness within at-risk communities is a barrier to effective flood risk management. However, the results presented indicate that increasing risk awareness alone will not necessarily have a significant impact on improving preparedness levels. Therefore, in order to improve the resilience of communities at risk, initiatives other than those with the sole function of raising awareness must be undertaken.

For the public at risk to be prepared for flooding, they must be able to access the relevant information. Information on risk and preparing for flooding is made available to the public by the OPW through two websites. The first, a flood information website, aims to provide practical help to all those whose homes or businesses may be at risk of flooding (OPW 2011a). The second, a flood hazard mapping website, shows information on areas that may be at risk of flooding (OPW, 2011b). Just 11 % of respondents within this sample had visited either of these websites, with the flood information website being slightly more popular than the flood hazard mapping site (with 9 % visiting compared to 6 %). As one respondent quoted, "*Was not aware that this website existed as there was no communication or information posts or otherwise*". When asked to rate the amount of information that is currently available in relation to both flood warnings and preparing for floods in Ireland, the majority of respondents (approximately 60 %) found the amount of information available to be "too little". Those who had visited either of the sites were more likely to rate the amount of information as "just right" than those who had not visited (Chi-square = 7.6, df = 2, $p = 0.022$). These findings, combined with a further result that the majority of those (60 %) that had accessed these sites found them to be helpful, suggest that highlighting the importance and increasing the awareness of these websites as a resource for flood information has the potential to reverse the perception that information is unavailable. A recommendation therefore from this study is that developing and raising awareness of available sources of flood-related information should be prioritised.

For flood communications, particularly flood warnings, to be successful, the information must be received, processed, interpreted and responded to effectively. However, the majority of respondents within this sample affected by floods had not received any warning during the last major flood (65 %). This figure depended on the case study area, decreasing to 40 % in Clonmel, where there is an official flood warning system in place, and increasing to 83 % in Dublin and Ballinasloe, where no such measures currently exist. Furthermore, results in Fig. 1.2 show that 80 % of those who received a warning of <2 h felt that this was not enough time to take action. The majority of those (67 %) receiving a longer lead time of 2–6 h, however, did have sufficient time to act, independent of the type of warning received. These results support suggestions made in scientific literature that for a warning to be effective there must be a lead time of at least 2 h (Parker et al. 2011).

Flood warnings are not always communicated to the public through their most preferred or accessible source. To investigate this, respondents were asked to identify from a list their most preferred method for receiving flood warnings. Results in Fig. 1.3 shows that the public at risk within this sample would prefer to receive flood warnings through an in-person visit. Given that this may not always be possible due to resource constraints, other popular sources include SMS messaging as well as phone calls. These results show a contrast to the current methods

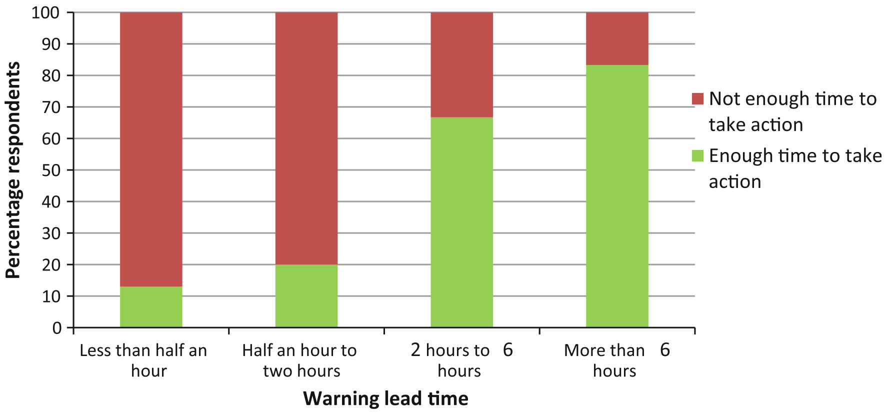

Fig. 1.2 Warning lead time received and time to take action

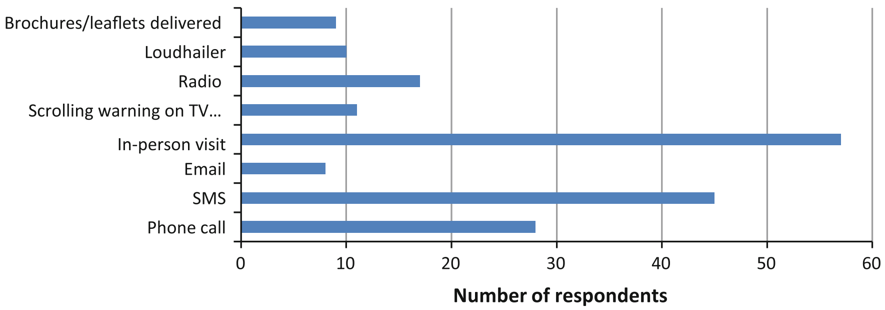

Fig. 1.3 Most preferred method for receiving a flood warning

of flood warning in Ireland, as the majority of respondents who received a warning during the last major flood received it through TV or radio announcements. Furthermore, demographic factors such as gender, age, language competency, education level and employment status were found to influence the preferred choice, reflected in respondents' comments such as:

> The best way to communicate with people in a flood situation is a guard/civil defence member/TD knocking on doors;
>
> I think a group message sent by text to mobile phones is the only foolproof method of generating awareness;
>
> There are a lot of elderly people in my area who do not use mobile phones or computers. For them a phone call or door-to-door would be best.

These results suggest that in order for everyone to be reached, multiple communication methods should be used, focusing on in-person visits, SMS messaging and phone calls where possible.

Further to receiving a flood warning, the public at risk must process and interpret the message. It is therefore crucial that the terminology used in the

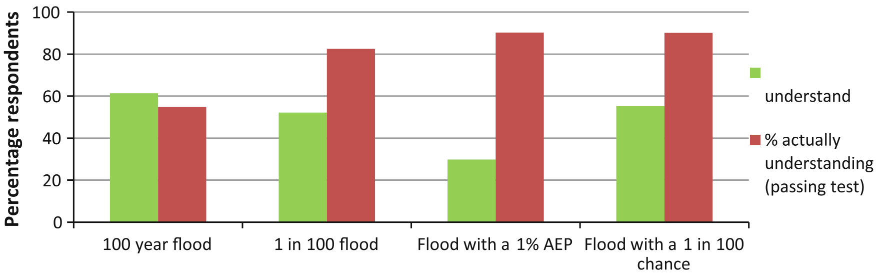

Fig. 1.4 Understanding of flood terminology in terms of claiming to understand and actually understanding

message is comprehensible. Terms such as a 100-year flood, a 1-in-100 flood, a flood with a 1 % annual exceedance probability (AEP), and a flood with a 1-in-100 chance of being equalled or exceeded are often used in flood warnings and communications. However, 40 % of respondents within this study claimed not to understand the 100-year flood term, increasing to over 70 % not understanding the 1 % AEP term. As the public's perception of their understanding may be different to their actual understanding of these terms, a test was presented to investigate whether the terms were correctly understood. This test was carried out by presenting the four flood terms and asking respondents to identify when each of these would happen again, with options given of "will happen in 100 years time" and "could happen any time". If respondents chose the first option, it was deduced that the term was not sufficiently understood. Results in Fig. 1.4 show that there are significant differences in how the public at risk interpret the terminology often used in flood warnings, with different levels of understanding for each term. This may lead to uncertainty being created in how people will react to this information. Interestingly, there was no correlation found between those who claimed to understand these terms and those who actually understood them. Factors such as perception of risk and previous flood experience, along with demographic factors such as age, speaking English as a first language, and employment status, had no effect on understanding these terms. More males than females, as well as those with higher education levels, claimed to understand these terms; however, these factors had no effect on actual understanding. From these findings it is clear that care is needed in deciding when and where these terms are used. Combining results from Figs. 1.4 and 1.5, however, suggests that the term "a flood with a 1-in-100 chance of being equalled or exceeded" should be used over the other three terms in flood communications, as it has both a high rate of understanding as well as a high preference rate.

Once the flood warning has been interpreted, a reaction will take place. Often, the first response upon receiving a warning is to tell someone. The majority of respondents within this sample would tell their neighbours, family and friends if they heard warning of an impending flood (Fig. 1.6). Only a small percentage (<2 %) admitted they would tell nobody, with one respondent quoting *"I would*

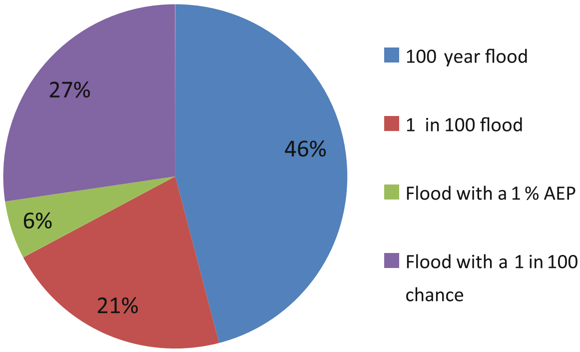

Fig. 1.5 Respondents' preferred terminology

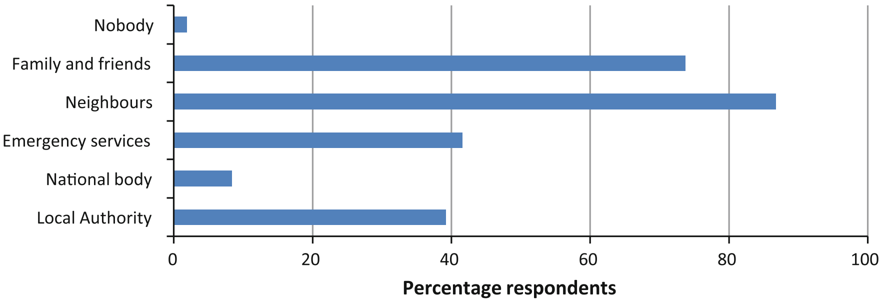

Fig. 1.6 Who would you tell of an impending flood

tell nobody, as no heed would be taken and my telling would get lost in some system". Approximately 40 % of respondents would tell the emergency services or the local authority, reducing to less than 10 % of those who would contact a national authority, with respondents quoting:

> No point contacting services; they never respond and flooding always happens when phones are not answered
>
> At previous flood warning conditions it was impossible to contact anyone in Dublin City Council or OPW; phones would not be answered
>
> As the local authority offices wouldn't be open at night time (after closing hours) what would be the point in contacting them?

Findings suggest poor lines of communication between the authorities and the public at risk, highlighting the importance of well-developed two-way communication channels between issuers and receivers of flood-related communication. The strength of communication within communities is a facilitator to effective flood risk communications and should be built on to promote increased community resilience, ensuring more people within the community are reached. This is reflected in comments from respondents such as:

> On the day in question I was awoken by my next-door neighbour standing on my wall and banging on my window. It's hard to believe but I may have slept through most of it if it wasn't for him.

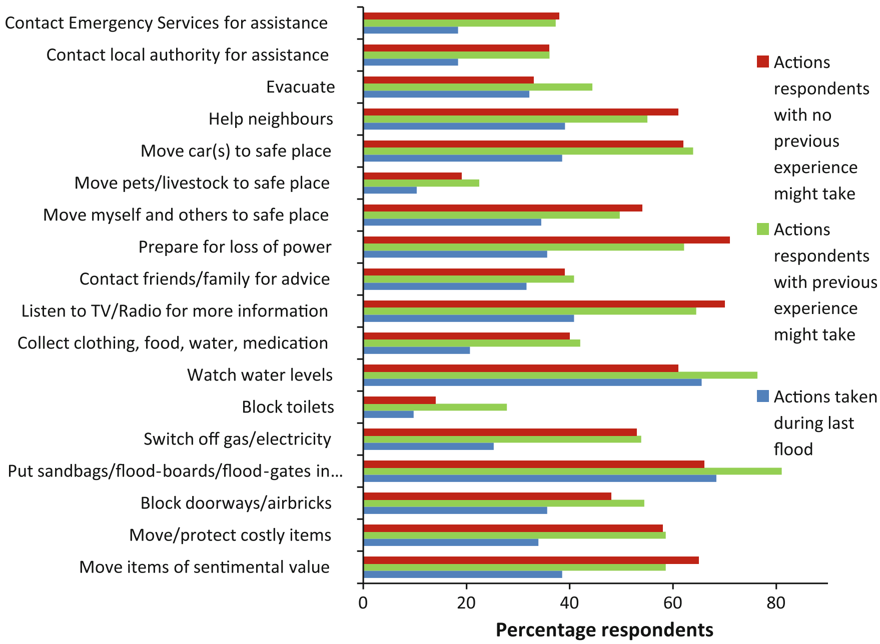

Fig. 1.7 Differences in actions taken during last flood and actions that might be taken in future floods for those with and without previous flood experience

To further investigate the differences in how the public at risk react upon receiving a flood warning, respondents affected by flooding were asked to identify from a list of 18 measures, which actions they carried out during the last major flood. In addition to this, all respondents were asked to choose from the same list of measures which actions they might take during a future flood, with results shown in Fig. 1.7. The most common action taken by respondents during the last major flood was to put sandbags, flood-boards or flood-gates in place, followed by watching the water levels. This was also the most common action respondents with previous experience would take in the future. These results contrast with actions those with no previous flood experience would most commonly take in future, i.e. listening to the TV or radio for more information and preparing for loss of power. Results suggest that being previously flooded had a large influence on what actions would be taken in the future. Those flooded previously chose options of evacuating, watching water levels, blocking toilets, putting sandbags, flood-boards or flood-gates in places, blocking doorways and moving pets or livestock to a safe place significantly more often than those without previous experience. These results indicate that being previously flooded leads to more preventative actions being taken, while those with no previous flood experience will seek further information. One respondent with no previous flood experience stated "*I don't know how to take action*". A recommendation can therefore be made based on these findings to provide information to those living in flood risk areas with no previous flood experience on how to effectively protect their homes from flood waters.

Conclusion

This paper identifies the barriers and obstacles to effective flood risk communication from an analysis of results from extensive quantitative data collected from the public at risk to fluvial, pluvial, coastal and "new" risks in four Irish case study areas focusing on pre-flood experiences such as perception of risk, residual risk, preparation for flood events and accessing information on flooding. In addition to this, during-flood experiences were focused on including receiving warnings and warning lead time, preferred communication methods, understanding terminology used in warnings as well as reacting to flood warnings in terms of both passing on the message and taking preventative actions. From this analysis, recommendations have been made on how the identified obstacles to effective flood risk communication can be overcome.

Recommendations based on pre-flood experiences from this study include:

- Target efforts to increase community awareness at those living in flood risk areas with no previous flood experience, focusing on new residents to the community.
- Continuously educate those living near structural defences of the residual risk that remains.
- Undertake initiatives other than those with the sole function of raising awareness.
- Develop and raise awareness of available sources of flood related information.

Recommendations based on during-flood experiences from this study include:

- Provide a warning lead time of at least 2 h.
- Use multiple communication methods, focusing on in-person visits, SMS messaging and phone calls where possible.
- Care is needed in deciding when and where terminology such as the "100-year flood" is used.
- Implement well-developed two-way communication channels between issuers and receivers of flood related communication.
- Build on existing communication networks within communities to promote increased community resilience, ensuring more people within the community are reached.
- Provide information to those living in flood risk areas with no previous flood experience on how to effectively protect their homes from flood waters.

These recommendations will be useful to those responsible for developing or improving existing flood risk management communication plans.

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Author Biographies

Roisin Bradford is a PhD student in the Centre for Water Resources Research (CWRR) in the School of Civil, Structural and Environmental Engineering in University College Dublin (UCD). Following graduating with a BEng in Civil Engineering from UCD in 2008, her research interests include understanding interpretive uncertainty in flood risk communications.

Dr John O'Sullivan is in the CWRR the School of Civil, Structural and Environmental Engineering at UCD. His current research is focused on river hydraulics, hydrology and flooding. Dr O'Sullivan has been involved in national and European projects (ERA-Net and INTERREG) in these areas.

Chapter 2
An Analysis of the Causes of Non-Responses to Cyclone Warnings and the Use of Indigenous Knowledge for Cyclone Forecasting in Bangladesh

Shitangsu Kumar Paul and Jayant K. Routray

Abstract This paper explores the causes of non-response to cyclone warning and unwillingness to seek refuge and identifies natural methods for predicting cyclones and storm surge through local knowledge, which could be integrated into a modern cyclone forecasting system in coastal Bangladesh. Despite significant progress in cyclone forecasting in Bangladesh, still it lacks in clear communication of warning information to people at risk at the local level, and also in terms of accuracy in the prediction of landfall timing as well as intensity factor. The study reveals that coastal inhabitants are frequently familiar with cyclones and aware of the potential risks; however, they do not respond to cyclone warnings proactively because of poor road networks, long distances between home and cyclone shelters, low capacity of cyclone shelters, fear of burglary and stealing of household assets and goods, disbelief and misinterpretation of warning information, etc. There is also a higher degree of fatalism among the people. There are other reasons why people do not respond to official warnings, such as poor understanding of cyclone warnings, past experience of the failure of warnings, no or limited income-earning opportunities during and after the cyclone if people decide to evacuate, pressure from employers to go fishing, etc. This study also explores the fact that coastal inhabitants can predict the onset of cyclones based on local indigenous knowledge gained through everyday life on the coast. This method of indigenous cyclone prediction is based on a combination of different factors, such as unusual animal behaviour, water and weather conditions, etc. The present study advocates building

S. K. Paul (✉)
Geography and Environmental Studies, University of Rajshahi, Rajshahi, 6205, Bangladesh
e-mail: shitangsuk@yahoo.com

J. K. Routray
Regional and Rural Development Planning (RRDP), and Disaster Preparedness, Mitigation and Management (DPMM), School of Environment, Resources and Development (SERD), Asian Institute of Technology, P.O. Box 4, Klong Luang, Pathumthani 12120, Thailand
e-mail: routray@ait.ac.th

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awareness of proactive responses to official cyclone early warnings while integrating local knowledge systems in order to improve the proactive response rate and establish reliable forecasting that would help in disaster mitigation and lessen the emergency management activities.

Keywords Cyclone warning · Community vulnerability · Indigenous knowledge · Cyclone sidr · Bangladesh

Introduction

Severe cyclones and storm surges are quite common in Bangladesh (Wisner et al. 2004; Ali 1999; Paul 2009a). Geographic location, the unique natural setting of the country and its tropical monsoon climate modify and regulate the climatic condition and make the country more vulnerable to cyclones and storm surges (As-Salek 1998; Madsen and Jakobsen 2004; Paul and Rahman 2006; Paul 2009a). The physical and meteorological conditions necessary for generating tropical cyclones exist in the Bay of Bengal (Murty and El-Sabh 1992; Haque 1997), which is considered to be one of the ideal grounds for cyclone formation as it has 6–10 % of tropical cyclones of the world (Gray 1985; Haque 1997; Murty and El-Sabh 1992; Paul 2009a, b). On average, annually 12–13 depressions are formed and at least one powerful cyclone strikes Bangladesh each year (Mooley 1980; Haque 1997; Paul 2009a, b). Global warming is thought to be an important cause of increased cyclone events in the Bay of Bengal (IPCC 2001; Emanuel 2005; Ahmed 2005). A growing body of studies is increasingly drawing attention to the potential impacts of climate change on coastal population, which is quite vulnerable to various natural catastrophes (Nicholls 1995; Nicholls et al. 1995; Mimura 1999; Nicholls et al. 1999). The Intergovernmental Panel on Climate Change (IPCC 2001) reports that cyclone tracts will remain unchanged, with the possibility of increasing peak intensities by 5–10 % under current climate change conditions. This would have severe implications for Bangladesh, which is already vulnerable to several hydro-meterological disasters (Ahmed 2005).

Several disastrous cyclones have struck Bangladesh: in 1822, 1876, 1961, 1965, 1970, and 1991 (Wisner et al. 2004; Dube et al. 2004; GoB 2008). Earlier studies show that 80–90 % of global losses and 53 % of total cyclone-related deaths worldwide occur in Bangladesh (Ali 1999; GoB 2008; Paul 2009a, b). About 42 % of deaths related to cyclone have been recorded in Bangladesh in the last two centuries (Nicholls et al. 1995). For example, in 1971 the cyclone-induced total death toll was estimated format between 300,000 and 500,000, with 100,000 missing people; estimated damage was about USD 450 million. After the 1991 cyclone, the official death toll was recorded as 140,161 and the total affected population totalled 10,721,707; estimated damage was USD 1.8 billion to 4.3 billion. Compared to the cyclones in 1970 and 1991, the death toll in 2007 was relatively small: approximately 3,406 people died and 55,000 were injured, with more than 1,000 missing, and estimated damage of USD 1.6 billion (Ali 1980; Haider et al. 1991; GoB 2008; Paul 2009a, b). In addition to the geophysical characteristics of the Bangladesh coast, the poor socio-economic conditions of coastal inhabitants also contribute to increasing the vulnerability of inhabitants to cyclones and storm surges (Paul 2009a). Livelihoods of coastal populations are highly dependent on ecosystems linked with agriculture, fishery, forestry and salt farming, etc. Therefore, the increasing trend of cyclones will certainly affect the livelihoods of vulnerable populations living in low-l ying coastal Bangladesh (Mian 2005, Islam 2008).

Despite being poor and vulnerable to a range of natural hazards, Bangladesh has made significant progress in disaster management in recent years (Paul 2009a, b). Studies by Blake (2008), Heath (2007), Hossain et al. (2008), and Shamsuddoha and Chowdhury (2007) confirm that the lower-than-expected death toll and damage caused by Cyclone Sidr in Bangladesh was the result of timely cyclone forecasting and dissemination of warnings, as well as the evacuation of vulnerable people living in cyclone-prone areas. Disaster warning is considered as a linear process of communication between warning-issuing organisations and recipients of the warnings (Sorensen and Sorensen 2006). Irrespective of hazards, the main objective of warning is to reduce disaster impacts through enabling people to take precautionary measures. Therefore, the success of warnings depends on appropriate hazard detection, information dissemination, and responses by affected people (McLuckie 1970; Rogers 1985; Sorensen and Mileti 1987; Quarantelli 1980; Haque 1997). In addition to a variety of socioeconomic factors, psychological and cultural factors may also determine the human response to warning (Drabek 2004; Post et al. 2009). A number of efforts have been made to document such factors during hurricanes (Dow and Cutter 1998), floods (Drabek 2000), and several other disasters (Sorensen 2000). A growing body of literature has recently been developed on human responses to hazard warning at individual and organisational level (Drabek 1986; Lindell and Perry 1992; Mileti and Sorensen 1990; Sorensen 2000; Mileti and Peek 2000), and has used theoretical framework to describe public response to warning messages (Wogalter et al. 1999; Lindell and Perry 2004). However, very little research has been conducted on seeking shelter in response to warnings (Liu et al. 1996; Sorensen 2000).

Apart from modern disaster forecasting, people can understand forthcoming danger by looking at natural signs (Gregg et al. 2006). Coastal inhabitants in Bangladesh can predict impending cyclones by using age-old indigenous knowledge gained from nature and their ancestors through their experiences of recurrent cyclones. Nonetheless, such indigenous knowledge and experiences are subsidised neither by government nor non-government organisations; nor is it formalised in policy mechanisms. Even coastal communities are not aware of their potential capabilities to face the challenges of the disasters. Research on understanding the relationship between natural hazard-warning signs and human behaviour is relatively scarce (Gregg et al. 2006). A few sporadic attempts have been made to address this issue, such as by documenting local knowledge on cyclone warning (Howell 2003) and ambiguous, seldom specific natural signs that can be used to predict tsunamis (Gregg et al. 2006). In Bangladesh, local knowledge on disaster mitigation has mostly emphasised riverine hazards; it includes methods of community response, cropping pattern adjustment and indigenous strategies for coping with flooding (Islam 1980; Paul 1984; Rasid and Paul 1987; Schmuck 1996; Rasid 1993, 2000; Haque and Zaman 1989, 1993, 1994; Rasid and Mallik 1995; del Ninno and Dorosh 2003; Rasid and Haider 2003; Few 2003; Brouwer et al. 2007; Khandker 2007; Paul and Routray 2010a), and for coping with riverbank erosion (Haque and Zaman 1989; Mamun 1996; Hutton and Haque 2004). Few studies focused only on measures to adapt climate change induced rise in sea level, coping with cyclone, storm surge and mitigation measures (Islam 1971, 1974, 1992; Murty and Neralla 1992; Murty and El-Sabh 1992; Khalil 1992, 1993; Matsuda 1993; Chowdhury et al. 1993; Ali 1999; Choudhury, et al. 2004; Karim and Mimura 2008; Paul 2009b; Paul and Routray 2010b), community responses to multiple coastal hazards (Parvin et al. 2008), dissemination of cyclone forecasting, or adaptive responses, preparedness and management issues (Haque 1995, 1997; Schmuck 2003; Paul and Rahman 2006; Khan 2008).

A review of the existing literature shows that, although a number of studies have been carried out in Bangladesh looking at different aspects of flooding, cyclone and storm surge, a systematic documentation of the causes of human ignorance of cyclone warning, reluctance to seek refuge, and the natural signs of cyclone and storm surge, is lacking. Systematic and in-depth studies on responses to cyclone forecasting in general and indigenous knowledge for predicting cyclones in particular virtually do not exist. It is therefore imperative to collect, compile and systematise the diverse range of indigenous knowledge before it disappears. This paper aims to fill this gap by showing human behavioural responses to cyclone warnings and identifying indigenous knowledge on natural warning signs of cyclones and storm surges. The paper also provides some policy measures to integrate local knowledge in modern cyclone forecasting, with particular reference to Cyclone Sidr in Bangladesh. The practical significance of these findings may help policymakers, planners and practitioners to advise on interventions for enhancing the effectiveness of current cyclone forecasting systems, with a broader goal of building a disaster-resilient coastal community.

Study Area and Methodology

The study was conducted in Angulkata Village of Amtoli Thana, Tatulbaria Village of Taltoti Thana in Bargona District, and Charkashem Village of Rangabali Thana in Patuakhali District in the central coastal area of Bangladesh (Fig. 2.1). Study villages were selected purposively based on earlier studies, which indicated vulnerability of all three locations to multiple coastal disasters (Ortiz 1994; Huq et al. 1996; Ali and Chowdhury 1997; Ali Khan et al. 2000; World Bank 2000; Singh et al. 2001). Considering such vulnerability, three study villages

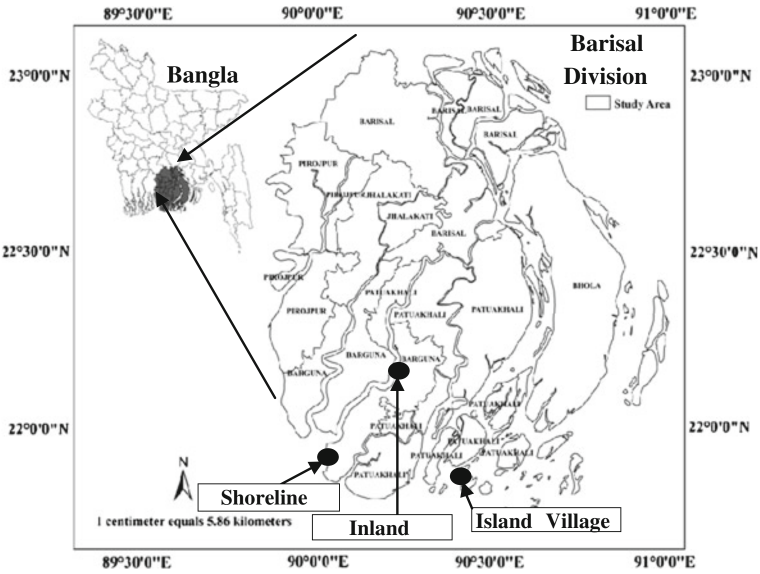

Fig. 2.1 Location map of the study villages

were selected to represent Island, Shoreline and Inland villages to explore the location variations in awareness among inhabitants. **Charkashem** is an offshore island, whereas Tatulbaria is located on the shoreline of the Bay of Bengal; Angulkata is approximately 30 km inland and located on the bank of the River Paira. Angulkata and Tatulbaria villages are surrounded by polder. The southern part of Charkashem Village is covered by planted mangroves. In the present study, Angulkata Village will be termed as Inland, Tatulbaria as Shoreline and Charkashem as Island village to understand the comparative pictures of three locations.

The research is based on both secondary and primary data. Primary data was collected by the first author through key informant interviews, focus group discussions and a household questionnaire survey. By assuming a 95 % confidence level, the total sample size for the household questionnaire survey was 331 out of 788 households. Samples were drawn proportionately by using simple random sampling from three villages. However, this provides opportunity to select households without any bias. Descriptive statistics are used to analyse data, while in a few cases a Chi-square test is used to identify similarities and differences among the villages. The present study is solely focused on the respondent's perception of various awareness-related issues. In-depth understanding, cross sectional data and expert opinion is to some extent missing for the confirmation of findings. Reliability and validity of study variables are not properly explored through triangulation.

Out of the total respondents, approximately 90 % were males and 10 % were females. About 86 and 64 % of respondents have settled in Island and Shoreline villages respectively from various inland locations. Respondents' spatial mobility in terms of permanent migration to vulnerable disaster-prone locations is very common in coastal Bangladesh. More than 64 % of the respondents are illiterate; 31 % have grade five and grade ten educational attainment, and 5 % a higher level of education. The most dominant primary occupation of respondents is fishing (34 %), followed by agriculture (29 %) and daily-wage labour (15 %). Dependency on agriculture is higher in Inland than in both Shoreline and Island villages. Average ownership of agricultural land is 0.35 acres. More than half (52.3 %) of the respondents do not own any farmland. The average annual household income is 72,483 Taka (USD 1049; 1 $ = 69.1 BDT in September 2010).

Cyclone Forecasting System in Bangladesh: A Brief Review

The Bangladesh Meteorological Department (BMD) is the main responsible organisation and authority of cyclone warning in Bangladesh. It not only prepares warnings but also provides warnings to the public media for dissemination (Miyan 2005); the Cyclone Preparedness Programme (CPP), meanwhile, is responsible for the dissemination of warnings to the coastal villagers. The Storm Warning Centre (SWC) is a specialised body of the BMD, responsible for weather forecasting and issuing warnings to sea and river ports, public, non-governmental organisations (NGOs), relief and rehabilitation authorities and local level administrative officials (Chowdhury 2002). CPP was established after the devastating cyclone of 1970. The League of Red Cross, currently the International Federation, was asked by the General Assembly of the United Nations to carry out pre-disaster planning for Bangladesh. In 1972, the CPP of Bangladesh Red Crescent Society (BDRCS) started its operations. In June 1973 it was jointly brought under the Bangladesh Ministry of Disaster Management and Relief (MDMR) and the Bangladesh Red Crescent Society (BDRCS) (CPP 2009).

After the formation of a cyclonic storm in the Bay of Bengal, the Storm Warning Centre of the BMD issues special weather bulletins from time to time till landfall. The volunteers are provided with a Depression Tracking Map, and they receive radio instruction from the CPP Control Room to plot the track on the map as bulletins are received from the BMD. The tasks of the volunteers include the arduous wide dissemination of warnings by bicycle, walking, using megaphones, sirens, signal lights, and signal flags (Paul 2009a). The cyclone warning flags are hoisted in port, cyclone shelters, public buildings, community centres, or local government organisations in coastal areas following a warning from the BMD to communicate an impending cyclone. The CPP volunteers ensure the hoisting of flags. One flag is hoisted for caution, two flags for danger and three flags for great danger. Such displays can serve as a means of warning dissemination and at the same time prepare the community for an appropriate response, which will in turn increase the effectiveness of warning (Miyan 2005).

In recent times, cyclone warning systems have improved a lot because of information and communication technology, especially Internet, mobile phones, and improved broadcasting technology with global television channels (Hossain et al. 2008). However, though significant improvements have been made in cyclone warning in Bangladesh, it still has several limitations (see Haque and Blair 1992, Jahan 1992, Hossain et al. 2008, Tatham et al. 2009). The existing warning system is cumbersome, not easy to understand and even sometimes incomprehensible to educated people as well (Haque and Blair 1992, Miyan 2005). Due to the criticism of having different signal systems for maritime and river ports, the BMD has recently unified the warning system with eight sets of signals using the Beaufort scale (Habib 2009). Tables 2.1 and 2.2 gives the cyclone warning signals for maritime and river ports (signal numbers five through seven are used for a weak or moderate cyclonic storm, depending upon the landfall point). Moreover, the language used in warning signals and special weather bulletins at the time of depression formation in the Bay of Bengal, which are disseminated through electronic media, is not simple. People are not conscious of the implications of different signal numbers; nor are they aware of the different signals for maritime and river ports. Therefore, the actual message often fails to be conveyed to the common people (Jahan 1992; Miyan 2005). Inaccurate predictions in terms of the precise location of cyclones, landfall timing, cyclone intensity and movement, intensity of impacts (for example the amount of rainfall from an impending cyclone), and storm surge height with specific stage (e.g. high/spring tide and low/neap tide) during the landfall, has often been criticised (Haque and Blair 1992; Miyan 2005; Hossain et al. 2008).

In the past, in many cases warnings were inaccurate on the landfall time of destructive cyclones. This is not a new phenomenon, as is revealed when the earlier studies of Frank and Hossain (1971), after the great Bhola cyclone in 1970, are compared with a study carried out after Cyclone Sidr in 2007 (Hossain et al. 2008). These weaknesses in the cyclone warning system of Bangladesh need to be addressed properly to improve the efficiency of the existing warning system for making people proactive and more resilient against future cyclones.

Discussions on Community Preparedness and Response to Cyclone Warning Based on Survey Results

The cyclone warning in November 2007 (Sidr) was disseminated among the coastal inhabitants more efficiently than with any other cyclone in the contemporary history of Bangladesh. Even though dissemination of warning was efficient, millions of people were trapped on tiny islands along the coastline with no place to go because of the flatness, low elevation of the land, and having no higher ground for shelters. In general due to effective early warning and massive evacuations, the death tolls were less in 1991 and 1970 cyclones. However, property damage was severe or even more that caused in 1991. The super-cyclone Sidr was first detected on 9 November 2007 between the Andaman and Nicobar Islands; it turned into a cyclonic storm with a

Table 2.1 Cyclone and storm surge impacts and other characteristics of study villages

Cyclone and storm surge Impacts and other attributes	Inland village	Shoreline village	Island village
Location	30 km away from the coast	Shoreline of the Bay of Bengal	Island in the Bay of Bengal
Storm surge height during Sidr (m)	1–1.5	3–4	>4
Coastal embankment	Earthen embankment on riverside	Earthen embankment along the coast	No embankment
Cyclone shelter	Available (one)	Nil	Nil
Educational institution	One primary school	Nil	Nil
Number of deaths due to Sidr in 2007	Male = 0 Female = 6 Children = 6 Total = 12	Male = 3 Female = 13 Children = 14 Total = 30	Male = 1 Female = 0 Children = 0 Total = 1
Number of injured people due to Sidr in 2007	Male = 26 Female = 39 Children = 22 Total = 87	Male = 27 Female = 23 Children = 8 Total = 58	Male = 11 Female = 11 Children = 9 Total = 31
Average damage (including loss of earnings, damage to houses, reconstruction cost, damages to crops, household assets, poultry, livestock, fishery, trees, boat, net and fishing accessories, and healthcare cost) per household (Taka)	64,597	96,796	69,033
Sickness per household (persons/100 household)	96	117	142
Households having access to food during and post cyclone (% household)	36	15	5
Migrated permanently	Six persons	Two persons	None

Source Key informants interview and household survey, 2009

core wind speed of 216 kph (135 mph) on 13 November. The cyclone struck off-shore islands at around 6.30 p.m. and made landfall by the evening of 15 November on the Khulna-Barisal coast of Bangladesh. Aslight difference was noticed in the landfall timing, which was predicted to be at noon on 15 November by the Bangladesh Meteorological Department (BMD). On 15 November, the Bangladesh Meteorological Department had advised the maritime port of Mongla to keep the Great Danger Signal No. X and Cox's Bazar signal No. IX hoisted. Messages had been sent out regularly to the coastal communities through electronic media, and Warning signal flag 3 was hoisted. The CPP mobilised its 44,000 volunteers to implement a community-based warning system utilising megaphones and other

Table 2.2 Cyclone signal system for maritime and river ports in Bangladesh

No.	Maritime signals		Riverine signals	
	Warning signal	Wind speed (kph)	Warnings signal	Wind speed (kph)
1	Distant cautionarys signal No. I	51–61	Not applicable	–
2	Distant warnings signal No. II	62–88	Not applicable	–
3	Local cautionary signal No. III	40–50	Local cautionary signal No. III	40–50
4	Warning signal No. IV	51–61	Warning signal No. IV	51–61
5	Dangers signal No. VI	62–88	Dangers signal No. VI	62–88
6	Great dangers signal No. VIII	89–117	Great danger signal No. VIII	89–117
7	Great dangers signal No. IX	118–170	Great danger signal No. IX	118–170
8	Great dangers signal No. X	>170	Great danger signal No. X	>170

Source Adopted from BMD (2009)

devices. Apart from the dissemination of warning the emergency response authority had prompted a massive evacuation of about 2 million people from low-lying coastal areas (GoB 2007).

People usually pass through several socio-psychological steps in the process of responding to a warning. These can include hearing the warning, understanding the meaning of the warning, personalising the risk, and finally deciding to respond to the warning (Mileti 1995). Therefore, the first step is receiving or hearing the cyclone warning as siren or message (Mileti and Sorensen 1987). The present study finds that among the surveyed respondents, 83.38 % had received warning prior to the landfall of Cyclone Sidr. However, Haque (1995) reported that more than 95 %—and Haque and Blair (1992) reported almost 99 % of respondents had received cyclone warning prior to the 1991 cyclone on the south-eastern coast of Bangladesh. Such findings reveal comparatively weaker dissemination of cyclone warning in the central areas of the coast of Bangladesh in 2007. The study also finds regional variation in the dissemination of cyclone warning; for example Inland villagers (95.45 %) had received more warning than Shoreline (90 %) and Island (13.95 %). Such disparities in cyclone warning dissemination were closely associated with the different levels of situation severity at different locations. Similarly, primary sources of cyclone warning significantly varied among the villages. Bangladesh Red Crescent Society Volunteers had played a vital role in disseminating the warning among Inland and Shoreline villagers, while radio broadcasting and word-of-mouth from neighbours were the major sources of cyclone warning in all three study villages. This finding is inconsistent with Haque (1995), who stated that BDCRS volunteers were the more important source of information in offshore islands. Local government officials and NGOs also played a vital role in Inland village, which is close to the sub-district headquarter. However, this finding is consistent with Haque's (1995) conclusion that local

Table 2.3 Primary sources of early warning for Cyclone Sidr, 2007 (multiple responses)

Sources of early warning	Study villages							
	Inland (N = 189)		Shoreline (N = 81)		Island (N = 6)		All (N = 276)	
	N	% of cases	N	% of cases	N	% of cases	N	% of cases
Radio	83	43.9	66	81.5	3	50	152	55.1
Television	5	2.6	2	2.5	0	0.0	7	2.5
Newspaper	4	2.1	0	0.0	0	0.0	4	1.4
Bangladesh red crescent society volunteers	139	73.5	71	87.6	1	16.7	211	76.4
Local government, NGOs	44	23.3	3	3.7	0	0.0	47	17.1
Word-of-mouth (peers, relatives, neighbours)	135	71.4	57	70.4	6	100	198	71.7

Source Household Survey, 2009

government officials were more important source of information in urban areas than islands. The warnings were received from a wider range of primary sources in the Inland and Shoreline communities than in the Island community. In general, radio broadcasting and word-of-mouth from neighbours or relatives were the most common sources of information in all three locations (Table 2.3).

Several earlier studies show that mass media and broadcast media are the most effective sources of primary information for warning dissemination (Perry et al. 1982; Quarantelli 1980), though some scholars argue that television is more effective than radio (Turner et al. 1981; Baker 1979). Some scholars in fact suggest that radio is more effective than television (Dillman et al. 1982, Drabek and Stephenson 1971). The findings of the present study suggest radio was an important broadcast media for disseminating cyclone forecasting in remote rural coastal areas of Bangladesh. The present study finds that 18.20 % of respondents in Inland, 21.10 % in Shoreline, and 14.00 % in Island, had radio. The majority of respondents in all three villages were detached from modern warning facilities and vulnerable to impending cyclones due to not having radio or any other means of communication. The present study explores the fact that 28.3 % respondents in the Inland, 34.4 % in Shoreline and 27.9 % in Island had rarely listened cyclone forecasting information. Only 13.6, 12.2 and 2.3 % of respondents regularly listened to weather forecasting in Inland, Shoreline and Island respectively (Table 2.4). Moreover, respondents with radio or television did not necessarily regularly listen to cyclone forecasting. Although many respondents in rural areas might not have had their own radio or television, many of them frequently listened to news using a neighbour's radio or television. When they heard news of cyclone formation in the Bay, they became more curious to know about the further development of the cyclone. Significant differences do not exist between villages in terms of listening of weather forecasting.

After receiving cyclone warning, the next stage is to understand such a warning in order to take proactive action (Mileti 1995). The present study finds that 48.5,

Table 2.4 Distribution of households based on numbers of people who listen to cyclone warnings

Listening pattern	Study villages						All villages	
	Inland		Shoreline		Island			
	N	%	N	%	N	%	N	%
Rarely	56	28.3	31	34.4	12	27.9	99	29.9
Sometimes	42	21.2	26	28.9	16	37.2	84	25.4
Often	50	25.3	16	17.8	8	18.6	74	22.4
Very often	23	11.6	6	6.7	6	14.0	35	10.6
Always	27	13.6	11	12.2	1	2.3	39	11.8
Total	198	100	90	100	43	100	331	100
Chi-square χ^2 Value = 12.696, df = 8, $p = 0.123$								

Source Household Survey, 2009

64.4 and 34.9 % of household members in Inland, Shoreline and Island respectively had some understanding of cyclone warning. This study also finds significant differences between villages in terms of family members' understanding of cyclone warning (χ^2 Value = 11.480, df = 2, $p = 0.003$). A higher number of household members in the Shoreline village had a good understanding of cyclone warning than the Inland and Island. Thus variation exists in the respondents' understanding of warning, which could be linked with the education level of household members (Perry et al. 1981). The present study also finds that a majority of respondents in all three villages did not have any idea about the implications of cyclone signals. About half of the respondents or family members in the Inland, about one quarter in the Shoreline and two-thirds of respondents in the Island village did not understand or did not have any idea about official cyclone signals. 17.2, 51.1 and 11.6 % of respondents or respondents' family members understood cyclone signals superficially, without having a clear idea about the implications of signals. 28.8, 12.2 and 14 % respondents understood some signals in the Inland, Shoreline and Island villages respectively (Table 2.5). By contrast, very few respondents in all three villages had some understanding about all the signals (5.1, 4.4 and 9.3 % in Inland, Shoreline and Island respectively). This study also finds that respondents with an understanding of all cyclone signals were in most cases the volunteers of CPP. Understanding of cyclone signals was better in Shoreline than in inland and Island. Better-educated people in all three villages had perhaps a better understanding of cyclone warning, while huge numbers of illiterates were incapable of grasping the meaning of cyclone forecasting signals.

Avoiding locations exposed to cyclones for fishing reveals a consciousness and personalisation of risks among fishing communities (Mileti 1995). This study finds that although the majority of the fishermen usually avoid cyclone-exposed locations for fishing, some of them were still forced to go fishing even though they had received a cyclone warning message. About half of the respondents in the Inland village who went fishing after the formation of the depression on the sea mentioned that their main reason was earning money for meeting daily household needs, compared with

Table 2.5 Distribution of households by household member's level of understanding of cyclone warning

Level of understanding	Study villages						All villages	
	Inland		Shoreline		Island			
	N	%	N	%	N	%	N	%
Understand all signals	10	5.1	4	4.4	1	2.3	15	4.5
Understand some signals	57	28.8	11	12.2	6	14.0	74	22.4
Understand superficially	34	17.2	46	51.1	5	11.6	85	25.7
Cannot understand	97	49.0	29	32.2	31	72.1	157	47.4
Total	198	100	90	100	43	100	331	100
Chi-square	χ^2 Value = 48.45, df = 6, $p = 0.000$							

Source Household Survey, 2009

12.5 and 17.4 % of respondents who went fishing for this reason in the Shoreline and Island villages. Non-availability of alternative jobs forced a large number of respondents to gofishing (29.2, 24 and 17.4 % in the Shoreline, Inland and Island villages respectively). Pressure to repay loans from "mahajans" or "arotdars", or paying regular instalments to NGOs, forced the behaviour of many of the respondents in Island (26.1 %), Shoreline (22.9 %) and Inland (4 %). These reasons were mentioned by the small-scale subsistence fishermen in all three villages, who live below the poverty line for most of the year. Moreover, comparatively high poverty is revealed in Island (39.1 %), followed by Shoreline (35.4 %) and Inland (24 %). Focus group discussions and field observations have found that this is linked to deep sea fishing. Arotdar usually provide conditional money to selected fishermen for preparing boat, nets and other fishing accessories. Some arotdar have their own fishing boats and nets, and usually employ fishermen on a seasonal basis. In many cases they provide advance money to the fishermen to work for whole season.

Factors Discouraging People from Seeking Refuge

Prior to the landfall of Sidr, a majority of households had received a cyclone warning and were aware of the potential impacts of damage from the cyclone and storm surge; responses, however, were varied. Only 18.7 % of respondents in Inland and 8.9 % in Shoreline responded to the cyclone warning by seeking refuge in nearby cyclone shelters; none of the respondents at all sought refuge in Island (Table 2.6). One cyclone shelter and one primary school-cum-cyclone shelter were available in Inland, while one cyclone shelter was available in the neighbouring village for Shoreline villagers. However, no cyclone shelter was available in Island. Due to the limited capacity and facilities of the cyclone shelters, very limited numbers of households (13.6 %) sought refugee in Inland and Shoreline.

This study finds that a majority of the respondents in all three villages were reluctant to follow and respond to the cyclone warning. In very few cases were all the members of a family evacuated; mostly women and children were sent to

Table 2.6 Households seeking refuge in cyclone shelters during Sidr

Refuge in cyclone shelter	Study villages							
	Inland		Shoreline		Island		All	
	N	%	N	%	N	%	N	%
Yes	37	18.7	8	8.9	0	0	45	13.6
No	161	81.3	82	91.1	43	100	286	86.4
Total	198	100	90	100	43	100	331	100
Chi-Square	χ^2 Value = 12.833, df = 2, p = 0.002							

Source Household Survey, 2009

Table 2.7 Causes of not seeking refuge in cyclone shelters during Cyclone Sidr

Causes of not seeking refuge	Study villages							
	Inland		Shoreline		Island		All Villages	
	N	%	N	%	N	%	N	%
Poor road network and long distance from home	108	22.09	42	22.95	39	33.05	189	23.92
Fear of stealing	105	21.47	28	15.30	5	4.24	138	17.47
Disbelieve	152	31.08	79	43.17	24	20.34	255	32.28
Cyclone was "God's will, so He will save us"	38	7.77	11	6.01	7	5.93	56	7.09
Low capacity of cyclone shelters	50	10.22	4	2.19	0	0.00	54	6.84
Thought that own house will provide protection	34	6.95	19	10.38	2	1.69	55	6.96
River barrier	0	0.00	0	0.00	41	34.75	41	5.19
Too old to move	2	0.41	0	0.00	0	0.00	2	0.25
Total	489	100.00	183	100.00	118	100.00	790	100.00

Source Household Survey, 2009

cyclone shelters. Many respondents, especially in Shoreline, mentioned that they were trying to move towards cyclone shelters but due to the high surge of water they attempted to make their way back home. However, they neither reached the shelter nor got back to the village. On the way many of them were washed away. The remaining vast majority of household members stayed in their own home or opted for some other emergency response, such as seeking refuge in a neighbour's house or simply inaction, thus facing potential loss and damage whilst remaining vulnerable to the impending cyclone and storm surge. A number of factors were responsible for this en masse inaction amongst respondents in the face of ruthless danger. The factors identified are presented in Table 2.7.

Poor communication and the long distance of cyclone centres from homes was a major cause (22.1, 23.0 and 38.2 % in Inland, Shoreline and Island respectively) for not seeking refuge in the cyclone shelters. The road network connecting coastal villages is in very poor condition and paths to cyclone shelters were unsafe prior to the cyclone because of excessive rainfall, high winds, flooded terrain and tidal waves. Island Village is less than one meter above the mean sea level, and, without the protection of any embankments or cyclone shelters, it remains extremely unsafe during cyclones and induced surges. About 40 % of respondents in Island identified poor road communication as one of the major causes for not seeking refuge in cyclone shelters located in other villages off the island. A large number of respondents (21.5 and 15.3 % respectively) mentioned fear of stealing or looting during evacuation as an important cause of inaction in Inland and Shoreline. Usually inhabitants in these two villages had more valuable household items than in Island. Hence, if they had taken refuge elsewhere and left their houses unattended, strangers might have stolen household goods and assets. Considering this, many of the respondents, especially in Inland, were reluctant to seek refuge. This response implies maintaining post-disaster law and order is a prerequisite for encouraging people to seek refuge in an emergency.

Disbelief of cyclone warnings was a major underlying factor mentioned by 31.08, 43.17 and 20.34 % of respondents in Inland, Shoreline and Island respectively. Respondents mentioned that they had received a high-alert tsunami warning two months previously, but nothing had happened. In fact, people had received cyclone warnings several times since the severe cyclone of 1991, but in most cases the storm had changed trajectory to hit elsewhere on the coast. Official communications and disseminated cyclone early warnings had turned out to be false on many occasions in the past. It was mentioned that coastal people sought refuge several times and stayed in the shelters for several hours; when the storm weakened, they returned home. In November 2007, the BMD warned that Sidr was going to make landfall at noon in Bangladesh: unfortunately it struck that evening at 6.30 p.m. Some respondents therefore mentioned that they went to the cyclone shelters, waited there for some time, then went back home. Cyclone warnings issued through radio, television and by CPP volunteers usually indicated the degree of potential hazard along with preparatory activities that should be undertaken. However, it is very important to observe and understand to what extent signals were transmitted to the community at this level. Another cause of disbelief was the relatively small number of occurrences of severe cyclones. Many respondents mentioned that they could not remember the 1970 incident, and only a few elderly people could recall the cyclone of 1991. Due to the 16-year time-gap, the incident had effectively been forgotten. Therefore people were encouraged to take no action firstly by the failure of tsunami warnings in the recent past, and secondly by the low frequency of severe events of this kind. Many respondents stated that the severity of the events is not as high as in the past. However, this finding confirms Perry and Lindell (1986), Landry and Rogers (1982), Turner et al. (1981) and Anderson (1969) in the assertion that previous experiences of similar severe disasters are positively linked with relaying warning and responses.

Fatalism is another cause of inaction: this accounted for 7.77, 6.01 and 5.93 % of respondents in Inland, Shoreline and Island respectively. Respondents in all three villages are Muslims, and a common statement was “The cyclone is Allah’s will. Allah will save us and people can do very little”. This finding is consistent with Haque (1993), Haque and Blair (1992) and Schmuck (2000), in that fatalism is a common psychological coping mechanism in rural Bangladesh. It also confirms Landry and Rogers (1982) and Turner et al. (1981), in that fatalism is negatively related to listening to warnings and the subsequent response. Rural people usually consider cyclone or other natural disasters to be punishments from God. Disaster-exposed people with no alternative but to live under socio-economic, infrastructural and logistical constraints usually surrender to God and try to find solutions through praying. Fatalism is seen as a passive measure in much of the literature, but the remote offshore villageIsland (Charkashem) has weak infrastructures that could hardly withstand strong cyclones and surge water. Hence, during cyclones and surges, climbing trees and praying to God provide the people with the psychological strength to overcome disaster impacts, which is reflected in the lower number of deaths in Island than in the other two villages. Religious belief is deep-rooted in coastal Bangladeshi society; hence some studies find association between gender aspects of hazard response and fatalism. For example, women in conservative Muslim societies are not allowed to leave home to go to cyclone shelters because of so-called "purdah" culture (Bern et al. 1993; Haider 1992). Cyclone shelters entail a lack of privacy, and men and women need to stay together for long hours until the disaster is over. Therefore, leaving homesteads and staying together with unknown males in a crowded room is not only uncomfortable for women from a conservative society but also creates a negative impression of women's status in the family and kinship group (Haque 1993). Many women are not allowed to seek refuge without prior permission from their husbands. In such a situation, women stay in the home and pray to God until the last minute, when they are forced out by surge water to evacuate with their children. However, this kind of behaviour and reliance on fatalism is gradually decreasing in coastal Bangladesh. A study by Haque (1991) revealed that 23 % of the surveyed population were dependent on fatalism as a survival strategy, while the present study affirms that a small percentage (7.9 %) of respondents belong to this category. However, this could be linked with the cultural aspect: traditionally people in south-west coastal areas are less conservative than on the south-east coast of Bangladesh.

Low capacity of cyclone shelters was a cause of inaction for 10.22 and 2.19 % of respondents in Inland and Shoreline respectively. However, no cyclone shelter is available in Island. Cyclone shelters are often found to be overcrowded and unhygienic, with no separate sanitation facilities for males and females, and very much uncomfortable to women (Islam et al. 2004; Paul et al. 2007). In many cases, shelters are occupied by nearby local elites first, and there is rarely space for marginalised vulnerable people. Thus, they are more likely to stay in highly vulnerable low-ying areas and take refuge on earthen embankments. Many respondents were found to be more optimistic, and strongly believed that their own house would provide greater protection as they could stay closer to their assets and livestock.

Cyclone shelters or other protective infrastructures are scarce and unavailable in most of the small islands; hence, anyone seeking refuge needs to cross the river to go to the mainland. A large proportion of respondents (34.75 %) opined that the river was a major barrier for Islanders to reach the cyclone shelter. Thus, locational

Table 2.8 Distribution of household able to predict cyclones using indigenous knowledge

Prediction of cyclone	Study villages						All villages	
	Inland		Shoreline		Island			
	N	%	N	%	N	%	N	%
Yes	47	23.7	49	54.4	17	39.5	113	34.1
No	151	76.3	41	45.6	26	60.5	218	65.9
Total	198	100	90	100	43	100	331	100
Chi-square	χ^2 Value = 26.589, df = 2, $p = 0.000$							

Source Household Survey, 2009

barrier is considered as a contributing factor towards inaction in response to cyclone warnings. As outlined above, religious belief, disbelief in cyclone warning, scarcity of safe infrastructure, socio-economic vulnerability and locational insecurity are the integral causes of the inaction of inhabitants always striving to survive in the fragile environment. Thus, without having a reliable and responsive warning system, even the existing availability of options remains under-utilised. As early warning is not simply a linear process of information dissemination, the success of a warning depends on the proactive response of individuals and the community as a whole. Therefore, effective early warning and awareness building among the potential victims of disaster is absolutely essential.

Indigenous Knowledge about Natural Warning Signs of Cyclones and Storm Surges

People can predict a forthcoming cyclone by observing nature with methods from their own experience. An attempt has been made in the present study to identify the indigenous knowledge system on cyclone prediction. Senior and elderly members of households have knowledge of cyclone prediction, as they have gone through several exposures and experiences in the past. The study reveals that 34.1 % of total respondents, and 23.7, 54.4 and 39.5 % of respondents in Inland, Shoreline and Island respectively, have the ability to predict cyclones (Table 2.8). This ability is also linked with a respondent's occupation. For instance, fishermen—especially deep-sea fishermen—closely observe nature every day. Hence, they have practical experiences of extreme weather, water conditions and animal behaviour to relate to the occurrence of cyclones. The respondents also mentioned that those who can predict forthcoming cyclones can anticipate the intensity of them as well.

Such knowledge varies significantly from village to village, and is rarely common to all three villages. In general, indicators can be grouped into three broad categories: observing the weather, observing the condition of the sea and rivers, and observing the unusual behaviour of animals. Moreover, people do not use

Table 2.9 Indigenous cyclone rediction indicators in coastal Bangladesh

Predicting variables and indicators	Study villages						All villages	
	Inland		Shoreline		Island			
	f	%	f	%	f	%	f	%
Unusual weather condition								
Drizzling and gloomy Sky and abnormal wind circulation[a,b]	13	7.2	15	5.8	16	7.5	44	6.7
Strong wind circulation from south or south-east[a,b]	10	5.6	12	4.6	17	8.0	39	6.0
Weather is unusually hot followed by rain[a,b]	8	4.4	11	4.2	18	8.5	37	5.7
Wind blowing in the deep sea as a circle	0	0.0	5	1.9	4	1.9	9	1.4
Muddy smell in the air[b]	7	3.9	5	1.9	4	1.9	16	2.5
Unusual water conditions								
Abnormally hot water in river/sea[a,b]	12	6.7	22	8.5	17	8.0	51	7.8
Dark/smoky/cloudy colour of water	2	1.1	19	7.3	12	5.6	33	5.1
Increase of water in the river, while cyclone move towards the coast	14	7.8	11	4.2	9	4.2	34	5.2
Huge roar of the sea/river	10	5.6	22	8.5	19	8.9	51	7.8
Gigantic weaves of water in the sea	0	0.0	13	5.0	12	5.6	25	3.8
Abnormal animal behaviours								
Cattle and dogs low and howl endlessly at night before strong cyclone[a]	14	7.8	17	6.5	9	4.2	40	6.1
Ants climb towards the roof of houses[a]	19	10.6	16	6.2	13	6.1	48	7.4
Sea birds, pigeons, move towards inland	6	3.3	21	8.1	16	7.5	43	6.6
Abnormal behaviour (jumping) of fish in ponds	17	9.4	15	5.8	1	0.5	33	5.1
Insects (flies) bite cattle to take shelter[b]	12	6.7	18	6.9	13	6.1	43	6.6
Bees/locusts move in clusters in the sky	9	5.0	7	2.7	4	1.9	20	3.1
Flies and mosquitoes increase[a,b]	16	8.9	19	7.3	17	8.0	52	8.0
Crabs come into courtyards or high places	2	1.1	5	1.9	7	3.3	14	2.1
Birds fly without destination	9	5.0	7	2.7	5	2.3	21	3.2
Total	180	100.0	260	100.0	213	100.0	653	100.0

[a] Most common indicators in all three villages; [b] observed at least one day before
Source Household Survey, 2009

single indicators for cyclone prediction, but follow a combination of factors for higher reliability to anticipate the forthcoming danger. Among others, drizzling and gloomy skies, abnormal wind circulation (6.7 %), strong wind circulation from the South or South–East (6.0 %), unusually hot weather followed by rain (5.7 %), circular wind patterns over deep-sea waters (1.4 %), and a muddy smell in the air (2.5 %), are all major indicators (Table 2.9). The first three of these indicators were commonly identified by all villagers in the three locations among those able to predict cyclones from their own experiences. “Circular wind patters over deep-sea waters” was identified by the respondents of Shoreline and Island, while “muddy smell oin the air at least a day before cyclone” was noticed most commonly in Inland, but also in Shoreline and Island villages.

Indicators in water conditions identified by the respondents were: abnormally hot water in river/sea (7.8 %), dark/smoky/cloudy colour of water (5.1 %), increase of water in the river while cyclone moves towards the coast (5.2 %), roaring sound of the sea/river (7.8 %), and gigantic waves of water in the sea (3.8 %). These were the most commonly reported water-related indicators. Abnormally hot water in river/sea and roaring sound of the sea/river were identified by the respondents irrespective of village locations. By contrast, indicators such as dark/smoky/cloudy colour of water, increase of water in the river, and gigantic waves of water in the sea, were mostly identified by the respondents from Shoreline and Island. However, variation exists in identifying water conditions, which is linked to the location and occupation of the respondents; for example, deep-sea fishermen can experience these indicators easily and clearly. They monitor sea water characteristics closely almost every day, so any deviation from normal water, for example in colour and temperature, is easily noticed by them.

Unusual animal behaviour was identified in all three villages, such as cattle and dogs howling endlessly at night before the strike of a strong cyclone (6.1 %), ants climbing towards the roof of houses (7.4 %), sea birds moving towards inland (6.6 %), abnormal jumping behaviour of fish in the pond (5.1 %), flies biting cattle to take shelter on them (6.6 %), bees/locusts moving in clusters in the sky (3.1 %), an increase in the number of flies and mosquitoes (8.0 %), crabs coming into courtyards or high places (2.1 %), and birds flying seemingly without destinations (3.2 %). The most common indicators noticed in all three villages were cattle and dogs lowing and howling endlessly at night before the occurrence of the strong cyclone, ants climbing towards the roof of houses, and the number of flies and mosquitoes increasing prior to cyclone strikes. Variations also existed for some indicators: for example, noticing the movement of sea birds and crabs was identified by an indicator by the respondents from the Shoreline and Island villages. Table 2.9 presents the indicators in general and their distribution among the three villages.

A majority of the respondents mentioned that they had learned these indicators through experience (63.7 %); others had learned them from elderly persons in the family or village (11.5 %), or from neighbours (24.8 %). No variation existed among the villages in terms of the learning sources of these indigenous natural means of cyclone prediction. This study finds that coastal communities' experiences are the main sources of such knowledge. It was also noticed that intergenerational transfer of such local knowledge is less among coastal communities, although it is important to transfer this knowledge from elderly to younger people. 34.1 % of the total respondents believed these prediction techniques were effective in anticipating the impending danger (Household Survey, 2009). More than half of the respondents in Shoreline, more than one-third in Island and about one quarter in Inland reported that such indigenous prediction techniques were very effective: this showed significant differences across the villages.

Conclusion and Policy Implications

Cyclones and storm surges are recurrent phenomena in coastal Bangladesh, causing significant damage every time they occur. In recent times the cyclone forecasting system in the country has been improved significantly in terms of identifying, monitoring and disseminating warnings among coastal inhabitants. Though progress has been made, criticisms should still be made of the complexity of warning language, the differing warning signals for maritime and river ports, the inaccuracy in the prediction of landfall timing and level of intensity (Haque and Blair 1992; Jahan 1992; Hossain et al. 2008; Tatham et al. 2009; Miyan 2005; Jahan 1992). Coastal inhabitants are quite familiar with the regular occurrence of cyclones and aware of the related potential risks. The present study reveals that the majority of the respondents in Inland and Shoreline had received a cyclone warning, while Island villagers were still beyond the reach of BDRC volunteers, government organisations and NGOs. Broadcasting media and word-of-mouth from relatives and neighbours were the main sources of early warnings; this was in spite of the fact that the government has given top priority to the islands and remote char lands for early warning dissemination (GoB 1999a, b). About 83.38 % of respondents had received warning prior to the occurrence of Sidr, while only 18.7 % in Inland and 8.9 % respondents in Shoreline had responded to the warning by seeking refuge in nearby cyclone shelters. None of the respondents in the Island village sought refuge. Many factors were responsible for this mass inaction, such as the poor road network and the long distance of cyclone shelters from homes, the fear of stealing, disbelief, fatalism, and the low capacity of shelters. People did not believe official warnings for several reasons, including a lack of understanding of cyclone warnings, past experience of the failure of warnings, a lack of income-earning activity at the place of removal, and pressure from an employer on inhabitants to continue fishing.

This study also reveals that coastal inhabitants can predict cyclones based on their indigenous knowledge by combining a number of indicators mostly founded on the unusual behaviour of animals and weather conditions. Therefore, it is important to accept and propagate the most reliable indicators; that is to say combinations of these indicators that will best predict the onset of a cyclone and the accompanying storm surge. Identification of those indicators should be used as supplementary information along with official cyclone warnings, in order to encourage wider acceptance among coastal communities. Most importantly, understanding of such indicators does not require any special or sophisticated equipment; a deep understanding and close monitoring of environmental factors are the only requirements. Many of these indicators provide enough time—from one to 2/3 days, depending on specific indicator(s)—for people to be proactive and take precautionary and preparatory measures. For example, ants climbing the wall toward the roof or insects biting cattle is usually observed at least 1–2 days before the occurrence of a cyclone. Abnormally hot weather and abnormally warm water in rivers or the sea is usually observed 6–24 h before the cyclone strikes. Hence, it is important to document and spread this indigenous knowledge among the people at risk, in order to help save their lives and assets in the absence of a scientific warning system.

This study also recommends increasing the number of cyclone shelters along the coast in remote locations, improving shelter environments and conditions, and ensuring post-cyclone law and order, in addition to providing timely early warning. Proper integration of indigenous knowledge-based cyclone forecasting with modern early warning systems is essential for greater acceptance and of disaster risk reduction. Therefore, the present study strongly advocates about the building of awareness on local knowledge and the official warning process. The transfer of such knowledge to the vast majority of the population of the coastal community would lead to better disaster mitigation and emergency management in coastal Bangladesh.

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Author Biographies

Dr Shitangsu Kumar Paul is an Associate Professor of Geography and Environmental Studies, Rajshahi University, Bangladesh. He has completed his MSc and PhD degrees from the Asian Institute of Technology. He has several national and international publications on disaster-related issues in Bangladesh.

Dr Jayant K. Routray is a Professor and Coordinator of Regional and Rural Development Planning (RRDP) and also Disaster Preparedness, Mitigation and Management (DPMM) academic programmes at the Asian Institute of Technology, Bangkok, Thailand. He has about 100 publications in national, regional and international referred journals covering different issues and areas related to RRDP, DPMM and climate change adaptation.

Chapter 3
Assessment of Climate and Human Induced Disaster Risk Over Shared Water Resources in the Balkhash Lake Drainage Basin

Pavel Propastin

Abstract This paper aims to assess the implications of climate change and human activity on the disaster risk for water resources in the Balkhash Lake drainage basin, which are shared between the Republic of Kazakhstan and the People's Republic of China. The long-term periodical fluctuations in the Balkhash Lake water levels demonstrate their intimate connection with components of its water regime, especially run-off from its main contributor, the Ili River, which flows from the Republic of China. A rapid increase in human activity in the Kazakh part of the drainage basin in the period 1970–1990 led to a significant drop in the Balkhash water level and devastating effects on wet ecosystems. The reduction of anthropogenic impact in the Balkhash Lake drainage basin after the collapse of the Soviet Union in 1991 coincided with favourable climate conditions during the 1990s and 2000s. This led to a significant rise in the water level in the Balkhash Lake and to the rehabilitation of its degraded ecosystems. However, a new challenge for the sustainable use of Lake Balkhash water resources appeared during the last decade, posed by the development of large irrigated areas in the upper part of the Ili River in the Republic of China. China is planning to reduce considerably the outflow of the Ili into Kazakhstan. Moreover, contemporary climate change causes changes in precipitation and temperature in the drainage basin. The paper presents three different scenarios for the development of the Balkhash Lake in the twenty-first century. The scenarios were simulated with respect to changes in human activity and climate parameters in both parts (Kazakhstan and China) of the Balkhash Lake basin. Two of the scenarios lead to disaster-like changes in the Balkhash Lake.

P. Propastin (✉)
Department of Geography, Georg-August University Göttingen, Goldschmidtstraße 5, 37077 Göttingen, Germany
e-mail: ppropas@uni-goettingen.de

P. Propastin
Department of Bioclimatology, Büsgen-Institute, Georg-August University Göttingen, Büsgenweg 2, 37077 Göttingen, Germany

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Introduction

Sustainable use of water resources is one of the main issues in present-day environmental management and development strategies at all levels from global to national and local. Interstate use of transboundary water resources is the most problematic and challenging topic in planning sustainable strategies for regions where two and more states share water resources. There are many examples from various regions of the world where transboundary water resources have led to conflicts between states (Pahl-Wostl 2007). With respect to this issue, the countries of Central Asia are no exception. After the break-up of the Soviet Union, over the past two decades the problem of transboundary water use became increasingly aggravated in this region (Polat 2002). The use of shared water resources in the region is a problem of paramount importance because all big rivers (the Irtysh, the Ishym, the Chu, the Talas, the Syrdarya, the Amudarya, the Ili) are transboundary rivers and two of three big lakes (the Caspy Sea, the Aral Sea) are shared between two and more states. Taking into account the stable population increase and weak economic development in this region, the problem of shared water resources will become more and more complicated in the near future. Recent literature contains numerous studies focusing on different problems of the shared water resources in the post-Soviet republics of Central Asia—Kazakhstan, Kyrgyzstan, Uzbekistan, Tajikistan, and Turkmenistan (Polat 2002; Hodgson 2010). Several international conferences and workshops have taken place (see e.g. Moerlins et al. 2006) and a number of international programmes have focused on this issue (among them Kazakhstan TACIS/European Union Program 2005) during the last two decades. In particular, great efforts have been made at both regional and international level to resolve the problem of shared water resources in the Aral Sea drainage basin. However, the progress achieved in resolving the problem of sharing water resources around the Aral Sea has been insignificant (Hodgson 2010). The same goes for other shared rivers and lakes in the region.

The problem of deteriorating agreement over sustainable use of shared water resources in Central Asia is aggravated through significant climate change in this region that has a strong impact on water resources (Aisen et al. 1997; Ibatulin et al. 2009). Generally, drylands are characterised by a considerable run-off variability of their rivers caused by a very high inter-annual variability of precipitation. The run-off instability leads to a high variability in the water level of lakes in drylands (Shnitnikov 1973). These phenomena are also characteristic of the water resources of Central Asia. Observations and climate projections have provided abundant evidence that water resources in Central Asia are very vulnerable and have the potential to be strongly impacted by climate change, with wide-ranging consequences for human society and ecosystems (Ibatulin et al. 2009; Kezer and Matsuyama 2006). Both temperature increase and rapid glacier retreat are poised to bring risks for the region's water resources. Assessment of both the current state and the prognostic trends of the region's water resources should take into account ongoing climate changes. Such assessments provide a theoretical and practical outline for sustainable water resource management in Central Asia (Ibatulin et al. 2009). Given the abundance of water resources shared between the countries in Central Asia, water management in the transboundary context should imply adaptation to climate change in the region (Pahl-Wostl 2007; UNECE 2009).

Among others, the climate change issue is crucial for the management of Lake Balkhash (Kazakhstan) and its drainage basin (Kazakhstan/China) in the transboundary context. Lake Balkhash is the world's fifth largest isolated water reservoir, with strong periodical fluctuations of water table, primarily conditioned by high variability of climate (Shnitnikov 1973). The Balkhash Lake's water regime demonstrates a striking connection with run-off from its main contributor, the Ili River, in which flows from the Republic of China. The filling of the Kapchagay reservoir (Kazakhstan), built on the Ili River in 1970, coincided with the last downward fluctuation and has led to the deepest drop in the lake's water level since measurements began. The filling of the Kapchagay reservoir was stopped at the end of 1980s because of the huge degradation risk for the whole region. The reduction of anthropogenic impact coinciding with favourable climate conditions led to a rise in the water level in the Balkhash Lake and to the rehabilitation of the region's ecosystems. However, a new challenge for the management of the water resources of Lake Balkhash appeared in the late 1990s, posed by development of large irrigated areas in the upper part of the Ili River in China. The People's Republic of China plans to reduce the run-off of the Ili River by 15–20 % in the very near future. Moreover, management of water resources in the Balkhash Lake basin is confronted more and more with the considerable effects of climate change in the region. An expected aridisation of the region's climate in the twenty-first century, combined with population growth both in Kazakhstan and China, will lead to increasing water scarcity in the Balkhash Lake basin (Ibatulin et al. 2009). As a consequence, the potential risk of conflicts over the shared Balkhash basin's resources between Kazakhstan and China will grow. Simultaneously, the risk of an environmental disaster (like the Aral Sea disaster) in the Balkhash Lake basin will be very high. The problem of disaster risk management in the Balkhash Lake basin in the context of climate change and transboundary use is discussed in the paper. Different scenarios for the development of the Balkhash Lake basin during the twenty-first century, with respect to changes in climate and human activity, are presented.

Characteristics of the Balkhash Lake Basin

Lake Balkhash is situated within the Balkhash-Alakol depression, which is enclosed by mountain ranges on all sides: the Tien Shan Mountain to the South,

Fig. 3.1 Map of the Lake Balkhash basin (interrupted *blue line*) with the countries boundary (*thick grey line*) (Colour figure online)

the Djungarsky Alatau to the East, the Chu-Ili Alatau to the West, and the Kazakh Low Hills Land to the North (Fig. 3.1). The watershed of Lake Balkhash is one of the most arid dischargeless watersheds in the world. Lake Balkhash has a catchment of 500,000 km^2, with about 85 % of the drainage area located in the Republic of Kazakhstan and 15 % in the People's Republic of China. The lake has a length of 605 km; its width varies from 4 to 74 km. The mean surface area of Lake Balkhash is about 17,000 km^2, ranging from 15,000 km^2 in regression phases to 19,500 km^2 in the transgression phases. All inflow to Lake Balkhash comes from the Tien Shan, the Djungarsky Alatau, and the run-off from their ridges. The two largest contributors to Lake Balkhash are the Ili River (about 78 % of the total inflow) and the Karatal River (about 15 % of the total inflow) (Shnitnikov 1973).

The level of Lake Balkhash undergoes rhythmical fluctuations, which had been driven by climate until the Kapchagay Reservoir on the upper part of the Ili River was constructed in 1970. Analyses of sediments from the bottom of Lake Balkhash have shown that the water level has historically fluctuated by 10 m (Petr 1992; Shnitnikov 1973). Gauge observations on water level have been taken since the mid-1800s (Fig. 3.2). During the gauge observation period, with no run-off regulation, the lake level used to change according to the intersecular cycle, from 344.4 (1911) to 340.7 (1987) m. The last regression of Lake Balkhash in the twentieth century (1970–1989) was strengthened due to the regulation of the Ili River run-off (Tursunov 2002; Kezer and Matsuyama 2006). In 1987, the lake level reached the lowest values recorded during the period of gauge observations: 340.7 m. The last transgression phase started at the end of the 1980s and continued till the mid-2000s. The last transgression was strongly associated with favourable climate conditions and the reduced anthropogenic impact in the region (Propastin 2011).

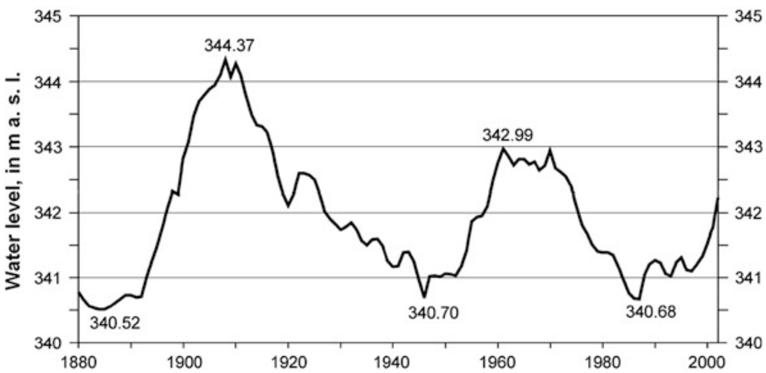

Fig. 3.2 Long-term variations of the water level of Lake Balkhash measured by gauges (1880–2001) (Tursunov 2002). Values are given in metres above the Baltic Sea water level

Problems in Management of the Lake Balkhash Water Resources

Vulnerability to Climate Change

The vulnerability of watersheds to climate variations needs to be considered in adaptive water resources management processes (Pahl-Wostl 2007). The Balkhash Lake basin is known to be highly vulnerable to inter-annual climatic dynamics, particularly precipitation and temperature (Tursunov 2002). The water level of Lake Balkhash is the most sensitive indicator of any changes in the lake drainage regime with respect to the natural variability of climate and human activity (Shnitnikov 1973; Petr 1992). Complex analyses of climate records and the Ili River run-off data showed that about 62 % of the run-off change during the last regression phase (1970–1989) was explained by natural variability, and 38 % by human activities including the retention of water in the Kapchagay Reservoir and use for irrigation (Kezer and Matsuyama 2006).

In this study, simple statistical tests to measure the vulnerability of the Balkhash Lake to climate conditions were made using data on the water table in the lake and a climate data set containing temperature and precipitation records (for the period 1989–2001) from 12 meteorological stations located in the upper reaches of the Balkhash Lake basin (the northern Tien-Shan). This climate data set is available from the Glacier-Climatic Research Group at the University of Idaho (http://www.sci.uidaho.edu/cae/data/cad/gmap.html). Regression analyses were carried out to quantify the relationships between these variables (Fig. 3.3). Both regression models were statistically significant at the 1 % level. The amount of explained variance was larger for the regression with temperature ($R^2 = 0.58$). A multiple regression model incorporating both precipitation and temperature as predicting factors explained 73 % of the variance in the Balkhash Lake water level:

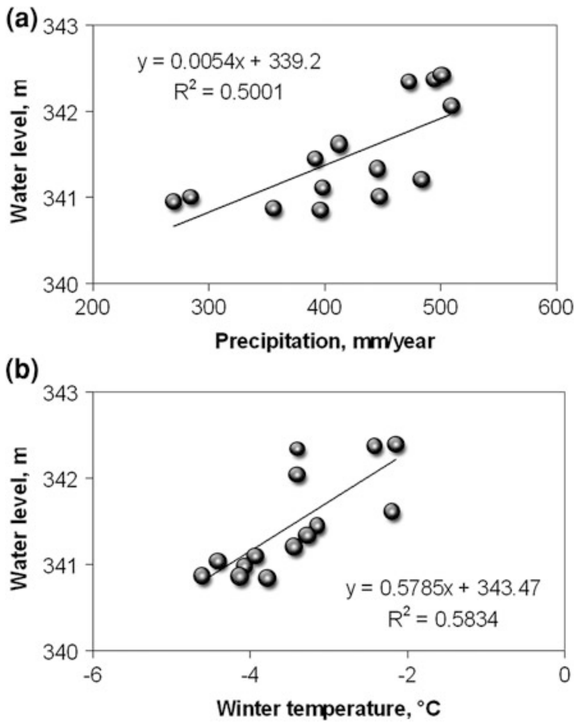

Fig. 3.3 Relationships between the mean annual water level in Lake Balkhash and annual precipitation (**a**) and mean winter temperature (**b**) in the lake basin

$$WL = 336.33 + 0.4957 \times T_a + 0.0051 \times P_a \tag{3.1}$$

where WL is water level in m, T_a is the mean temperature (°C), and P_a is the annual precipitation (mm/year) in the Balkhash Lake basin. The regression was significant at the $p < 0.001$ level.

In order to estimate the individual influence of each of the climate variables on the variation of water level by excluding the influence of another one, we also calculated partial regression coefficients of normalised precipitation P_a and normalised temperature T_a. According to our calculations, the partial regression coefficient for precipitation amounts to 0.36, whereas those for temperature are 0.41. The results of the simple and normalised regression analysis show that the impact of temperature and precipitation on the Balkhash Lake water level is more or less equivalent. These findings correspond to findings from recent studies on the Balkhash Lake basin (Aisen et al. 1997; Kezer and Matsuyama 2006) demonstrating that the main factor determining the change in river run-off from the Tien-Shan is the impact of temperature, whereas the increase in precipitation throughout the Tien-Shan was less strongly associated with an increase in river run-off.

Generally, the results of the above statistical tests detect high vulnerability of the Balkhash Lake to climate variability, which corresponds closely to the findings of Ibatulin et al. (2009) and Kezer and Matsuyama (2006).

Human Impact in the Balkhash Lake Basin

Generally, four historical stages in the development of human activity in the Balkhash Lake basin can be clearly distinguished (Propastin 2011). Before the construction of the Kapchagay dam in 1970, the hydrological regime of Lake Balkhash was mainly determined by climatic factors (i.e. precipitation and temperature). During this phase, the anthropogenic impact in the Balkhash Lake basin comprised moderate development of irrigation in the Kazakhian part of the basin and practically no human activity in the Chinese part. The second phase (the beginning of 1970 to the end of the 1980s) was characterised by a strong increase in anthropogenic impact associated with the filling of the Kapchagay reservoir and the rapid extension of the irrigation area in the Kazakhian part of the Balkhash Lake basin. Here, the irrigation land took in an area of about 500,000 ha. By the end of 1980s, the degradation of Lake Balkhash and its environments reached its peak (Tlenbekov and Piven 1993; Kipshakbaev and Abdrasov 1994). The degradation included the following developments: (i) degradation of wetlands in the Lake Balkhash basin, (ii) rising salinity in the lake, (iii) a decline in fish stocks, and (iv) an alteration of natural hydrological patterns. The water table of the Balkhash Lake fell to its deepest level during the whole period of gauge observations—340.6 m. The third phase (the end of the 1980s to the beginning of the 2000s) is associated with a rapid shrink of anthropogenic impact in the Kazakhian part of the Balkhash Lake basin caused by the collapse of the Soviet Union. The filling of the Kapchagay reservoir was stopped; most of the irrigated land was abandoned. This phase was accompanied by favourable climate conditions associated with a significant increase in precipitation (Matsuyama and Kezer 2009) and temperature. The water level of Lake Balkhash rose gradually during the third phase and by the beginning of the 2000s had reached 342 m. Consequently, the ecosystem of the Balkhash Lake was characterised by a broad rehabilitation (Propastin et al. 2007). The fourth phase started in the early 2000s and is associated with an increase in water intake from the Ili River in the Chinese part of the drainage basin. More than 75 % of the total inflow into Lake Balkhash originates in Chinese territory (the Ili River). China has great demand for the water resources of the Balkhash Lake basin. The irrigation areas in the Ili River catchment are being extended and should achieve an area of 500,000 hectares. There is also a plan to build a channel connecting the Kashe River (the largest contributor to the Ili River in the Chinese territory) with the industrial centre Karamay. Another intended channel should bring the water of the Tekes (the second largest contributor to the Ili River in China) to the Tarim depression, in order to increase agricultural production in that region (Tursunov 2002). The Chinese Government has also designed 15 water reservoirs to be built in the upper flows of all three of the Ili's major contributories—Tekes, Kashe und Kunes. The increase in water distraction from the Ili River by China is an increasing risk factor for the sustainable development of the Balkhash Lake and the whole region.

Climate Trends in the Balkhash Lake Basin and Their Effects on Water Resources

According to published results of climate records analyses, the main reason for the changing climate in Central Asia is a considerable increase in air temperature. For Kazakhstan as a whole, the increase in average temperature during the period 1936–2005 was 0.26 °C over each ten-year period (Ibatulin et al. 2009). Certainly, the increase in temperature varied across the country, depending on several factors such as topography and vegetation cover. A more significant rise in temperature was registered in the plains; in mountainous areas the increase was less, and in some cases cooling was even observed. Generally, the rate of warming has been faster in winter than in summer. Thus, in Kazakhstan, the average winter temperature rose by 0.44 °C over each ten-year period, whereas the summer temperature rose by 0.14 °C per decade (Ibatulin et al. 2009). Comparable temperature change was observed in areas of Kazakhstan bordering Chinese territory. Changes in precipitation were also positive for most parts of Central Asia, except the Moyinkum desert (Kazakhstan) and the region of Lake Zaysan (Kazakhstan). On the whole, winter precipitation was the major contributor to the general trend in annual precipitation throughout Central Asia. Changes in summer precipitation, in terms of both increases and decreases, were insignificant throughout the whole region (Ibatulin et al. 2009).

For the Balkhash Lake basin, the change in air temperature has been characterised by gradual, increasing trends over the last 70 years. Here, winter temperature increased at a rate of 0.4–0.6 °C per decade in the lowland, and 0.1–0.2 °C per decade in the mountainous areas. The increase in summer temperature had a value of 0.1–0.2 °C per decade in the lowlands, and 0.1 °C/decade in the mountainous parts of the basin (Ibatulin et al. 2009). The precipitation around Lake Balkhash has increased since the end of the nineteenth century. Large negative anomalies are concentrated before 1950, while positive anomalies persist into the twenty-first century (Matsuyama and Kezer 2009). In the mountainous areas, the increase in precipitation has been more pronounced than in the lowlands. In the lowlands, winter precipitation increased by 2–4 mm per decade; in the mountainous areas by 6–8 mm/decade. Similarly, summer precipitation showed a greater increase in the mountainous areas: 2–4 mm per decade versus 0–2 mm per decade in the lowlands (Ibatulin et al. 2009).

Warming in the mountainous areas causes significant retreat of glaciers in Central Asia as a whole, not just in the Balkhash Lake basin (Aisen et al. 1997).

Glaciers are long-term reservoirs of water. They produce melt water in summer, when the reserves of seasonal snow are depleted, thereby also feeding into the rivers flowing into the Balkhash Lake. The rivers that feed Lake Balkhash originate in the glaciers of the northern and eastern Tien-Shan and the Dzhungar Alatau. During the second half of the twentieth century, in the Balkhash Lake basin glaciers reduced in area by about 36 %. Calculations showed that this melting of glaciers may result in a contemporary increase in water inflow from rivers in excess of 10 % (Ibatulin et al. 2009). This may be a reason for the Balkhash's water table rise during the last transgression phase (end of the 1980s–dato). However, this contemporary water table rise will stop and then go into reverse when the melting of the glaciers becomes slower, because the glacier volume will be getting smaller and smaller. Finally, the melting will end with the total disappearance of the glaciers. The studies suggest that as a consequence of glacier disappearance the Ili River's run-off will decline at the rate of about 2.3 km^3 per year (11.5 %), resulting in a decline of inflow water in the Balkhash Lake by 2.5 km^3 per year (10.5 %) (Ibatulin et al. 2009).

Forecasting Disaster Risk in the Balkhash Lake Basin with Respect to Climate Change and Anthropogenic Impact

Any strategy for sustainable water use should respond appropriately both to changes in anthropogenic impact and future climate conditions. Forecasting disaster risk is one of the key tasks in developing strategies for sustainable use of water resources. With respect to the Balkhash Lake basin, the political and economic development of China during the last two decades generates a new challenge for water resource management in the region. While the irrigation area in Kazakhstan has been rapidly reduced, water consumption in the Chinese part of the Balkhash Lake basin has been progressively increased. Moreover, the People's Republic of China plans to increase its water intake from the Ili River in the very near future. Such an extension of the irrigation production in this region would require additional water consumption of about 7 km^3 per year. In this case, the annual Ili River run-off to Lake Balkhash would be only 8.5 km^3 per year. If all these Chinese plans were realised, the future of the Balkhash Lake might be gloomy. A massive new disruption of the Balkhash hydrological regime would be accompanied by several environmental, economic and social consequences in the whole region.

In this study, different scenarios for the Balkhash Lake basin with respect to changed future climatic and anthropogenic impacts have been developed. In these scenarios, we modelled the water volume, water table, and area of Lake Balkhash, considering different degrees of anthropogenic impact and projections of climate parameters into the future. The model was based on the following equation of water balance in the Balkhash Lake (enhanced following Ratkovich et al. 1990):

$$\Delta V = Q_o + Q_u + P - E - A_R - A_{IR} - E_R \qquad (3.2)$$

Where ΔV is change in water volume of the lake (km^3/year), Q_o is overground run-off including rainfall, water from snow and glacier melting (km^3/year), Q_u is inflow of underground water (km^3/year), P is precipitation on the lake surface (km^3/year), E is evaporation from the lake surface (km^3/year), A_R is retention of water in the Kapchagay Reservoir (km^3/year), A_{IR} is intake of water for irrigation (km^3/year), and E_R is evaporation from the surface of the Kapchagay reservoir (km^3/year). By calculating the P, E, and E_R parameters, we have made projections of the contemporary trends in precipitation and temperature into the future (i.e. precipitation increase is 0.4 mm/year and temperature increase is 0.06 °C/year; see above). Parameter Q_o was taken from Ratkovich et al. (1990). In order to account for glacier retreat, the corresponding part of water coming from glaciers (at present 3.66 km^3) was subtracted from Q_o. Parameter Q_u was taken from Shnitnikov (1973).

The following scenarios were simulated:

This scenario reflects the present-day situation in water use (slight intensity): strongly reduced irrigation areas in Kazakhstan (200,000 ha); relatively small irrigation areas in China (100,000 ha). Retention of water in the Kapchagay reservoir is low (0.1 km^3/year). No water retention in Chinese reservoirs. Reduction of glaciers in the Balkhash Lake basin is 0.75 % per annum (Ibatulin et al. 2009).

This scenario reflects a situation with an intermediate-intensive use of water resources: the present-day development of the Republic of Kazakhstan and the rapid economic development of the Chinese part of the Balkhash Lake basin. Assumptions: present irrigation areas in Kazakhstan (200,000 ha); strongly increased irrigation areas in China (450,000 ha). Retention of water in the Kapchagay reservoir is low (0.1 km^3/year); retention of water in Chinese reservoirs is increased (0.1 km^3/year). Reduction of glaciers in the Balkhash Lake basin is 0.75 % per annum.

This scenario reflects a situation with the most intensive water use: rapid development of both Kazakhstan and Chinese parts. Assumptions: a new extension of irrigation areas in Kazakhstan to the level of the Soviet era (500,000 ha); strongly increased irrigation areas in China (450,000 ha). Retention of water in the Kapchagay reservoir is at the Soviet level (0.7 km^3/year); retention of water in Chinese reservoirs reaches 0.7 km^3 per year. Reduction of glaciers in the Balkhash Lake basin is 0.75 % per annum.

The results of the simulations are presented in Table 3.1 and Fig. 3.4. The least dramatic scenario implies that the Ili run-off would reduce from 15 to about 12 km^3. In this case, the surface area of the Balkhash would shrink to about 14,000 km^2 and the water level would fall to 340.2 m a.s.l. The retreat of glaciers will significantly affect the run-off only in the second half of the twenty-first century. Increases in evaporation because of the rise in temperature are fully compensated by an increase in precipitation. This scenario shows a positive development in the second half of the twenty-first century (Fig. 3.4). The lake would somewhat rehabilitate during the period 2050–2100, showing a slight

Table 3.1 Scenarios for the Balkhash Lake according to different assumed water use intensities with respect to climate change in the basin and economic development in Kazakhstan and China

Parameter	Degraded state (1989)	"Near normal" state (2002)	Scenario (year)		
			1 (2045)	2 (2058)	3 (2063)
Water table, m above sea level	340.7	342.3	340.2	338.0	336.0
Lake's surface area, km^2	15,800	19,000	14,146	9,190	4,980
Water volume, km^3	83.06	103.20	72.39	41.13	14.56

In brackets, years of the equilibrium set up are given

increase in all parameters. The water table would increase to 340.5 m, while the surface area would occupy about 15,000 km^2. In the intermediate scenario, the run-off of the Ili River would be reduced by 7–8 km^3 per year. The surface area would be reduced to an area of below 10,000 km^2. In this case, the lake would break up into two separated parts. In the most terrible scenario, the run-off of the Ili River would be reduced from 15 to 5 km^3 per year. In this case, the water level would fall to about 336 m and the lake surface area would decrease to about 5,000 km^2. The lake would break up into 3–6 separate parts. In this scenario the environmental disaster in the Balkhash Lake basin would be comparable in scale to the present-day situation in the Aral Sea basin.

Conclusions

The paper presented the problem of water use in the Balkhash Lake basin, which is shared between Kazakhstan (about 60 % of the total area) and China. Lake Balkhash and its environments are very fragile systems that respond with high sensitivity to changes both in climate and anthropogenic factors. During the Soviet era, the Balkhash Lake was threatened by water over-use in the Republic of Kazakhstan. The over-use caused the severe exhaustion of wet ecosystems in the Ili River delta and the drying up of the Balkhash Lake. After the break up of the Soviet Union, the lake experienced a broad rehabilitation caused by a huge decrease in anthropogenic impacts in the lake basin. However, the threat from China to the Balkhash Lake has been growing since the early 2000s. Planned measures by China to increase water intake have caused alarm among ecologists and planners, who are anxious about the consequences for the environment in the Balkhash Lake and the lower reaches of the Ili River.

Three different scenarios of future development in the Balkhash Lake basin were simulated in this study in order to assess disaster risk with respect to climate change and human activity. Only Scenario 1 showed more or less acceptable developments that do not threaten the existence of the Balkhash Lake. The realisation of either Scenarios 2 or 3 would make an environmental disaster in the

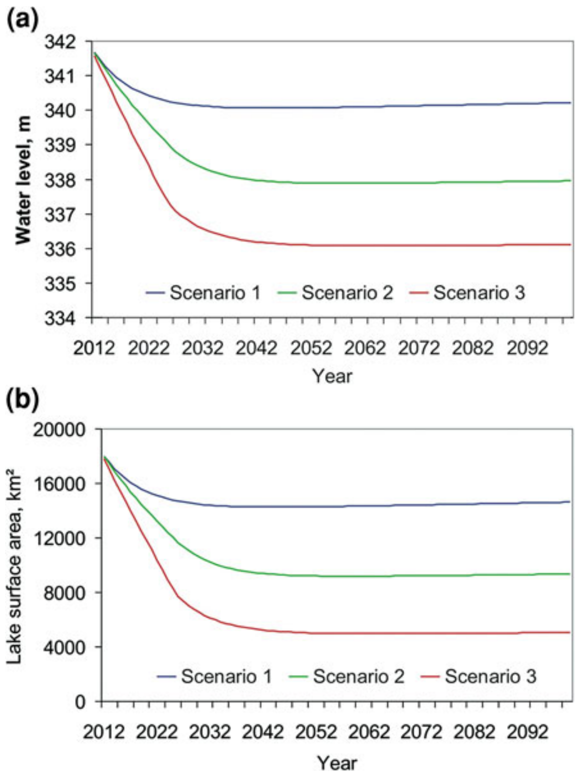

Fig. 3.4 Water level (**a**) and surface area (**b**) of the Balkhash Lake simulated assuming different scenarios of development in the basin

Balkhash Lake unavoidable. According to the scenarios, the Balkhash Lake can endure only slight anthropogenic activity in its basin. If the human activity is growing in one of the shared basin areas, the lake shows an immediate reaction, with disturbing effects for surrounding ecosystems. The analyses detected that a realisation of Chinese plans for increasing water intake (assuming the present level of water use in the Kazakh part of the basin) would cause a natural disaster in the Balkhash Lake (Scenario 2). A significant increase in human activity in both parts of the Balkhash Lake basin (Scenario 3) would lead to disaster conditions similar to the Aral Sea, with the break up of the lake surface into several divided parts and the drying up huge areas.

In the very near future, preservation of the ecosystem in the basin and regulation of the Balkhash Lake hydrological regime will mostly depend on water consumption in the Chinese part of the Balkhash Lake basin. Any successful management strategy for the Kazakh part of the Balkhash Lake basin can be established only with the close cooperation of the Republic of China.

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Author Biography

Pavel Propastin, born in Kazakhstan, received an MA in Geography and a PhD in Remote Sensing and GIS from the Georg-August University, Göttingen, Germany, in 2003 and 2007 respectively. He is currently a Postdoctoral Research Associate in the Department of Cartography, GIS and Remote Sensing Bioclimatology at the Georg-August University, Göttingen, Germany. He is also employed within a research project in the Department of Bioclimatology at the same university. His main research activities focus on integration of remote sensing and GIS in studies on climate dynamics and their impacts on ecosystems. His current address is: Department of Geography, Georg-August University Göttingen, Goldschmidtstr. 5, 37077, Göttingen, Germany, Email: ppropas@uni-goettingen.de

Chapter 4
Understanding the Links Between Climate Change and Disaster Management in Pacific Island Countries

Pritika Bijay, Walter Leal Filho and Veronika Schulte

Abstract Small island developing states (SIDS) are especially vulnerable to problems associated with climate change and, of course, with disasters, for two main reasons: (1) Their geographical location, in regions vulnerable to sea level rises; (2) Their limited capacity to adapt, as a result of constraints in respect of access to financial resources and technologies. This chapter discusses how Pacific Island Countries (PICs) address the challenges of climate change in the Pacific region. It shows some of the empirical evidence available and outlines some of the actions currently being taken on climate change and disaster risk management in the Pacific Island states. Finally, it summarises some of the lessons learned from the Pacific region and lists some of the challenges and measures that need to be implemented in order to achieve a better integration of climate change and disaster management in the Pacific Island Countries. This chapter is partly based on the experiences gained through the "Small Developing Island Renewable Energy Knowledge and Technology Transfer Network (DIREKT)", which is a cooperation scheme involving universities from Germany, Fiji, Mauritius, Barbados, and Trinidad and Tobago. The aim of this project is to strengthen the science and technology capacity, in the field of renewable energy, of a sample of ACP (Africa, Caribbean and Pacific) small island developing states, by means of technology

P. Bijay (✉)
Faculty of Science, Technology and Environment, School of Engineering and Physics,
The University of the South Pacific, Laucala Campus, Suva, Fiji
e-mail: pritika_m@usp.ac.fj

W. L. Filho · V. Schulte
Faculty of Life Sciences, Research and Transfer Centre "Applications of Life Sciences",
Hamburg University of Applied Sciences, Lohbruegger Kirchstraße 65, Sector 4S,
Room 0.33, 21033 Hamburg, Germany
e-mail: info@iccip.net

V. Schulte
e-mail: veronika.schulte@haw-hamburg.de

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Keywords Climate change · Disaster management · Pacific region · Renewable energy · Small island developing states

Introduction

The Pacific region is composed of 22 Pacific Island countries, which are scattered over one-third of the globe. The total population of the South Pacific, excluding Australia and New Zealand, is about 8 million, half of which is in Papua New Guinea. Agriculture, fishing and tourism are major industries in the region. Whilst the greatest challenge faced by the governments of the Pacific Island Countries remains the creation of jobs for a rapidly increasing population, environmental concerns related to the increased exploitation of natural resources are also becoming an issue.

The Pacific region is particularly exposed to the world's worst natural disasters, such as earthquakes, tsunamis, cyclones, and many others. Some examples of these natural disasters would include not only the 2004 tsunami which affected most of South East Asia, but especially also the 2009 earthquake in Samoa. This earthquake generated a tsunami which affected not only Samoa, but also American Samoa and Tonga, where more than 189 people were killed, most of them children in Samoa (ONE News 2009). The 2009 flooding in Fiji is another example, which affected the towns of Nadi, Labasa, Sigatoka, Ba and many rural villages on one of Fiji's main islands—Viti Levu—resulting in the deaths of eight people (Go-Fiji.com, n.d.).

There are some signs that the frequency of natural disasters seem to be increasing in number and size, due to a number of factors. One such factor is believed to be climate change, as it relates to disruptions in water cycles and subsequent floods or droughts.

Human activity is believed to play a major role in altering the climate and many of these activities are producing effects comparable to the natural forces that influence the climate (Trenberth et al. 2000). The frequency and intensity of severe weather events such as cyclones, floods, droughts and heavy precipitation events are expected to rise even with relatively small average temperature increases. This is a result of global warming (UNFCCC 2007).

There is a clear link between disaster vulnerability, disaster management and climate change. This chapter will therefore focus on the actions being currently taken by the Pacific Island Countries (PICs) on climate change adaptation and disaster risk management. Most of the issues discussed in this chapter are mostly drawn from literature research.

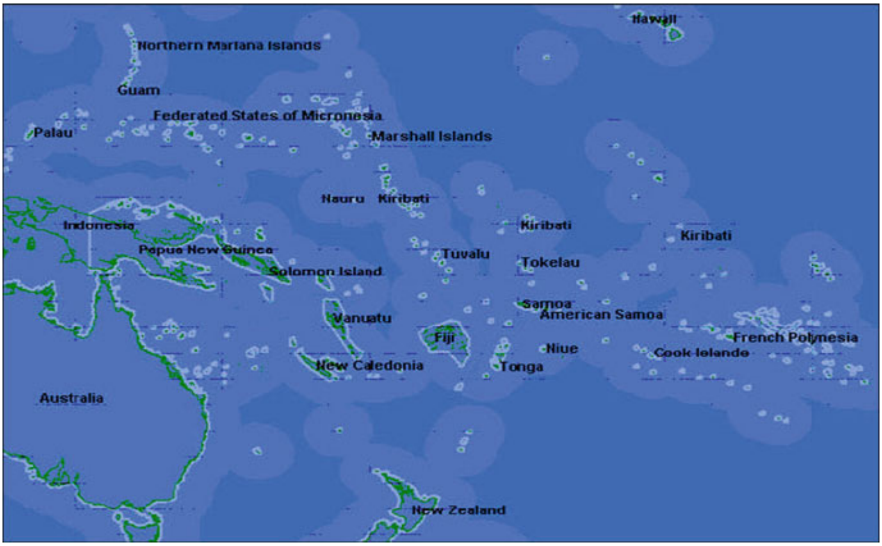

Fig. 4.1 Map of the Pacific Island Countries (*Source* http://www.whycos.org/rubrique.php3?id_rubrique=40)

Identifying the Consequences of Climate Change in the Pacific Region

Climate change is considered as one of the greatest risks to the people of the Pacific Island Countries (PICs). This poses a threat to properties on the one hand, but also to the livelihoods, security and welfare of the people of the Pacific on the other. Some of the most vulnerable of the PICs are shown in Fig. 4.1, which presents an overview of the South Pacific region.

The Pacific Island Forum Leaders, i.e. the leaders of the regional organisation that congregates the countries in the region, have stated that if the issue of climate change is not immediately and effectively addressed the impacts have the potential to cause severe damage, undermine security and undo progress towards the achievement of national priorities and the Millennium Development Goals (MDGs) in the Pacific. In the Niue Declaration on Climate Change (United Nations, n.d.), the Pacific Island Forum Leaders stated that PICs are considered to be one of the lowest contributors of factors contributing to climate change, yet they are among the most vulnerable to its impacts.

It therefore becomes extremely important that PICs develop ways to adapt to and address the impacts of climate change. The Pacific Islands Framework for Action on Climate Change (2006–2015) was adopted by Forum Leaders in 2005. This was essentially established to provide an integrated, programmatical approach to addressing the interlinked causes and effects of climate change related impacts in the region (SPREP, n.d.). The goal of this framework is to build the capacity of the Pacific island people to be resilient to the risks and impacts of climate change through implementing adaptation measures, contributing to the mitigation of greenhouse gas emissions, improving decision-making and good governance, improving understanding of climate change and its effects, education and awareness, and developing and strengthening partnership and cooperation (SPREP, n.d.).

Many organisations, societies and ordinary people in PICs are involved in pursuing a path of sustainable development. This will ensure that PICs will be more resilient to climate change impacts. Moreover, many PICs are reducing their dependence on fossil fuels and switching to renewable energy, which will lower greenhouse gas emissions. The use of cost-effective measures to improve energy efficiency and promoting the use of low-carbon technologies present clear benefits for the region (Australian Government 2009). These measures, besides helping to reduce emissions, also bring other benefits, such as enhanced energy security (Australian Government 2009).

Another way PICs have identified of addressing climate change is by improving access to increased resources and improving the ability to effectively manage and utilise these resources. In August 2010, Forum Leaders noted the importance of sufficient, sustainable and timely resources being made available to PICs to enable them to mitigate and adapt to climate change (Saili et al. 2011). The leaders also agreed on (i) the importance of effective coordination and management of climate change resources and response efforts, particularly at national level, and (ii) the need for PICs to drive the prioritisation of climate change resources and activities through their national and sectoral plans and systems (Saili et al. 2011).

Many developed countries and donor agencies are also working actively with the relevant organisations in the PICs to provide assistance in adapting to the impacts of climate change.

For example, the Australian Government has established the Department of Climate Change (DCC), which is actively working with AusAID in strengthening the capacity of neighbouring countries by providing information, tools and training to enable regional decision-makers to identify and incorporate climate change adaption into planning and development strategies (Scott and Simpson 2009). In addition, the government of New Zealand is supporting a wide range of climate projects, and international development agencies from countries such as Germany and the United Kingdom are engaged in the provision of technical assistance.

PICs have articulated their priorities for addressing climate change in the region through the Pacific Plan for Strengthening Regional Coordination and Integration, the Niue Declaration on Climate Change, and the Pacific Islands Framework for Action on Climate Change 2006–2015, and nationally through documents such as the National Adaptation Programmes of Action and the United Nations Framework Convention on Climate Change (UNFCCC) National Communications (Australian Government 2009). These documents have the advantage of setting a framework against which action can be taken and results can be measured.

Examples of Action Currently Being Taken Against Climate Change, and Disaster Risk Management in the Pacific Island Countries

As stated above, PICs experience some of the worst natural disasters. These include earthquakes, droughts, cyclones, floods, tsunamis, volcanic eruptions and landslides. The change in climate is believed to be influencing these natural disasters. The Intergovernmental Panel on Climate Change (IPCC 2007) has concluded that the frequency as well as the severity of hot and cold extremes and heavy precipitation events is increasing, and this trend is expected to continue. Therefore, the PICs need to be prepared for these natural hazards; they should also expect such events to occur more frequently and be more intense, rendering them even more vulnerable.

In order to be able to successfully address the issue of climate change and disaster risk management, PICs need to promote a number of measures.

For example:

- In-country government arrangements demanding risk reduction considerations across all sectors.
- The promotion of community-based risk reduction initiatives through provincial and local governments, and through civil society and all stakeholder groups (World Bank 2010).
- The relocation of some families to higher grounds; an example is Kiribati, where, due to the rising sea level, a number of villagers had to relocate.

These simple adaptation measures could lead to the successful protection of property, as well as of human lives.

It can be said that policy development and planning does exist in most PICs in terms of climate change adaptation and disaster risk reduction. An example is the Joint National Action Plan on Climate Change Adaptation and Disaster Risk Management 2010–2015, developed in Tonga. Tonga is the first PIC in the region to develop such a document, which highlights national and community priority goals and activities to be implemented in order to enable the people and environment of Tonga to adapt to the impacts of climate change and to mitigate disaster risks (Kingdom of Tonga 2010).

Although policy development and planning are in place, in-country capacity and relevant information remain major constraints. Risk reduction actions on the ground remain limited, despite major efforts by donor and stakeholder institutions at both national and regional level.

In the report “Institutional and Policy Analysis of Disaster Risk Reduction and Climate Change Adaptation in Pacific Island Countries”, four pilot countries—Cook Islands (approximate population: 25,600), Fiji (approximate population: 837,271), Palau (approximate population: 21,000), and Vanuatu (approximate population: 225,000)—were subjected to an institutional and policy analysis related to climate change adaptation and disaster risk reduction. The following section summarises the findings from the four PICs (Hay 2009).

Cook Island

On Cook Island, disaster risk reduction and climate change adaptation have been mainstreamed in development planning processes through the National Sustainable Development Strategy (NSDS). With resilience as a goal, this allows for an integrated approach to climate change adaptation/disaster risk reduction. The NSDS acknowledges that investment in infrastructure, as called for in the Infrastructure Management Plan, requires effective management structures to ensure its sustainability, including the guarantee of budgeting for future maintenance costs and also climate-proofing infrastructure as a safeguard against the impact of weather-related phenomena.

At local level, mainstreaming is being seen through NSDS Goal Six: "a safe and resilient community". This specifically looks at enhancing community resilience to natural disasters and climate change. Many planned actions in the NSDS—for example prioritising several cyclone-damaged harbours and airports in the Outer Islands for reconstruction and upgrade—are expected to contribute to this goal indirectly; construction of cyclone shelters on atolls in the Northern Group islands is also a key priority.

A National Action Plan (NAP) for Disaster Risk Management has been prepared, which takes climate change adaptation into consideration; this, however, is quite limited. However, through the NAP, climate change adaptation and disaster risk reduction are included in the national budget process with, approximately EUR 230,000 set aside each year as a disaster contingency fund. At local level, ecosystem-based projects to build community resilience are being implemented. Activities such as identifying priority hazards requiring attention and measures to deal with them are being incorporated in the respective plans and budgets. The Outer Island Councils are being trained, which will enable them to create sustainable planning processes including planning for climate change.

Similarly, looking at climate change adaptation at national level, a National Adaptation Plan is under preparation. A number of projects are being implemented with regard to water, waste and sanitation which include aspects of climate change adaptation. Locally, the government works closely with NGOs such as the Red Cross to undertake assessments, raise awareness and implement adaptation measures. Capacity and vulnerability assessments have been conducted in seven out of the fifteen inhabited islands. Plans are in place to complete assessments in all other inhabited islands and ecosystem-based management plans are being developed for each pearl-farming community.

Fiji

On a national scale, the People's Charter for Change, Peace and Progress, outlines the need for Fiji to be environmentally sustainable. Fiji's draft Strategic Development Plan (SDP) 2007–2011 recognised the need to develop response plans and early warning systems for floods and other natural hazards. It also urged the mainstreaming of disaster risk reduction into sectoral development plans, policies and programmes, noting that this is crucial for sustainable development and community resilience. The Sustainable Economic and Empowerment Development Strategy (SEEDS) 2008–2010 proposed integrating disaster risk reduction into political decisions and states that government efforts are underpinned by a "risk management approach", but that no particular strategy is included to address the issue. The local focus is on community-based capacity building with the aim of reducing dependency achieving community resilience and sustainable development.

The key policy and planning instruments for disaster management at national level in Fiji include the National Disaster Risk Management Act, the National Disaster Risk Management Plan, the National Disaster Risk Management Policy, Hazard Contingency Plans and Agency Support Plans. All these call for a safer and more resilient Fiji, using an all-hazards approach—both natural and human-induced. The focus is on disaster risk management and not just disaster management. Instruments for Disaster Risk Management in Fiji include Community Support Plans. Fiji has adopted the integrated Local Level Risk Management Approach (LLRMA). LLRM helps communities to manage and reduce disaster risk, as well as to foresee and control the emergence of new risks such as those related to climate change. This is done through work on local governance and community planning and preparedness, as well as through individual participation and motivation. An Emergency Management Volunteer Service has been established whereby volunteers are provided with community-based training, including training on initial damage assessment and community-based disaster risk management. Projects on combatting river bank erosion, landslide and flooding risk reduction and mitigation are being implemented. Similarly, many communities in Fiji are learning important lessons about managing the impacts of climate change; examples of local projects are the Climate Witness Programmes in Kabara, Tikina Wai, building coastal resilience to climate change in Tikina Wai and strengthening community marine resources management practices through ecosystem-based management and design.

Palau

The 2020 Palau National Master Development Plan (PNMDP) outlines the nation's priority developments, which include mainstreaming disaster risk reduction. Palau's National Disaster Risk Management Framework contains a vision of safe, resilient and prepared communities in Palau. The Government of Palau is generally committed to climate change adaptation principles and activities. However, there is a key gap in the government's understanding and the anticipated impacts of climate change extremes and variability are not adequately reflected in overall economic development, livelihood security, food security and infrastructure resilience. Similarly, on a local level there is a gap between the government's centralised climate change agenda and the limited engagement and consultations with Palau's decentralised and very active environmental NGO networks and the private sector tourism industry.

The National Disaster Risk Management Framework (NDRMF) was completed in early 2010. This Framework focuses on all types of hazards, human-induced and natural; the Framework establishes a mechanism for effective control, coordination, decision-making, accountability and organisational arrangements for all aspects of disaster management and disaster risk reduction. It describes organisational arrangements to maximise the use of available resources to strengthen mitigation, preparedness, response and relief, as well as "all-hazards" recovery planning. The framework uses an integrated approach by involving all levels of government, departments, sectors and communities to promote integrated planning and collaboration for disaster management and disaster risk reduction. Disaster risk reduction programmes and activities are being developed and incorporated into programmes that address community development and coping mechanisms for times of disaster in Palau. Relevant traditional knowledge and practices are being included in all national, state and community disaster risk reduction plans.

Palau has also developed documents, for example the First National Communication to the United Nations Framework Convention on Climate Change (UNFCCC), which propose several vulnerability and adaptation strategies and actions for climate change. However, there is a surprising lack of understanding about adaptation to climate change and only a few isolated, donor-driven projects include some level of adaptation in their activities. Palau also pays a great emphasis to environmental protection, resource management, land-use planning, and health and welfare, which therefore can play a major role in terms of climate change adaptation. However, progress in the adaptation implementation process has been very slow. This can be largely attributed to the lack of significant administrative and operational systems independent of the national government in the individual states of Palau (except for Koror), and also to the traditional governance systems that are embedded in the country's modern governance structures.

Vanuatu

In Vanuatu, disaster risk management has been integrated in the Priorities and Action Agenda (PAA). An important priority of this strategy is to mainstream disaster risk reduction as well as climate change measures. Another main focus of this strategy is to implement risk reduction programmes in communities. Vanuatu also has a National Disaster Act (2000), which focuses primarily on preparedness and response arrangements for disasters.

With regard to climate change adaptation, a discussion paper on Climate Change Policy and Implementation Strategy has been prepared in Vanuatu. The purpose of this is to provide a summary on climate change development in Vanuatu including future areas that the government and other stakeholders need to address. This chapter also determines issues that have been identified over the years that may form the basis for a climate change policy. Finally, it looks at developing a preliminary climate change policy framework for consultation purposes. The policy paper proposes a policy framework which will mainstream climate change issues in all its environmental, social, and economic planning structures and processes for sustainable development at national and community level.

A number of organisations are involved in disaster risk reduction as well as climate change adaptation in Vanuatu. Some examples include Vanuatu's Meteorological Department, parts of the Agriculture Department involved in disaster response, the Department of Internal Affairs, which coordinates responses between provincial authorities, the National Advisory Committee of Climate Change (NACC), which assists in raising awareness on disaster risk reduction through its climate change core team, and the Ministry of Lands and Natural Resources, which incorporates risk reduction into land, water and energy planning. The Foundation of the Peoples of the South Pacific International (FSPI) is a network of non-governmental organisations in the South Pacific. This organisation has engaged communities in Vanuatu in participatory methods of problem identification, risk analysis and action planning in the country. The initiative is for the development of a people-centred early warning system and community-based disaster risk reduction and disaster risk management plans, or for safer village plans. These will be reinforced through participatory research, dissemination of traditional and modern vulnerability reduction methods, social conditions and skills that contribute to community resilience in PICs, including Vanuatu.

Vanuatu's National Adaptation Programme of Action (NAPA) has identified agriculture and food security, sustainable tourism development, community-based marine resource management and sustainable forestry management as the priority sector. Several projects are being implemented in these priority areas; an example is the GTZ-funded and South Pacific Commission executed project focusing on sustainable agro-forestry management as a means of building resilience to climate change.

Overview of Other PICs

Other PICs have also made considerable progress in addressing climate-related and other natural hazard risks. In Kiribati, efforts to improve the enabling environment have been made through the two phases of the Kiribati Adaptation Project. According to the World Bank Synthesis Report (2009), the Solomon Islands

Government has created a new, higher-level Climate Change Division and is bolstering its staff and resources. The Marshall Islands has also completed a National Action Plan for disaster risk management.

Other practices are being carried out in the PICs to deal with underlying vulnerabilities and exposure to hazards. As stated in the World Bank Synthesis Report (2009), in Vanuatu a village at risk from coastal flooding has been relocated and fitted with water-harvesting systems on rooftops to guard against the risk of droughts. The Marshall Islands has embarked on a project to improve water-harvesting and water-quality in order to reduce drought impact and risks to health. Papua New Guinea, on the other hand, has undertaken to reduce drought risks in the highlands by promoting crop diversification and by the provision of wells in villages. Further disaster risk reduction and climate change adaptation projects in Fiji and Samoa include the Navua Local Level Risk Management Project (Fiji), World Wildlife Fund for Nature WWF Coastal Resilience (Fiji), Samoa Community Based Adaption, and many more projects, some of which are pilot projects and others forming part of a global initiative (Gero et al. 2010).

Although some activities are underway in the Pacific region, most are one-off activities or pilot projects. Most of these projects are donor-funded and often driven by donors and NGOs. Evidence of long-term initiatives and more comprehensive and detailed programmes of risk reduction tends to be lacking; hence it is necessary to focus on these points to ensure the successful integration of climate change adaptation and disaster management.

Challenges and Measures for Integration of Climate Change and Disaster Management in the PICs

Identifying the challenges and measures that exist is of extreme importance. Once these challenges have been identified and implemented then the integration of climate change and disaster management becomes easier and more fruitful.

The following are some challenges that have been identified in the integration of climate change adaptation and risk reduction in the Pacific Region:

i. better political frameworks;
ii. increased access to adaptation technologies;
iii. better access to funding for risk reduction, especially in living areas known to be vulnerable;
iv. clear sets of targets and indicators on how to reach them.

The World Bank Policy Note “Not If, But When” (2006) stated that countries are developing national strategies on risk reduction (through the NAP for disaster risk and/or the NAPA for climate change) at national level; however, few of these countries have actually fully implemented their national strategies on risk reduction. According to the policy note, most PICs lack the practical measures that need to be taken to strengthen their programmes against the risk of natural hazards, including climate change. An effort needs to be made to successfully implement the strategies developed for risk reduction by PICs.

Institutional arrangements are also crucial, especially at national level. More informed decision-making is possible through effective leadership. An effective institutional arrangement at national level is possible if there is stronger strategic and operational planning (World Bank 2009). Most PICs require assistance and guidance in order to achieve an effective institutional arrangement.

There are potential overlaps that exist between coordination on climate change adaptation (led by environment ministries) and on disaster risk management (led by National Disaster Management Offices). If both sectors work together in developing strategies and policies and implementing projects then a consistent and comprehensive approach may emerge from complementary policies.

Another challenge that has been identified is that proactive disaster risk mitigation has attracted limited funding. Problems are also compounded by limited capacity to implement risk management activities. According to the "Not If, But When" Policy Note, even though donors allocate emergency funds for disasters they are often unable to divert them to preventive efforts. Donors need to understand risk management of natural hazards as an important component of development funding, and as a result reward countries willing to take proactive action.

The problem of human resource capacity needs to be overcome before the integration of climate change adaptation and disaster risk management can be successful. Often the technical assistance given to projects is unsustainable, and regional organisations, due to the sheer scale of the challenge, are often limited to an advisory or limited back-up role (World Bank 2009). There is a general lack of in-country capacity for implementation of projects. For example, Kiribati has received donor funding over the last decade aimed at creating an enabling environment conducive to sustainable risk reduction, principally with regard to climate change adaptation. However, they lack in-country human capacity to implement these (World Bank 2009).

Furthermore, experience has shown that stand-alone climate and disaster risk programmes are often undermined by unfavourable national policies or investments. In order to be effective, climate and disaster risk management needs to be incorporated into the national processes that are crucial to decision-making.

The Policy Note concludes by pointing out that climate and disaster risk management requires an enabling national environment under which key players such as communities, government, and the private sector, can implement risk-reduction behaviour.

In a report by Gero et al. (2010), the authors identify the challenges of agency and architecture that provide the greatest hurdles to the integration of climate change adaptation and disaster risk reduction in the Pacific. Agency or agents are actors with the authority to make decisions, and they are mostly from non-governmental sectors (Bierman 2007). Architecture simply refers to the extant institutional framework. Gero et al. (2010) note that having multiple agents, on a local to a global scale, makes it difficult for some organisations to find their forte without duplicating the efforts of others. Agents working in climate change adaptation and disaster risk reduction in the Pacific usually have limited time. Hence, liaising and corresponding with even more partners can be detrimental to their "other" work. Therefore, if there is a better understanding of roles and responsibilities amongst agents, this could lead to reduced duplication and better collaboration and cooperation in the Pacific.

Similarly, Gero et al. (2010) also mention that the proliferation of different policies and funding mechanisms, the separation of responsibility for climate change adaptation and disaster risk reduction via the Pacific Islands Applied Geoscience Commission (SOPAC) and the Pacific Regional Environment Programme (SPREP), in addition to the overall institutional architecture, has created barriers to a streamlined approach and the meaningful integration of climate change adaptation and disaster risk reduction. Therefore, if the challenge of architecture can be overcome the Pacific could go a long way towards successfully integrating climate change adaptation and disaster risk reduction, as well as providing the means for better cooperation and collaboration between agents.

Summary and Lessons Learned From the Pacific Region in Integration of Disaster Management and Climate Change Adaptation

The Global Environment Facility (GEF) 2008 Pacific Alliance for Sustainability Report on future investment programmes contains a number of observations and lessons learned from the past 15 years of activity in the Pacific Region. Some of the lessons mentioned are also applicable to successful integration of disaster management and climate change adaptation. One such lesson is that in-country capacity needs to be built up. Preference should be given to the use of national and regional experts who have received the advanced training that allows them to play critical roles, rather than getting experts from overseas. Adaptation needs to go beyond such obvious actions as building sea walls or relocating. There needs to be awareness raising, capacity building, mainstreaming into development plans, acquiring of knowledge and data, and assessing of risk at all levels (World Bank 2010).

Secondly, the report mentioned that the most robust, effective and efficient project design is one based on regional coordination and cooperation with national implementation. It also notes that governments often lack adequate resources to develop and maintain management and research capabilities. There is a tendency to rely quite heavily on external assistance programmes. This can be unsustainable in the long term.

Finally, the report summarises barriers that have to be addressed in order to meet both national aspirations and GEF requirements. These include the problems of balancing community-focused actions with national drive, regional coordination, and the delivery of global benefits, programmatical with project-based approaches, national with regional projects, and planning with action. The report also mentions the necessity for increased absorptive capacity, limited co-financing, sharing expertise and sharing information.

Since 2003, the Secretariat of the Pacific Community has been engaged in implementing a sustainable agricultural development programme throughout the Pacific Region. According to the ISDR report (2008), the Development of Sustainable Agriculture in the Pacific programme (DSAP) employs a participatory approach in working with local farmers throughout the region to improve their food security and livelihoods, thus improving their resilience to disasters and climate change. The lesson learned through this programme is that a participatory approach that assesses the needs of all members of the community is important for the successful implementation of sustainable projects. The report also stated that, in order for participatory processes to be successful and be sustainable, time is required.

Conclusion

It is apparent that the changing climate and the increasing frequency of natural disasters occurring in the Pacific will have significant implications for the livelihood of many people and communities in the PICs. Therefore, it is of the utmost importance to identify needs, gaps, and lessons learned, as well as challenges and measures that need to be implemented in order to achieve a better integration of climate change and disaster management in the Pacific. Most of the PICs, with the support of the respective governments, donors, regional and international organisations as well as regional and international inter-governmental organisations, are already involved in discussions and establishing collaborative mechanisms to this end. Successful integration of climate change adaptation and disaster risk reduction can contribute to national development, ensuring an improved response to disasters and decreasing vulnerability and hazard exposure.

With the continued support and efforts of the respective organisations involved in climate change adaptation and disaster risk reduction in PICs, it is hoped that the vulnerability of many communities in PICs will be reduced. But in order for this to be achieved it is important to provide them with the materials and resources they need in order to adapt.

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Author Biographies

Ms. Pritika Bijay Is the Project Manager for DIREKT (Small Developing Island Renewable Energy Knowledge and Technology Transfer Network), an EU-funded project. She is responsible for managing the project activities in Fiji and the Pacific and is currently based at the University of the South Pacific in Fiji. Her areas of interest are renewable energy, climate change adaptation and mitigation.

Prof. Walter Leal Filho heads the International Climate Change Information Programme (ICCIP) and coordinates the online climate change conference series.

Ms Veronika Schulte has been coordinating EU projects at a national and international level since 2004. In previous and current projects, she has dealt with issues such as renewable energy, environmental management, climate change, innovation and sustainability.

Chapter 5
Climate Change Induced Glacier Retreat and Risk Management: Glacial Lake Outburst Floods (GLOFs) in the Apolobamba Mountain Range, Bolivia

Dirk Hoffmann and Daniel Weggenmann

Abstract Due to global warming, tropical glaciers in the Bolivian Andes have lost about half of their volume and surface area since 1975. Throughout the Apolobamba mountain range, the retreat of glaciers has resulted in the formation of small and medium-sized lakes on the glacier terminus. Many of the glacial lakes are contained only by loose moraine debris: thus they can pose a significant threat to human settlements and infrastructure downstream. Considering the fact that the *Cordillera de Apolobamba* holds the largest continuous glaciated area in Bolivia, which measured 220 km^2 in the 1980s, there is a legitimate concern regarding the dangers that might affect this mountain region. Yet there is no documentation available on glacial lakes in the Apolobamba mountain range; indeed there is little awareness of the related risks. Only recently has glacial retreat, and climate change impacts in general, been given some importance in the planning and management of the Apolobamba National Protected Area for Integrated Management, thereby opening a discussion on natural hazard threats and the development of adaptation strategies with the objective of minimising risks for human populations and local infrastructure. This paper presents documentation of glacier retreat and the forming of glacial lakes in the *Cordillera* of Apolobamba over the last 35 years. In addition, the risk potential of glacial lake outburst floods and the risk awareness of the local population will be analysed in relation to park management options, and ideas outlined for more detailed studies of glacial lake outburst floods in Bolivia.

D. Hoffmann (✉)
Instituto Boliviano de la Montaña—BMI, Casilla 3-12417, La Paz, Bolivia
e-mail: dirk.hoffmann@berlin.de

D. Weggenmann
Heidelberg University, Heidelberg, Germany
e-mail: D-Weggenmann@gmx.de

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Climate Change, Glaciers and Glacial Lakes

Global Warming and Climate Change Scenarios

Climate change is a reality today and its consequences can already be seen quite clearly in the Bolivian Andes (Oxfam 2009; Hoffmann 2010c). Temperature, precipitation and humidity have changed significantly over the last half century (Vuille et al. 2008). Studies now show a temperature increase of around 0.32 to 0.34 °C per decade, compared to around 0.10 °C for the decades after 1939 (Oxfam 2009).

Due to the complex topography of the Andes, climate change projections are difficult to make, and validated regional climate models only exist for a few mountains areas such as the European Alps (Neu 2009; PNUD-Bolivia 2011). Global scenarios, such as those developed by the Intergovernmental Panel on Climate Change (IPCC), are still too large in scale to give meaningful projections for individual mountain locations (IPCC 2007).

Evidence from other mountain regions of the world (Rocky Mountains, Swiss Alps), as well as scenarios for the Andes, shows that temperature increase is higher at higher elevations (Bradley et al. 2006; IPCC 2007). This leads Vuille et al. (2008) to state that warming in the tropical Andes is likely to be of similar magnitude to that in the Arctic—which is several degrees above the global average.

As to precipitation changes, they are even more difficult to predict for mountainous areas due to the heterogeneity of the landscape (Hoffmann et al. 2011). In addition, the Andes region is heavily dependent on changes in El Niño (ENSO) patterns, a natural climate phenomenon, which is still poorly understood (Neu 2009; IPCC 2007).

Glacial Retreat

Due to global warming and climate change, retreat of tropical glaciers located in the Central Andes has been observed over the past two decades. Some scientists believe that the melting of glaciers and changes in mountain ecosystems may provide an early glimpse of what could come to pass also in other environments, and that mountains thus act as early warning systems (Neu 2009).

In Bolivia, an unknown number of the smaller and lower altitude glaciers have already disappeared. According to current climate change forecasts, a temperature increase of between 5–6 °C is expected to occur at altitudes higher than 5,000 m during the 21st century (IPCC 2007). A temperature increase of this magnitude will likely cause the disappearance of the majority of tropical glaciers in Bolivia's *Cordillera Oriental* by the middle of this century (Hoffmann 2010b; Painter 2007). This will have grave consequences for local hazard potential and water cycles (Haeberli and Zemp 2009).

Forming of Glacial Lakes

Glacial lakes can be found in all mountain ranges in the world where glaciers are present. After the so-called Little Ice Age (1550–1850), when glaciers began to shrink, moraines were formed at the glacier tongue (Mool et al. 2001). In the course of global warming induced glacier shrinkage, many glacial lakes have been formed between the retreating glacier und the former end-moraine, thus leading to widespread GLOF hazards (Kaltenborn et al. 2010). The rapid accumulation of water can lead to a moraine breach. The huge amount of discharge contains water and debris and poses the most dangerous glacier hazard to downstream people and infrastructure (Richardson and Reynolds 2000). These disastrous flood waves are generally known as Glacial Lake Outburst Floods (GLOF).

In the recent past, Glacial Lake Outburst Floods have destroyed infrastructure mostly in developing countries and killed thousands of people (Richardson and Reynolds 2000; Ives et al. 2010). In Peru, glacial lakes have been investigated and monitored since an outburst flood destroyed the city of Huaráz in 1941, killing 4,500 people (Lliboutry et al., 1977). In Central and South Asia a huge amount of glacial lakes have been identified after several catastrophic discharges (Richardson and Reynolds 2000; Yamada 1998; Mool et al. 2001). Clague and Evans (2000) studied glacier flood waves in the Rocky Mountains, in particular in western Canada. The risk of glacial lake outburst floods in the European Alps has a different dimension, because the lakes are smaller and the infrastructure and settlements are generally much closer to the hazard sources (Huggel et al. 2002). Here even small lakes can cause serious damage (Huggel et al. 2002). Haeberli (1983), who compiled the data on flood disasters in the Alps, mentions that inventories of glacial lakes and potentially dangerous glacial lakes rarely exist.

Glacial Retreat and the Formation of Glacial Lakes in the *Cordillera* Apolobamba

The Apolobamba Mountain Range

The *Cordillera* Apolobamba is the northernmost part of the eastern branch of the Andean *Cordillera* in Bolivia, reaching into Peru. It lies about 250 km northwest of La Paz and north of Lake Titicaca. It forms part of the *Cordillera Real*, which in turn is part of the *Cordillera Oriental*, the Eastern Andean mountain chain. It stretchesfor some 75 km, regularly reaching heights of more than 5,000 m, with some peaks higher than 5,500 m (Montes de Oca 2005; SERNAP 2006a).

The Apolobamba mountain range is one of the least explored and least accessible mountain ranges in the Andes. The high mountain area is characterised by vulnerable ecosystems depending heavily on glaciers, which are subject to intense melting due to global warming (Fig. 5.1).

Historically, the whole region used to be Caupolicán province, which is today made up of the provinces of Franz Tamayo and Abel Iturralde, which in turn comprise the *municipios* of Pelechuco, Curva and Charazani. Apolobamba is not only biologically a very rich and diverse and area (Tarquino and Flores 2011), but also in terms of cultural diversity: the local Kallawaya population has been declared Intangible Cultural Heritage of Humanity by UNESCO in 2003.

Over the centuries this mountain range, which now forms part of the Apolobamba Protected Area (formerly “Ulla Ulla”), has acted as a barrier as well as an intersection between the *altiplano* highlands and the Amazon lowlands. At present, there are more than 16,000 inhabitants in the area above 3,000 m, the majority of whom make a living off the land as small-scale farmers and herders. Only a fraction of the population are traditionally described as being Kallawaya, a term referring to the itinerant Andean “healers” or shamans using medicinal plants from the region.

However, on the basis of the country’s new constitution (2009), attempts are now underway to establish this region as an autonomous indigenous Kallawaya territory. It is unclear what would happen to the large non-Kallawaya population of the area in such a context. Another still-unresolved question is what role the newly instituted “traditional” local decision-making bodies would play versus the existing municipalities.

Glacier Recession in the Bolivian Andes

Modest glacier recession in the Bolivian Andes—as elsewhere in the world—started in the last decades of the 19th century, after the end of the Little Ice Age (LIA) (Vuille et al. 2008).

The accelerated melting of glaciers, however, commenced around 1980. At that time, glacier area in Bolivia’s mountain ranges was calculated to be 566 km^2 by

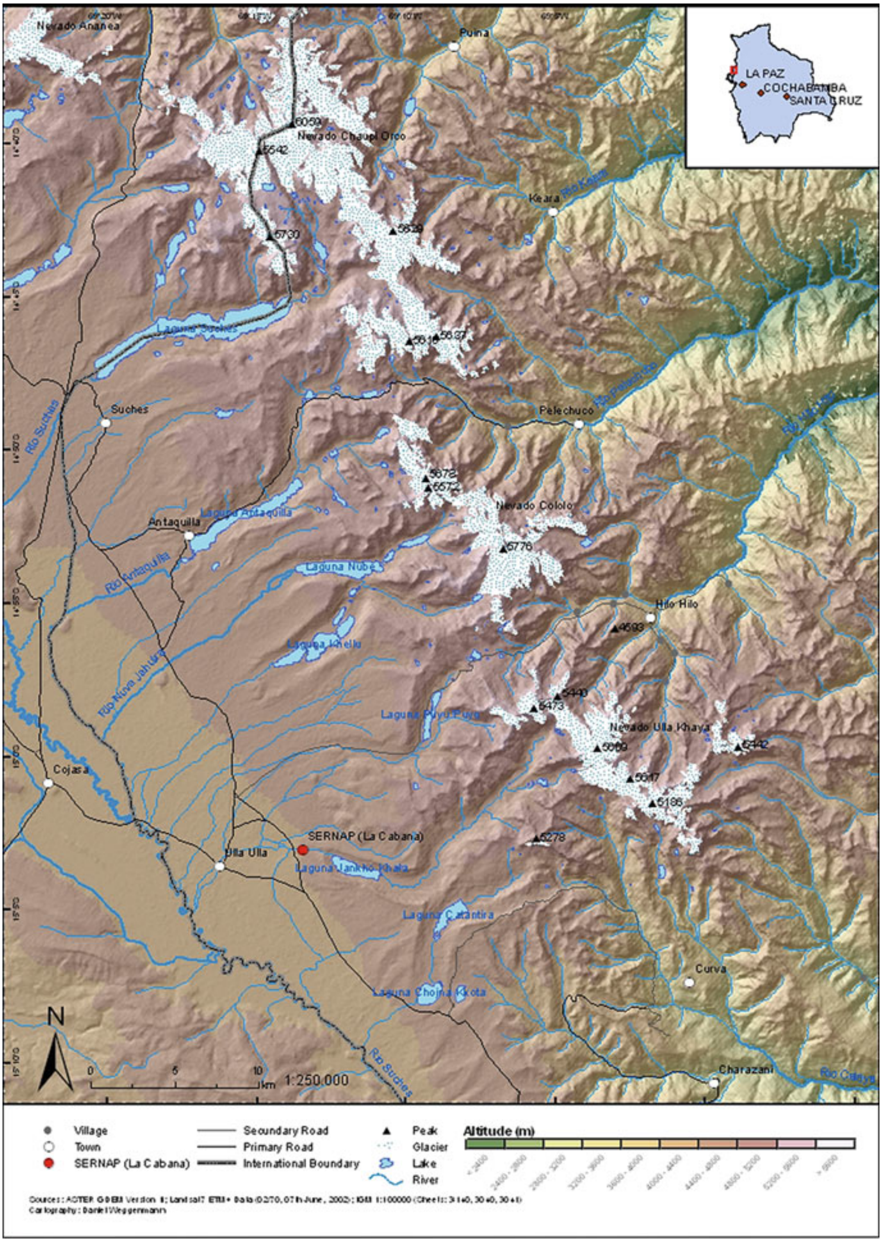

Fig. 5.1 Map of *Cordillera* Apolobamba, glaciated area and glacial lakes

the German geographer Ekkehard Jordan (1991). According to the World Glacier Monitoring Service, glaciated areas in Bolivia amount to 534 km^2 (WGMS 2008; Kaser and Osmaston 2002).

Thus far, research on glacial retreat has focused largely on the Bolivian *Cordillera Real*, with a recent study of 376 glaciers (based on exact photogrammetric measurements of 21 glaciers) coming to the conclusion that glacier volume loss between 1963 and 2006 amounted to 43 %, and that surface area loss for the period 1975–2006 was 48 % (Soruco et al. 2009).

Even though there is almost no documentation available on glacial retreat in the Apolobamba mountain range—which accounts for about 7.5 % of the world's tropical glaciers (Jordan 1991)—the results for the *Cordillera Real* from Soruco (2009) and his team suggest that the *Cordillera* Apolobamba must have experienced a similar decline over the past 35 years. This data is corroborated by Tarquino and Flores (2011).

It is thus safe to assume that tropical glaciers in the Bolivia Andes have melted away noticeably since 1975, resulting in a reduction in surface area and volume of around 50 %. Considering the present rate of global warming, it is also safe to assume that the majority of the smaller and low-lying glaciers will disappear within a few decades (Hoffmann 2008; Vuille et al. 2008).

Glacial Lakes in the Cordillera of Apolobamba

Considering the fact that the *Cordillera de Apolobamba* holds the largest continuous glaciated area in Bolivia, which measured 220 km^2 in the 1980s—a good third of Bolivia's glacier area (Jordan 1991)—under conditions of climate change it is an area where glacier lakes are destined to be formed.

The Bolivian part is subdivided into three glacier regions (from North to South): Chaupi Orco, Cololo and Ulla Khaya, separated by the *Abra de Pelechuco* (Pelechuco Pass) and the *Abra de Sorapata* (Sorapata Pass).

The Chaupi Orco region contains 129 km^2 of glacier area and 346 glaciers; the Cololo region contains 43 km^2 and 135 glaciers, and the Ulla Khaya region 47 km^2 and 171 glaciers (Jordan 1991).

As to the "glacial lakes", however, a note of caution: in various, especially older texts (Martin 1965; Seltzer et al. 1995), the term "glacier lakes" is used to refer to those lakes that formed 18–25,000 years ago at the end of the Last Glacial Maximum (LGM), which means they have existed all through the Holocene.

They are the remains of the Late Pleistocene glaciation of the Apolobamba mountain range, which took place in three marked advances leaving behind a number of large glacier lakes on the shallow western side towards the Ulla Ulla high plain. The largest of these are the Suches, Cololo, Nubi, Khellu and Jankho Khala lakes (Rafiqpoor 1994; Lauer and Rafiqpoor 1986). We, however, are only concerned with those glacial lakes of recent formation – those which were formed in the last 30 years, are higher up in the mountains and much smaller than those mentioned above.

Data on the lake (2008): Length: 574 m; Area: 0.079 km^2; Volume: 0.937 km^3; Change in area 1986–2008: 8.22 % (Weggenmann 2011).

Fig. 5.2 Moraine-dammed Laguna Isquillani in Apolobamba's Ulla Khaya region (*Source* Dirk Hoffmann, May 2011)

Throughout the Apolobamba mountain range, the retreat of glaciers has resulted in the formation of small and medium-sized lakes on the glacier terminus. Many of the glacial lakes are contained only by loose moraine debris; thus they can pose a significant threat to human settlements and infrastructure downstream (see Fig. 5.2). Yet there is no documentation available on glacial lakes in the Apolobamba mountain range.

Over the past 25 years, from 1986 to 2008, the number of contemporary glacier lakes has gone from 174 to 216 for the whole *Cordillera* Apolobamba, which is an increase of more than 20 % (Weggenmann 2011). The total lake area has gone up during the same time-span from 47,882 to 50,062 km^2. The average lake size is about 0.231 km^2. The average growth rate in the period 1986–2008 was about 4.5 % and the increase in the number of lakes was about 24 % (Weggenmann, 2011).

GLOF risks in Apolobamba

GLOF Risks

Haeberli and Zemp (2009) point out that the new lakes which form in local depressions of glacier beds, which are now becoming exposed, constitute a growing hazard in terms of flood waves and debris flows caused by moraine breaching or by rock avalanches from de-glaciated slopes, or slopes containing degrading permafrost (Haeberli and Zemp 2009). Similarly, Neu maintains that the "melting of glaciers and permafrost will trigger the release of loose rock and soil and exacerbate the danger of rockfall, debris flows, and mud flows. A specific risk is the build-up of glacial lakes and the threat of lake outbursts, which could result in destruction of property and death" (Neu 2009).

Glacial Lake Outburst Floods (GLOFs) represent the most dangerous and far-reaching glacial hazard in high mountain areas. The serious risks relate to loss of human life and destruction of costly infrastructure such as hydropower plants, roads and agricultural land (Huggel et al. 2004; Richardson and Reynolds 2000). This risk is likely to increase in the future, as continued glacier recession will lead to lake formation on the larger glaciers at higher altitudes (Kaltenborn et al. 2010).

In contrast, the most recent and most comprehensive compilation on the state of knowledge about climate change, water and food security in Bolivia does not mention the possibility of GLOFs in mountain regions, even though it has a whole chapter dedicated to climate risks and risk management (PNUD-Bolivia 2011).

Huggel et al. (2004) further warn that glacier floods are triggered by the outburst of water reservoirs in, on, or underneath the margins of glaciers, while outbursts from moraine-dammed lakes can be triggered by overtopping, piping, or slippage on steep slopes, or by a combination thereof (Huggel et al. 2004). The risk of a moraine breach outburst flood is very high in almost all glaciated mountain ranges in the world (Haeberli 1983; Clague and Evans 1994; Yamada 1998).

Among the triggers of glacial lake outburst floods we also find earthquakes, a subject that has been given fairly little attention in recent decades (despite the Huaraz incident in 1970), and which in fact has only recently been mentioned in relation to Himalayan glaciers (Singh Khadka 2011; Ives et al. 2010). There are however no systematic studies, neither in the Himalayas nor in the Bolivian Andes. Because of the remoteness of many glacial lakes, there is often a lack of even basic data on potential danger areas and the local communities at risk.

The Keara Incident, November 2009

The possibility of a GLOF in the highlands of the Bolivian Andes is no longer only a theoretical possibility: on 3 November 2009, at about 11:00 a.m., a glacial lake above the small village of Keara in Apolobamba's Chaupi Orco region emptied its contents within a few minutes and sent a wave of water downstream, flooding cultivated fields, destroying several kilometres of a local dirt road, washing away pedestrian bridges and killing a number of farm animals. The small community of Keara, which belongs to the *municipio* of Pelechuco and which is located on the Eastern Andean slopes at an altitude of around 3,800 m, was left without road communication for several months (Fig. 5.3).

Satellite images obtained from google.earth clearly show the glacier holding up the lake. There was no technical inquiry, and it has not been established exactly what happened. Still, at present this is the only documented case of a glacier lake outburst flood. This is thanks to the field technician Martín Apaza, who,

Fig. 5.3 Satellite image of the ice-dammed glacial lake above Keara (*Source* Google Earth, 4 August 2005)

Fig. 5.4 The glacial lake after the outbreak

accompanied by locals, went up to the lake the day after the outbreak, took photographs and filed a first-hand report (Apaza Ticona 2009) (Figs. 5.4 and 5.5).

Preliminary Risk Assessment and Classification of Glacial Lakes

Throughout the Cordillera range, the retreat of glaciers has resulted in the formation of small and medium-sized lakes. Many of the lakes are geologically volatile,

Fig. 5.5 Breach in the moraine dam below the glacial lake (*Source* Martín Apaza Ticona, 4 November 2009)

contained only by loose moraine debris, and pose a significant natural hazard threat to human settlements and infrastructure located below. Considering the prevalent occurrence of similar natural disasters (i.e. GLOF—Glacial Lake Outburst Floods) in other regions of the Andes and Himalayas, there is legitimate concern regarding the dangers that may affect many mountain regions of Bolivia (Hoffmann 2010b).

The majority of glacial lakes in the Andes have not been identified or studied properly. This, in large part, is due to the remoteness of the high mountain regions (Huggel et al. 2002). At present, in Bolivia none of the over 200 glacial lakes have been studied. Also, common maps in Bolivia either have been elaborated or use decades-old data, where glacial lakes formed in the context of climate change are not included. Many of the recent glacier lakes started forming during the last 30 to 40 years, after accelerated glacier recession due to climate change set in.

In view of this reality, the Bolivian Mountain Institute (BMI) has proposed a detailed investigation of all glacial lakes in the *Cordillera Oriental* and the evaluation of categories of risks for each one (Hoffmann 2010b). Due to lack of funding, the realisation of this proposal has not been possible until now. However, thanks to the interest and initiative of German geologist Daniel Weggenmann of Heidelberg University a start has been made: as part of his graduate thesis, Weggenmann has produced a glacial lake inventory for the whole *Cordillera Apolobamba*, the main glaciated mountain range in Bolivia (Weggenmann 2011).

It is thus that we can consider the detection of glacial lakes as a necessary first step towards the process of investigation into the possible risks associated with them. This step corresponds with "Level 1" of the methodological approach suggested by Christian Huggel et al. (2002): "The first level comprises the basic detection of glacier lakes over large areas" (Huggel et al. 2002). To achieve an overview of the existing lakes, the normalised difference water index (NDWI) established by Huggel et al. (2002) was used. Level 2 and Level 3 involve more detailed investigation of lakes detected in Level 1. Further on, topographical maps, satellite images, and hydrological maps were used, as well as the compilation of glacier maps put together by German geographer Ekkehard Jordan (1991).

In a second phase, this information will have to be complemented with data on infrastructure, human settlements and general terrain characteristics to allow for an assessment of potential damage. Topography is an especially important factor when assessing risk of glacier lake outburst floods. There is a marked difference between the shallow slopes on the western side and the abrupt and narrow valleys on the eastern side of the Apolobamba mountain range.

At present, such a risk assessment is being undertaken, which will provide a general vision and complete overview of the existence and dynamics in the *Cordillera* Apolobamba, Bolivia's main glacierised region. It will also come up with a classification and a listing of those lakes considered most dangerous (Weggenmann 2011). These should consequently be monitored and studied in more detail, including aspects of human vulnerability. Municipal and other planners will have to integrate this information into spatial and infrastructure planning in order to put the results of the present glacier lake risk assessment into practice, thus helping communities and the protected area in the region prepare for these potential risks.

Social and Political Responses

The "National Area for Integrated Nature Management—Apolobamba, ANMIN-A"

As a social and political setting we will consider, on the one hand, the Apolobamba National Protected Area for Integrated Management (ANMIN), and on the other the three municipalities involved with the glacierized upper part of the region, namely Pelechuco, Curva and Charazani.

The area was first declared the National Reserve Ulla Ulla in 1972 in order to protect the vicuna. The area has a size of approximately 240,000 ha (Supreme Decree D.S. 10070). In 1977 it was recognised as a UNESCO Biosphere Reserve. More than a decade later, in 2000, and again by Supreme Decree (D.S. 25652), the area was expanded to 483,743 ha and received a new name and category: "National Area for Integrated Natural Management—Apolobamba", or "ANMIN-A" (Ribera and Libermann 2006; SERNAP 2006a, b). Its altitude ranges from around 800 to more than 6,000 m in the Chaupi Orco region. ANMIN Apolobamba is by far the reserve with the largest glacier area: about 150 km^2, or one-third of all Bolivia's glaciers, are located in the region.

ANMIN Apolobamba is situated in the West of the district of La Paz, and belongs to the administative provinces Bautista Saavedra, Franz Tamayo and Larecaja A number of archeological sites and pre-Colombian routes are also located in the region, and it is home to the Kallawaya culture, which has been declared a "masterpiece of oral and intangible heritage of humanity" (Layme et al. 2007). The park's management plan dates from 2006 and is the central planning document (SERNAP 2006a). In its "diagnosis" there is a brief mention of climate change and glacier retreat, but on the whole this topic is not developed further; glacial lakes are not even mentioned.

Only recently have glacial retreat and climate change impacts in general been given some importance in the planning and management of the Apolobamba National Protected Area for Integrated Management, thereby opening a discussion on natural hazard threats and the development of adaptation strategies with the objective of minimising risks for human populations and local infrastructure.

The management plan is presently being adjusted to the new situation after the voting of a new Constitution in 2009, which presents park managers with a unique opportunity to put adaptation to climate change high on the park's future agenda. One of the issues that should urgently be addressed is the existence and ongoing formation of glacial lakes at high altitudes. An integral risk potential analysis should be carried out, involving the local communities that would be the ultimate beneficiaries of the initiation of glacial lake management activities. The park could thus play a leading role in disaster risk mitigation and adaptation of local communities to the impacts of climate change.

Risk Awareness of Local Actors

Melting glaciers are widely recognised as being the most visible sign of climate change, due to their often very fast response time and the clear visibility of their reaction to the public (Vuille et al. 2008; Hoffmann 2010a). This, however, does not mean that glacial lakes have also acquired more importance in the eyes of the people. Until now, in all publications on the impacts of climate change on protected areas in Bolivia, the focus has exclusively been upon biodiversity and water availability; GLOF risks have not been considered (Arnold Torrez and Barroso Pauletti 2008; Hoffmann 2010c).

However, the theme of International Mountain Day, celebrated by the United Nations in 2009, was "Risk Management of Catastrophes in Mountain Regions", and explicitly mentioned GLOFs as a risk for mountain dwellers (Eamer et al. 2007). This is a sign of the growing attention that GLOFs are receiving at international level.

Talking to the local population and park staff of Apolobamba immediately shows that there is indeed very little awareness of the risks related to glacial lagoons. The same holds true for the political and administrative personnel of the three small municipalities. The explanation might be provided in part by Huggel et al. (2004), who emphasise the fact that glacier retreat and permafrost degradation could lead to conditions never before experienced (Huggel et al. 2004). Risks related to glacial lakes are completely new; local societies do not have any references to help them understand and assess them, let alone react to them, leaving them virtually unprepared.

Two workshops on "local perceptions of climate change" that were held as part of the GLORIA project on long-term observation of high mountain biodiversity in the face of climate change in the upper parts of Apolobamba (Puyo Puyo and Cañuma communities) close to the glaciated areas of the Ulla Khaya region, did not reveal any sense of danger in relation to these newly formed glacial lakes. The workshop report reads as follows:

> *"The Cordillera Apolobamba presents glaciers along its whole extension that are being converted to water. The existence of numerous lakes in the highlands, as well as several streams, presents great social and environmental potential. Intensive fish production has developed in the high-altitude lakes (commercial trout breeding), and so has the breeding of native species. Studies have demonstrated the potential that these lagoons hold, besides being a landscape attraction for tourism."* (Canqui 2008, own translation.)

In each of the workshops around 50 villagers participated, interacting with a group of researchers from La Paz's UMSA state university in focused discussion groups and plenary sessions. Considering the number of communities in the Apolobamba region and the cultural diversity of the different population groups, the area of local perceptions of climate change clearly needs further research, especially from the various social science disciplines.

Establishment of a (Glacial Lake) Monitoring System

In relation to the potential risk of glacier lake outburst floods, various authors call for risk management and hazard mapping, as well as risk monitoring and installation or improvement of early warning systems (Marty 2009; Eamer et al. 2007). Glacial lakes, however, are still not seen as a risk to populations, either by authorities or by the local people themselves. The total surprise of the community of Keara at the GLOF event of November 2009 made clear that there exists no traditional practice for this type of hazard. The incident, however, triggered a discussion within the community and it remains to be seen where this process leads. One possibility would be the relocation of part of the village in order to strengthen the community's resilience to glacial lake outburst floods in the wake of continued global warming. Here we have a challenging research topic for anthropologists on the conditions necessary for community-based adaptation; this may even be a first step towards the community-based management of newly formed glacial lakes.

In 2010 the park management of Apolobamba National Area for Integrated Nature Management decided to establish a monitoring system, considered crucial to monitor biodiversity and the use of natural resources by locals within the protected area (Tarquino and Flores 2011). Following the national park administration's tradition of participatory planning, the monitoring system has been set up with the participation of the park rangers, together with a small technical support team. The monitoring system is based on the strategic areas defined for the planning of the whole System of Protected Areas, one of those areas being the "preservation of the natural and cultural heritage" (Tarquino and Flores 2011). The following elements have been defined as objects for monitoring: water bodies, glaciers, traditional tubers, fauna, Andean peat bogs (*bofedales*), climate, conflicts, mining, knowledge of traditional medicinal plants, rituals and ruins.

Efforts by scientists have been successful in convincing park guards and representatives of local populations that glacial lakes could indeed pose a risk and should therefore be monitored. Once the complete analysis of glacial lakes is available, it is hoped that a small number of lakes can be regularly visited. Monitoring is being realised by park guards themselves at intervals of about two months. It is also hoped that these monitoring activities will lead to the park guards informing the local communities about possible risks associated with these newly formed glacial lakes.

Additional efforts are currently underway to integrate photographic glacier and glacial lake monitoring into the monitoring system of ANMIN Apolobamba as part of its management scheme. The photographs will also be used for public awareness campaigns, in recognition of the fact that visual evidence is often the most convincing way of disseminating knowledge to a non-scientific audience (Byers 2007).

Conclusions

Glacial retreat and climate change impacts in general, have not yet been given the necessary importance in the planning and management of ANMIN Apolobamba. There is however a growing and legitimate concern regarding the dangers that might affect this mountain region, including the possibilities of glacial lake outburst floods (GLOF). The classification and listing of the Apolobamba glacial lakes according to their risk potential, currently being prepared by Weggenmann (2011), will be a valuable input for the local monitoring of the most dangerous of those lakes.

In the second phase of research, still to be undertaken, empirical studies of the landscape will be shared with municipalities and local communities, thereby opening the discussion on natural hazard threats and the development of adaptation strategies with the objective of minimising risks for human populations and local infrastructure (Hoffmann 2010b).

A direct policy implication is the critical need to promote multiple stakeholder platforms in land-use planning (López Sotomayor 2008), fostering dialogue mechanisms and improving mutual knowledge of stakeholders as part of the participatory process. Here various actors are being called upon. Will local communities be willing and able to exert pressure for such a process to be organised? Will the municipal government of Pelechuco understand the new challenges posed by retreating glaciers and act upon them accordingly? And, maybe most importantly, will the park's new director push for the continuation of the monitoring system and give priority to its implementation? Very much depends on each of these actors individually as well as on their mutual interactions, if attempts to channel these emerging challenges into existing local institutions are to provoke concrete action.

The ANMIN Apolobamba monitoring system is not only an innovative approach towards participatory monitoring, in that park guards themselves have a key role in the planning and implementation; it is also an example of inter-institutional alliances, bringing together state actors (SERNAP national parks administration and municipalities), academic and research institutions (Ecological Institute of UMSA university and Bolivian Mountain Institute—BMI) with local actors (*comunidades*, park guards and Apolobamba management committee).

Last but not least, it is a concrete and practical example of local adaptation to climate change.

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Author Biographies

Dirk Hoffmann holds a first degree MA in Latin American Studies from the Free University Berlin and has an MSc in Environmental Protection from the Humboldt University Berlin. From 2009 to 2011 he was working with the Ecological Institute (IE) of the Bolivian state university Universidad Mayor de San Andrés (UMSA), La Paz, as a coordinator of the Climate Change Research Programme. At present he is director of the Bolivian Mountain Institute (BMI), a non-profit foundation with its headquarters in La Paz. The subject of his ongoing PhD is the influence of protected areas on landscape transformation in high mountain regions under conditions of climate change.

Daniel Weggenmann received his Diploma from Heidelberg University in 2011. In his thesis he studied the development of the glacial lakes in the Apolobamba mountain range in the context of climate change.

Chapter 6
Current and Future Impacts of Extreme Flood Events

Maddalen Mendizabal, Roberto Moncho and Peter Torp

Abstract Inadequate timber extraction management of forests, cattle farming, abusive recreational practices, and rapid urban expansion are all factors that create significant problems in the Cantabrian area watershed for the sustainable management of the hydrological ecosystem services. These problems, added to the consequences of climate change, are already causing tangible and intangible damage to human and natural systems. Particularly for this coastal area, it is necessary to analyse flooding on a local scale. Therefore, the impact of climate change on extreme precipitation and its influence on discharge is researched in the Atlantic climate basin in the context of short, fast-flowing rivers. In this chapter, ENSEMBLES RT3 climate model outputs are analysed and calibrated with local observation data recorded daily. The hydrological/hydraulic coupling model (MikeShe-Mike11) is applied by forcing the validated model output. In order for results to remain spatially representative, basin and urban scales are studied. According to the results, under the medium greenhouse emission scenario (A1B), the Regional Climate Models HIRHAM (2001–2050) and RACMO (2051–2100) show an increase in extreme precipitation. The expected changes show spatial variability depending on local characteristics (topography, proximity to the coast, vegetation, etc.) and ranging between 6–26 % for HIRHAM and 11–12 % for RACMO. These changes in precipitation affect the river flow. An increase of 22 ± 2 % is expected in the HIRHAM climatic model for upstream peak

M. Mendizabal (✉) · R. Moncho · P. Torp
Environment Unit Tecnalia Research & Innovation, Parque Tecnológico de Bizkaia.
Edificio 700, E-48160 DERIO (Bizkaia), SPAIN
e-mail: maddalen.mendizabal@tecnalia.com

R. Moncho
e-mail: robert@temps.cat

P. Torp
e-mail: Ptl@dhigroup.com

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discharge with a return period exceeding 50 years. The change in precipitation also causes an increase in flood damage. This is a result of the expected change in the river's peak flow by 2,050 leading to an expansion of 3 % in the flood area as well as impacting the intensity of flooding. In this context, it has been necessary to define and assess the different adaptation options.

Keywords Climate change · Impacts · Hazard · Floods · Discharge · Damage · Adaptation

Introduction

Future climate change will affect aquatic systems in a range of different ways. In terms of the hydrological cycle, it is expected that changes in hydro-meteorological variables (air temperature, precipitation, evapotranspiration) will affect discharges. The Intergovernmental Panel for Climate Change's Fourth Assessment Report shows there is evidence that the recent warming of the climate system could result in more frequent extreme precipitation events, an increased likelihood of winter floods, accelerated melting of snow and ice, longer and more frequent droughts, and the rising of the sea level (IPCC 2007). Projections under the IPCC IS92a scenario (similar to SRES A1B) (IPCC 1992) and two Global Climate Models (GCMs, Lehner et al. 2006) indicate that flood risk will increase in northern, central and eastern Europe (IPCC 2007). The increase on intense short-duration precipitation in most of Europe is likely to lead to an increased risk of flash floods (EEA 2004). Furthermore, it is likely that up to 20 % of the world's population will live in areas where river flood potential could increase by the 2080s (IPCC 2007).

According to the studies carried out in Spain there is no evidence that daily maximum precipitation is going to increase by the year 2100 (under A2 and B2 scenarios). This study reveals important uncertainties related to the differences in the results between projections. However, an increase in the proportion of the daily maximum precipitation in the total annual precipitation is expected in a number of regions. This could be due to the decreasing trend of the total annual rainfall (CEDEX 2011). Under the A1B scenario, extreme precipitation may, despite the inherent uncertainty, increase by the middle of the century (AEMET 2011).

The climatic conditions and geography of the Iberian Peninsula favour the generation of floods. In Spain, floods have historically had strong socio-economic impacts—there have been more than 1,525 flood-related fatalities in the past five decades (MARM 2011).

Focusing on precipitation in the Basque Country, the regional models show an annual rainfall reduction, especially during the summer months. It is estimated to be between 15–20 % for the final stage of the 21st century (projections simulated by the model developed for the Third Assessment Report of the IPCC, and confirmed in the Fourth Report) (IPCC 2001; IPCC 2007). Recent studies also estimate a 10 % increase in extreme rainfall (daily precipitation) (Moncho et al. 2010; Chust et al. forthcoming). The main change could be further conditioned by the seasonal distribution of rainfall (with a higher spatial and temporal heterogeneity) than for their own percentage decrease in absolute values (there are not significant differences between different climatic regions of the Basque Country, but the decrease in rainfall could be more evident in the middle and south part of the region) (Santa Coloma et al. forthcoming).

The main goal of this chapter is to assess the hydrological response to climate changes in extreme flow conditions in the Nerbioi river basin (Basque Country, northern Spain). Four sub-objectives are defined to achieve this aim: (1) to select future climate projections for the case study area from a wide spectrum of possibilities; (2) to calibrate the hydrological model with observation data; (3) to simulate run-off, introducing the selected regional climate models data; (4) to identify the changes in the flood-prone area and in natural phenomenon severity (in terms of flood depth and velocity).

It is expected that the rise in extreme precipitation could increase the discharge in the Nerbioi river basin. In this context, it is necessary to define and evaluate the different adaptation options, whether they arealready in practice or are merely conceivable given current scientific knowledge, in terms of their ability to lower the vulnerability of water resources to climate change.

For example, changes in land use could be one means of adapting our basin systems. Land use plays an important role in the water balance of a river. It varies both the proportion of precipitation that runs off and the fraction that is lost through evapo-transpiration (Jackson et al. 2008; O'Connell et al. 2004). Both climate change and adaptation strategies will therefore have an impact on the hydrodynamic conditions of rivers; changes in flow conditions will have a severe ecological, economic and social impact. For the above reasons, the aim of this work is to analyse the expected impacts and the adaptation options.

Methods

Case Study: General Description of the Nerbioi River Basin

The Nerbioi basin, situated in the middle of the Basque Country (Fig. 6.1), covers about 500 km^2. It includes important rural and urban populations (those with more than 144,000 inhabitants), and the lower central part of the basin is densely populated. Additionally, land use management in agricultural and forestry areas supports water ecosystem services. The main concerns with regard to the Nerbioi watershed are associated with flood events and the control of erosion. In the river basin, inadequate management of forests for timber extraction, cattle farming and abusive recreational practices, together with rapid urban expansion, are creating significant problems with respect to the sustainable management of the hydrological ecosystem services.

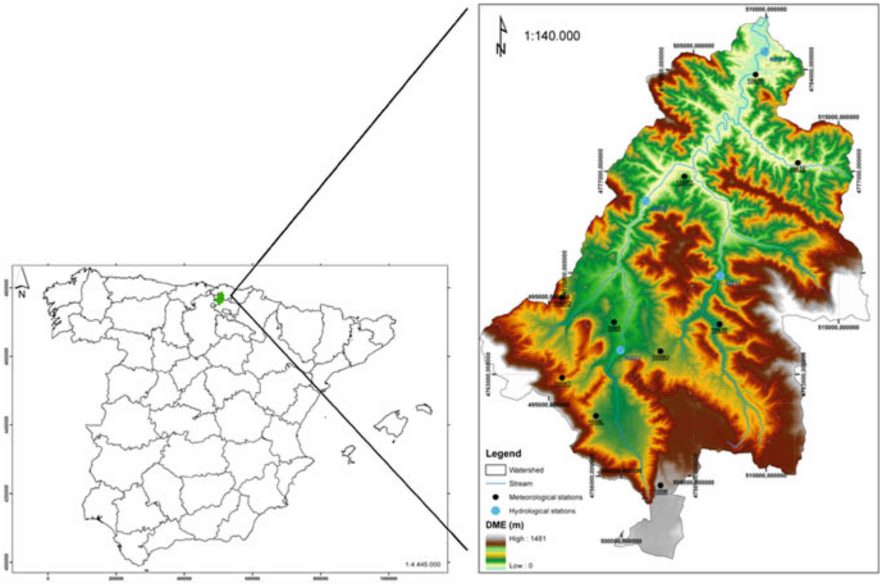

Fig. 6.1 Location of the case study. Northern coast of the Iberian Peninsula (*left image*). Digital model elevation of the nerbioi basin including the location of the meteorological and hydrological stations (*right image*)

The watershed is located on the Cantabrian side of the peninsula, with short, fast-flowing rivers. This topography is caused by the proximity of the mountains to the sea; the fast flow comes from the frequent rains. The length of the Nerbioi River is 25 km, including six tributaries.

The study area has an Atlantic climate, generally with frequent and abundant rainfall, mild winters and cool summers. In the basin, the mean averages of annual rainfall are 1,087 ± 64 mm and those of annual temperature are 13.7 ± 5.7 °C. Analysis of trends in annual precipitation does not show a significant change in the last 53 years (Fig. 6.2).

There are seven meteorological stations in the basin with a common daily data period from October 1986 to September 1995 (Table 6.1).

Homogenisation and control techniques have been carried out for the quality of the data. Values are missing from five stations: missing values amount to about 1–3 % of the total daily data. A reconstruction of the series is applied by linear regression between the best-correlated stations.

A comparison of the average annual precipitation recorded at each of the seven stations is estimated for each altitude (measured from sea level) during the period 1986–1995. This showed no correlation between increase in precipitation and elevation.

Three gauging stations have been installed in the basin since 1987 to record daily discharge data (NB01, NB04 and NB11). Run-off is dominated by rainfall.

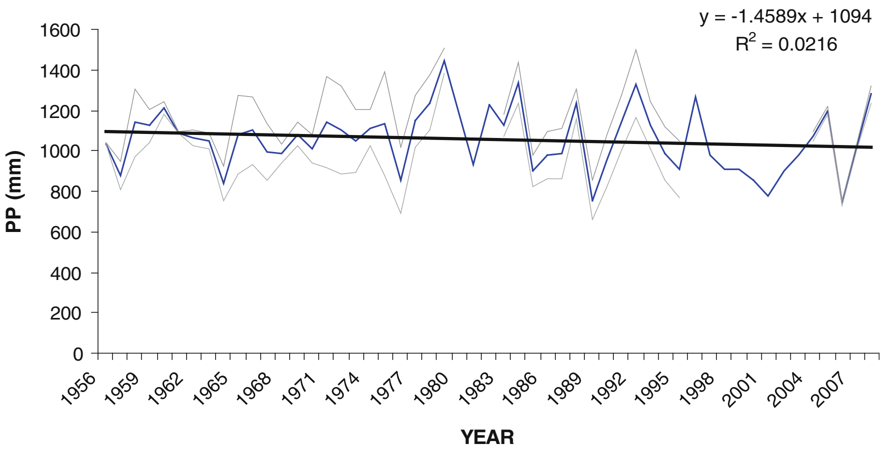

Fig. 6.2 Changes in annual precipitation during the last 53 years in the study area

The input flow volume at NB01 station includes the precipitation contribution both of the basin and of the Nerbioi waterfall (precipitation in-flows coming out of the watershed) (Table 6.2).

In terms of land use, the area is mostly covered by forest, scrub and pasture. Forest accounts for 44 % of the total area; scrubs and pasture cover 44 % (22 % respectively); built-up areas account about 9 %. The remainder is bare soil and water. Soil types in the area include mostly cambisol, ranker and rendzinda; to a lesser extent, litosol, acrisol, fluvisol, luvisol and regosol are also found.

Climate Change Projections Description

The calibrated future precipitation projections were studied in order to establish future climate change effects. Changes in the probability of the precipitation were analysed. The periods selected were 2001–2040 and 2041–2080, compared with the reference period, 1961–2000. The data series of each model from the ENSEMBLES RT3 (Hewitt, Hewitt 2005) were extracted. All the series corresponding to 20 cells of the grid were averaged, obtaining one representative series for each area of interest. This meant the future projection was approximately equally probable, since there is no correspondence between a grid point and a station. The projections considered in this study were made under the A1B climate scenario, which assumes an increase in emissions during the first half of the present century, turning to a decrease in the middle of the century due to the more efficient use of technologies. Four RCMs were selected for this research, covering the Basque Country reasonably comprehensively: ALADIN (from CNRM, Spiridonov et al. 2005), RACMO (from KNMI, Lenderik et al. 2003), HIRHAM (from METNO, Haugen et al. 2006) and PROMES (from UCLM, Castro et al. 1993). These RCMs were

Table 6.1 Precipitation data in mm/day

Station	Max.	Mean	Standard dev.	Filled gaps (%)
1,060	97.1	2.9	7.6	0
10,65O	101.7	2.9	7.3	0
10,61O	98	2.9	7.8	2
10,59I	100.1	2.7	7.1	1
10,59O	100.5	3	8.0	1
1,067P	95	3.3	8.3	3
1,059L	88.9	2.7	7.0	2

Table 6.2 Data from the three gauging stations for the period 1987–1994

Station	Years	Min.	Max.	Mean	Standard dev.	Missing values
NB01	1989–1994	0.018	32.053	1.191	2.959	26
NB04	1987–1994	0.62	235.823	8.336	20.013	290
NB11	1991–1994	0.021	66.71	1.98	6.27	90

NB01: This station is under natural flow regime and under natural conditions. It is considered a good station (Intecsa-Inarsa, 2003)
NB04: This station is considered under natural flow regime, because it has already received the returns of the upstream intakes. It is considered a good station (Intecsa-Inarsa 2003)
NB11: This station is under natural flow regime. On account of its location (steep and curved), it is not considered a very good station (Intecsa-Inarsa 2003)

driven by three different GCMs: ECHAM5 (Roeckner et al. 1999), ARPEGE (Gibelin and Déqué 2003) and HadCM3 (Rowell 2005).

The RCM series outputs and observations (defined hereafter as references) were standardised on a daily and monthly basis in order to extract the statistics for each month for the comparison of the model with the reference series. The standardisation was undertaken using cumulative probability from daily precipitation records. The commonly known probability distributions (Gamma, GEV, Exponential, Pareto, etc.) do not always suit the whole spectrum of precipitation; hence, it was necessary to use an alternative. We observed that the empirical return period of the data is better adjusted to a Generalised Pareto model with a variable exponent (Moncho et al. in review).

Hydrological-Hydraulic Model Description

In this study, the distributed MikeShe-Mike11 model is used to perform the surface water simulations. MikeShe-Mike11 is an integrated hydrological and hydraulic coupled modelling tool. It provides a physically distributed and process-based model (Fig. 6.3).

As a physically distributed model, MikeShe-Mike11 requires numerous input data sets: on the one hand, it requires the meteorological and hydrological data, (rainfall time series, evapotranspiration and gauging stations); on the other, it

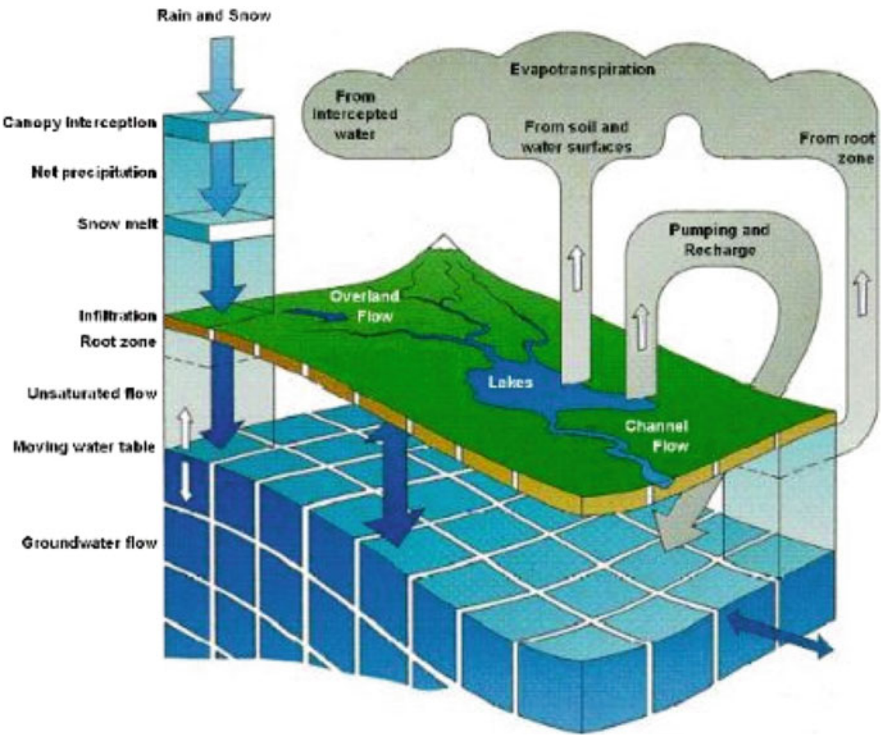

Fig. 6.3 Hydrological processes modelled by MikeShe (DHI)

requires the cartography data (Digital Terrain Model and derivatives like flow direction, soil maps, geological and hydro-geological maps, vegetation cover maps, etc.). Table 6.3summarises the pre-processed information to be put into the MikeShe-Mike11 model.

The variables pre-processed by Mike are the overland flow, channel flow, evapotranspiration, unsaturated zone flow and saturated zone flow.

To simulate a river run-off hydrograph, a dynamic overland flow (by finite difference), a channel flow (by Kynematic approach), 2D gravity flow for the unsaturated zone, and 3D finite difference flow in the saturated zone model were implemented. For the land use and unsaturated zone definition, two DHI databases were coupled with local studies in order to better represent vegetation and soil texture (vegetation by leaf area index and root information, and soil by retention curve and hydraulic conductivity information) (Iñiguez et al. 1980; DFG 1991; Martínez Fernández, et al. 1996; Batías et al. 2006; Regional Cartography Services, thematic maps).

The temporal resolution of the model was one day, and the spatial resolution 200 × 200 metres for the entire zone and 50 metres for the floodplain area. Mike21 was used for the flood simulation, as it simulates water velocity in the flood-prone area better than MikeShe-Mike11.

Table 6.3 Input data for the MikeShe-Mike11 model

Data type	Specifications	Scale (spatial-temporal)	Source
Meteorological	Precipitation	45 km^2/1 station daily	State meteorological agency
	Temperature	167 km^2/1 station daily	State meteorological agency
Hydrological	Gauging station	167 km^2/1 station-every 10 min	Environment department, DBF
Topography	Digital elevation Model	Pixel: 5 × 5 m	Regional cartography services
Hydrography	Watershed and streams	1:25,000	Regional cartography services
Land use	Vegetation	1:10,000	Regional cartography services
Soil	Soil profile definition	1:25,000	Regional cartography services/ herrero et al. 1980.
Regolith thickness	Lower level	1:25,000	Regional cartography services

Calibration of parameters was necessary for the model application in order to improve accuracy. Mike-She has an automatic calibration method to calculate a coefficient of correlation and Nash–Sutcliffe. The calibration is performed through estimation, comparing the recorded and simulated daily flows for a stated variable in the model and the entire time period of evaluation (since it was the period common to all the gauging station records, the calibration was carried out for the period 1989–1994). Nash–Sutcliffe indicates to what extent the relationship between the observed and simulated values correspond to a 1:1 ratio. The correlation coefficient shows the strength of the relationship between the observed and the simulated data. R^2 is the square of the Pearson product moment correlation coefficient and describes the proportion of the total variance in the observed data that can be explained by the model.

The recorded discharge was used as in-flow in the river model for the calibration period (boundary condition). For the analysis of climate change impacts, it was decided to maintain a constant flow as a boundary condition in order to determine whether there was variation in discharge magnitude due to future precipitation predictions. Therefore, with this model the river run-off is simulated at daily intervals for present and future precipitation.

Data Analysis and Results

Precipitation Projections

Two of the four models analyzsed for the Nerbioi basin show an increase in extreme precipitation: the HIRHAM (2050) and the RACMO model (2100) (Fig. 6.4). The models PROMES (2040) and ALADIN (2050) suggest a decrease,

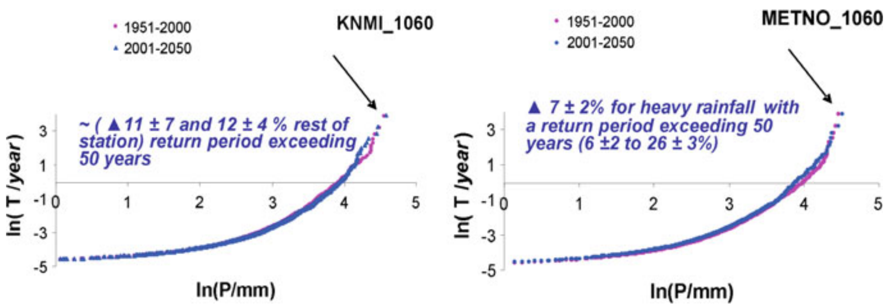

Fig. 6.4 Future calibrated rainfall of the RACMO (from KNMI—left graph) and HIRHAM (from METNO—right graph) models. The calibration is done for the central station 1060 (*data in figures*) and for the other six stations of the basin (*data in brackets*). The change percentage is given with the standard deviation

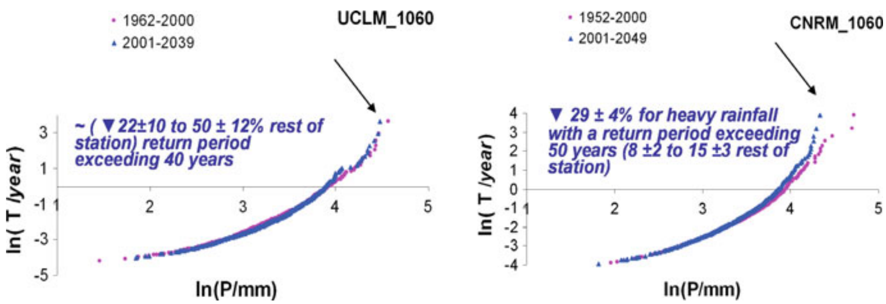

Fig. 6.5 Future calibrated rainfall of the PROMES (from UCLM—left graph) and ALADIN (from CNRM—right graph) models. The calibration is done for the central station 1,060 figures and for the other six stations of the basin (*data in brackets*). The change percentage is given with the standard deviation

according to the A1B scenario and for the period 2040 and 2050 respectively (Fig. 6.5) (Table 6.4).

Even taking into account the medium greenhouse emission scenario, it is therefore expected that extreme precipitation will change during the 21st century, although there is uncertainty in the change signal and percentage due to the climatic models.

When analysing regional scale, the four climatic models suggest a 10 % rise in extreme precipitation (Moncho et al. 2010; Oscar et al. forthcoming). On this scale the expected change is therefore positive, and it is expected that changes in local catchments will vary along spatial lines depending on local characteristics (topography, proximity to the coast, vegetation, etc.). To have more consistency at catchment level, in future it will be necessary to analyse more models.

Precipitation projections with a high uncertainty range have been obtained. The researchers are therefore working on decreasing the precipitation calibration error to less than 10 % in the ongoing research. For this chapter, and for the next

Table 6.4 Change in precipitation (%) and standard deviation (Ds) for each climatic model (HIRHAM, RACMO, PROMES and ALADIN) and each meteorological station

Station	HIRHAM (2001–2050)		RACMO (2050–2100)		PROMES (2001–2039)		ALADIN (2001–2049)	
	%	Ds	%	Ds	%	Ds	%	Ds
1,060	7	2	Ns	–	Ns		–29	4
1,067P	13	4	Ns	–	–33	8	Ns	–
1,059I	9	3	Ns	–	–22	10	–15	3
1,059L	6	2	Ns	–	–30	6	–8	2
1,059O	15	3	11	7	–33	15	Ns	–
1,061O	Ns	–	Ns	–	–30	7	–15	3
1,065O	26	3	12	4	–50	12	Ns	–

Table 6.5 Calibration. ME = mean error, MAE = mean absolute error, RMSE = root mean square error, STDres = standard deviation of the residual

Name	ME	MAE	RMSE	STDres	Correlation (R)	Nash–sutcliffe (R^2)
NB04	0.137	3.725	10.12	10.12	0.9	0.74

sections of this work, the HIRHAM and RACMO models have been considered. The goal is to support the study in defining the workflow for the impact of climate change on flood events. The aim of this workflow is to present a method that could be applied in the ongoing studies to decrease the uncertainty band and obtain more models with the same signal.

Calibration of the Hydrological-Hydraulic Model

The calibration of the model is applied to periods with observed meteorology and run-off data. Data from seven meteorological stations and tree gauging river points are selected for this analysis during the period 1989–1994. One of the gauging stations is in the upper stream; another is in the middle stream, and the last one downstream. Therefore, the model was calibrated using the full length of the available hydro-meteorological data series (Table 6.5) and could not be validated by applying the calibrated version to subsets of the calibration period. This was because the subset calibration was inadequate, and validation for single years did not produce reliable results (Hagg et al. 2007). Furthermore, it was not possible to validate the model for the future climate scenarios (Roosmalen, Sonnenborg and Jensen 2009). The change in discharge percentage was calculated because it is more accurate than the absolute values. In March 1991, November 1991, and October 1992, flood events were documented in the case study. The model exceeded the measured river run-off, except in November 1991 at the NB11 station (in this case the simulated river run-off underestimates that recorded) (Fig. 6.5).

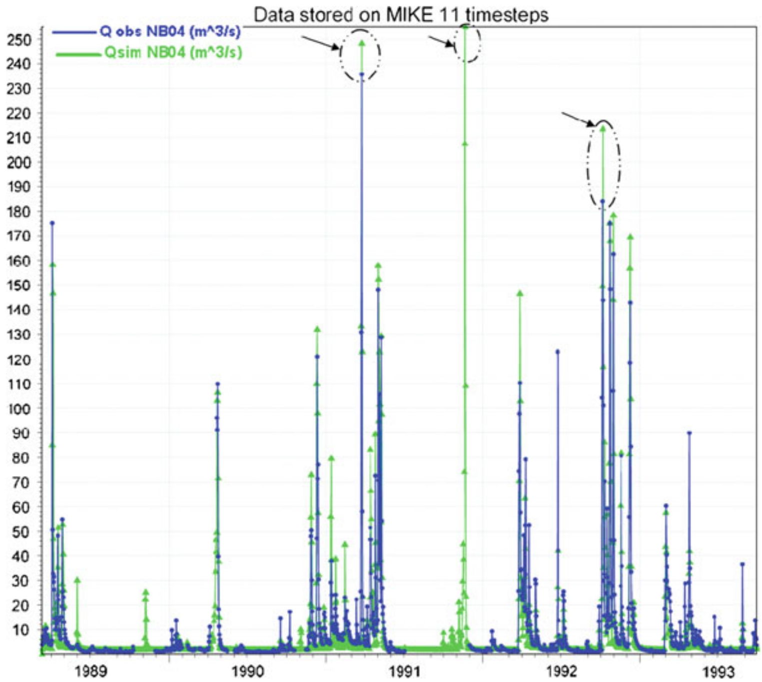

Fig. 6.6 Results of the calibration, showing the simulated flow and observed flow (*NB04 gauging station*)

Run-off Simulation Introducing Regional Climate Model Data

To evaluate the basin hydrological response to climate change, the MikeShe-Mike11 hydrological-hydraulic coupled model was guided by projected climatic variables. The main aim was to evaluate the shifts in the magnitude of run-off. To answer this question a comparison was made between present-day discharge (the reference period) and the hydrological response to precipitation projections. In this task, the changes in the daily flow are determined.

The hydrological-hydraulic model outputs within a daily run-off and differences in relation to the reference period were calculated (1951–2000). An increase of 22 ± 2 % was expected for upstream peak discharge (NB01) with a return period exceeding 50 years and for the HIRHAM climatic model; 20 ± 3 % was exüected for the middle stream (NB11) and 14 ± 10 % for downstream (NB04) (not significant) (Fig. 6.7). For the RACMO climatic model and the period 2051–2100 there is no significant change in peak discharge.

In relation to the NB01 station, which is located upstream of the municipal area of Amurrio (where the urban effects of the discharge were analysed in the next task),

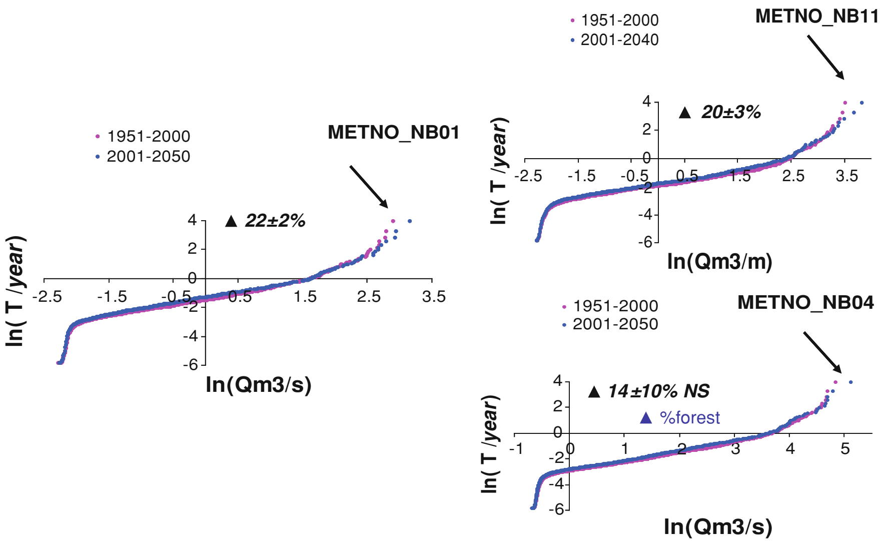

Fig. 6.7 Discharge projections for the three stations (NB01, NB11 and NB04) according to the HIRHAM climate inputs (from METNO)

the discharge for each return period was estimated according to Pareto approximation (Table 6.6). This increase in discharge was applied to the observed gauging data in order to simulate flood events under conditions of climate change.

Changes in Flood-Prone Area and in Natural Phenomenon Severity

The main goal is to obtain the flood-prone area and the velocity and water level caused by future precipitation and stream flow conditions in flooded zones. For this purpose, precipitation and stream flow projections were used as inputs upstream of the urban areas (NB01 station). Analysis of floods in the urban area under conditions of climate change was obtained as output: changes in the flood-prone area and in severity of events were calculated.

The municipal area of Amurrio in the Nerbioi River basin will see a 8.7 % increase in flood-prone area as a result of the expected change in the river's peak flow (+ 22 %) by 2050 (HIRHAM model). Water level and velocity will increase slightly, though not significantly, due to climate change effects (new zones were detected with highest water level and velocity) (Fig. 6.8). The new zones predicted to become vulnerable due to these changes are industrial and residential zones and roads, as well as green areas.

According to the results in the industrial area, in the highest part of the municipality, the flooded area would probably cover the car-park. The water would

Table 6.6 Change in discharge for the period 2001–2050 with respect to the reference period (1951–2000) (%) and the error (%) both for the HIRHAM climatic model and for different return periods. Measurements taken at station NB01, located shortly upstream of the urban area

Return period (year)	Changes (%)	Error (%)
1	–3.19	0.49
10	10.94	1.19
20	15.58	1.57
30	18.39	1.85
50	22.02	2.27

have a height of two metres, causing danger to people and vehicles. Furthermore, a water height of one metre height would reach the residential area, causing large differences in pressure on the walls of buildings (HR Wallingford et al. 2006a; Ramsbottom et al. 2003; Jonkman et al. 2002).

At water-speeds of more than 2 m/s, the stability of foundations and poles can be affected by erosion (Ramsbottom et al. 2003). According to the results of the study, the top speed of 2 m/s is found close to some points of the channel (represented in purple in Fig. 6.8). In the industrial area, this patch covers the road giving access to buildings; this is potentially dangerous for people.There is also another built-up and residential area where the water would rise higher than 2 m/s.

The second aim was to evaluate the Flood Hazard Rating through the depth of flooding data and the speed of flood waters (HR Wallingford et al. 2006a). Combinations of depth and speed are generally considered to be the fundamental cause of death/serious injury during floods (Abt et al. 1989; Ramsbottom et al. 2003). A change in the level of flood hazard due to climate change was identified, which is essential in order to prioritise action. For the Amurrio municipality, the level of hazard to people is expected to increase 1.5 points in severity for 500-year events. Furthermore, areas exposed to extreme hazard are expected to increase by 16 %. New areas exposed to a very low/low/high level of hazard also appear under this scenario (Fig. 6.9).

With a hazard factor of 1 it is difficult for people to walk in flooded areas; when this exceeds 1.4 it is almost impossible. In Amurrio, several areas are identified as vulnerable to future hazards: the car-park and the industrial zone road, the nearby football field, residential areas, and other industrial areas.

Conclusions and Adaptation Strategies

The hydrological models can incorporate future projected climatic variables. Moreover, these models could be combined with hypothetical changes in land use and socio-economic scenarios. This feature makes them a useful tool to study climate change impacts on hydrological processes and the effects of adaptation strategies.

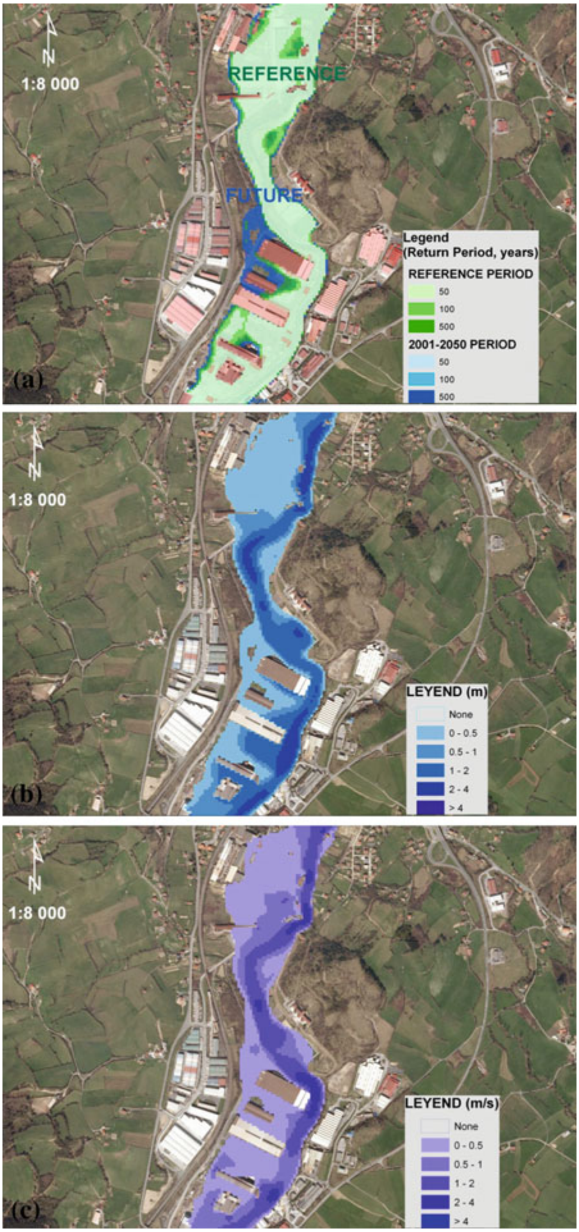

Fig. 6.8 **a** Flood extent map: future (2001–2050) and reference period maps according to return period (50, 100 and 500 years); **b** water depth data (m) for 500-year events under conditions of climate change; **c** velocity data (m/s) for 500-year events under conditions of climate change

According to the first available results, the regional analysis of the climatic models suggests a 10 % rise in extreme precipitation which would lead to an increase in losses due to flooding. In the Nerbioi river basin, the municipal area of Amurrio would experience a 15 % increase in damage due to flooding as a result of the expected change in the river's peak flow (+ 22 %) by 2050. This could lead

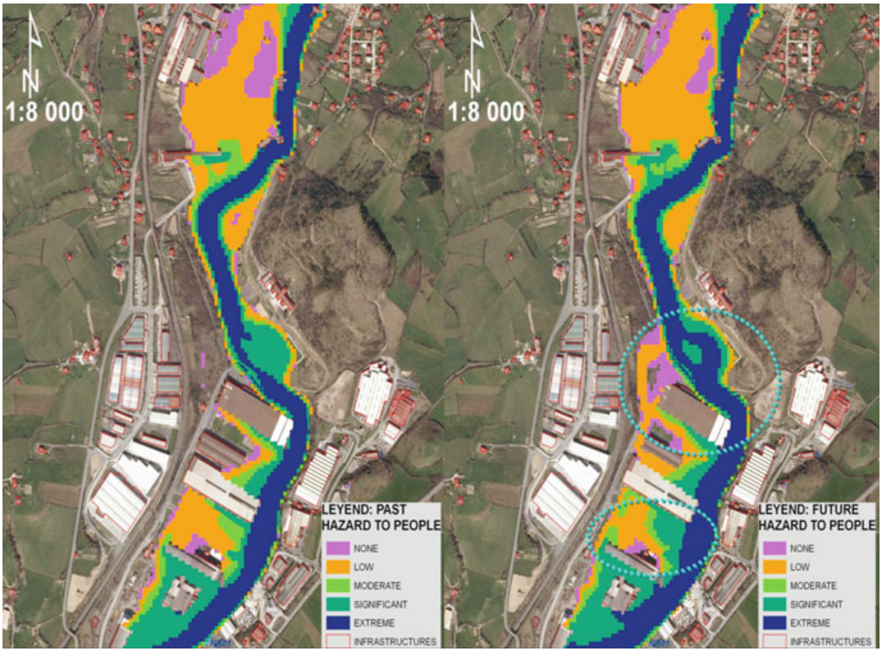

Fig. 6.9 Hazard to people for 500-year events for the reference period (*left image*) and future period under conditions of climate change (*right image*)

to an expansion in the flood area (+ 3 %) as well as a change in the level of severity.

This type of research plays an important role in assessing the potential impacts of climate change on peak discharge and the consequences of this for flood hazard and human safety on a local scale.

In this context, it is necessary to define and evaluate different adaptation options, which may already be in practice or could be conceivable given current scientific knowledge. Adaptation measures should also be evaluated in terms of their ability to lower the vulnerability of water resources to climate change. A meso scale adaptation strategy is suggested to define the land use model to reduce peak discharge and flood-prone area. It is observed how the vegetation affects the generation of run-off: the forest decreases the river peak discharge, and the total transformation of land from forest to pasture has a negative effect on the minimum flow which would be less significant if average rainfall were predicted to decrease. Thus, the basins need solutions to different situations. For mountainous small catchments, such as Nerbioi, adaptation measures consist of promoting a mosaic landscape, where areas of vegetation are spatially distributed.

Furthermore, an urban scale adaptation strategy is proposed to define specific actions. Measures are defined to decrease exposure (through territorial and urban planning, promoting "space for the river", suggesting means of compatible use, constructing protection with restrictions on use); to decrease sensitivity (improving building materials, promoting rehabilitation policy), and to increase the responsiveness of the receptor (early warning systems, emergency management).

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Author Biographies

Maddalen Mendizabal has a PhD in Biological Science and a Degree in Environmental Sciences from the University of the Basque Country (2004). She has worked at GIS-TELEDEK S.COOP in Spain, where she was responsible for R&D. Her expertise is in joint-venture projects and technological know-how transfer. She has a qualification in Advances Studies, specialising in GIS and integrated models of protected areas (Natura 2000) (November 2005). She has been Project Leader in the fields of climate change, regional adaptation strategy and territorial sustainability at Tecnalia R&I since February 2008. She has been actively involved in European initiatives for the last four years.

Robert Moncho has a Degree in Physics, specialising in theoretical physics and meteorology. He has also completed two additional courses in meteorology and has been a member of the "Fundación para la Investigación del Clima" (Spain) since 2010. Over the last year he has participated in six projects on climate change, and has published three articles in international journals.

Peter Torp Larsen, Managing Director of DHI Spain, holds an MSc from the Danish Technical University, specialising in hydraulics. He has 15 years of experience in areas related to water resource management, especially in the areas of flooding, reservoir management and urban planning. Besides seven years work in Spain he has international experience in the USA, Denmark, Malaysia, and South Africa.

Chapter 7
Development Challenges of Multi-Functional Coastal System in the Niger Delta, Nigeria

Yemi Akegbejo-Samsons

Abstract As coastal populations in Africa continue to grow and pressures on the environment from land-based and marine human activities increase, coastal and marine living resources and their habitats are being lost or damaged in ways that are both decreasing livelihood opportunities and aggravating poverty. Coasts are experiencing the adverse consequences of hazards related to climate and sea level. While physical exposure can significantly influence vulnerability for both human populations and natural systems, a lack of adaptive capacity is often the most important factor that creates a hotspot of human vulnerability. Nigeria's Niger Delta is widely recognised for its rich and diverse biological resources and these natural systems form the foundation of the economy of the country, from which the majority of the population derive their livelihood. Threatened terrestrial and marine ecosystems translate to threatened livelihoods in Africa. In the Niger Delta of Nigeria exploitation of these non-living resources has damaged the coastal environment and has caused civil conflict. This paper presents the different categories of this system's coastal resources and highlights the different methods of exploitation and the consequences of these methods. The paper exposes the different challenges of this multi-functional ecosystem of Africa's most populous country, which also ranks fourth in the world oil producer's list. It concludes by suggesting various ways of managing this oil-rich environment.

Keywords Coastal system · Marine habitats · Livelihood · Poverty · Vulnerability · Ecosystem · Exploitation · Oil exploration · Niger Delta · Nigeria

Y. Akegbejo-Samsons (✉)
Department of Aquaculture and Fisheries Management, University of Agriculture,
PMB 2240, Abeokuta, Nigeria
e-mail: samsons56@yahoo.co.uk

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Introduction

The coastal zone, where land meets ocean, is one of the most dynamic natural systems. Here, the three main components of our planet—the hydrosphere, the lithosphere, and the atmosphere—meet and interact, forming interconnected systems. Coastlines are formed by morphological changes governed by climatic and geological processes. They constitute a transition zone where land and freshwater meet saline water, and across which the effects of land on the ocean, and vice versa, are transferred and modified.

In Africa, coastal zones are characterised by the presence of highly productive ecosystems (mangroves, estuaries, deltas, coral reefs) which constitute the basis for important economic activities like tourism and fisheries. The concentration of populations and industries with important urban centres (Lagos in Nigeria had 36 million people in 2005) is another characteristic of these coastal zones. For example, 40 % of the population of West Africa lives in coastal cities and it is expected that the coast between Accra (Ghana) and the Niger Delta (about 500 km) will become a continuous urban megalopolis with more than 50 million people by 2020 (Hewawasam, 2002 cited by Nyong, 2005). The pressures of a dramatically growing population are illustrated in changing land use surrounding the entire south–south and south-eastern area of Nigeria's coastal floodplains. The impact of a population explosion on farmland and forest is clearly seen in contrasting images of the entire Niger Delta, with the conversion of large areas of forest and riparian woodland to agriculture between 1976 and 2007. Limited productivity and labour opportunities, notably the oil exploration conglomerates in the off-shore areas, and prolonged youth restiveness is a key driver of migration, particularly where climate variability is high. Migration triggered by ecological vulnerability—particularly floods—is significant in number and frequency, but commonly temporary and local/regional in nature.

Coasts are experiencing the adverse consequences of hazards related to climate change and sea level. While physical exposure can significantly influence vulnerability for both human populations and natural systems, a lack of adaptive capacity is often the most important factor in creating a hotspot of human vulnerability. Nigeria's Niger Delta is widely recognised for its rich and diverse biological resources and these natural systems form the foundation of the economy of the country, from which the majority of the population derive their livelihood. Threatened terrestrial and marine ecosystems translate to threatened livelihoods in Africa. In the Niger Delta of Nigeria exploitation of these non-living resources has damaged the coastal environment and has caused civil conflict. This paper presents the different categories of the coastal resources of this system and highlights the different methods of exploitation and the consequences of these methods. The paper exposes the different challenges of this multi-functional ecosystem of Africa's most populous country, which also ranks fourth in the world oil producer's list. It concludes by suggesting various ways of managing this oil-rich environment.

Coastal Situation Synopsis

In nearly all parts of the world, livelihood opportunities for people living along the coastline are changing; coastal areas are experiencing rapidly expanding populations, putting an ever increasing pressure on limited resources. In the western Indian Ocean, fisheries contribute significantly to all national economies, with stocks including tuna exploited under licence by foreign fleets. In Mozambique and Tanzania, estuarine prawn fisheries make an important economic contribution. In the Mediterranean, where foreign industrial fleets are becoming prevalent, there may still be some scope for increased production, but at the expense of the size of fish caught. In the last three decades, imports of fish and fishery products by African countries exceeded the exports of the same in quantity, although the gap is gradually decreasing. Conversely, export values were far in excess of import values. This is because many African countries import large quantities of low-grade species, like mackerel and sardinelles, and export high grade species like shrimps and snappers, and other demersal species (Lindeboom, 2002).

Marine environmental resources are under serious threat. This is due to many different factors. The overexploitation of fisheries on artisanal and industrial scales using unsustainable fishing methods, and the introduction to coastal ecosystems of invasive alien species from marine sources, are contributory factors and concerns. Coastal ecosystems, especially estuaries and lagoon wetlands, are becoming increasingly affected by enormous human activities. Fish stocks such as clupeids (*Sardinella aurita, Illisha Africana),* shrimps and snappers are being depleted, coastal erosion is threatening communities and tourism facilities, and rare species are being driven towards extinction (Francis and Bryceson 2001). The productivity of these resources is in decline as the environmental-carrying capacity decreases due to increasing coastal pollution, habitat destruction, resource depletion, and change in water quality and disruption of water flows (SCL Project 2000).

Coastal waters are increasingly being polluted. Discharges of industrial effluents and municipal sewage, discharge from storm water drains, run-off or seepage containing fertiliser and pesticide residues, oil spills, operational discharges of solid waste, sewage and oil, ballast water discharges, and effluent from the recently established mariculture industry, collectively and individually present a real threat to coastal water quality, particularly in bays and other semi enclosed or sheltered waters where dispersion and dilution are low.

Coastal Scenario in Nigeria

Coastal zones worldwide are home to large and growing populations and it are fast undergoing environmental decline. The coastal zone of Nigeria has recorded intense human activities resulting in widespread modification of the natural environment and systems. There exists a high annual rate of erosion along some portions of the transgressive mud beach coast, salt water intrusion into land areas, degradation resulting from canalisation and dredging for oil and gas pipeline, loss of forest as a result of logging activities, loss of marshland and mangrove forests, and permanent inundation of land area as a result of reduction in ground level. This has made the area an ecologically stressed environment which should be of concern to geographers, environmental scientists, natural resource managers and planners and policy makers. The coastal area of Nigeria is among the most vulnerable of all environments to global climate change. There are multiple reasons when one looks at the high level of massive utilisation of the coastal area by the oil and gas industry, vis-à-vis the uncontrolled level of pollution presented by oil exploration, exploitation and distribution in the entire Niger Delta. The Niger Delta mangroves are today threatened by various human activities such as over logging, clearance for the passage of oil pipes and seismic lines, and swamp reclamation for urban development. Projected impacts from global warming include rising sea levels, stronger tropical cyclones, larger storm surges, increasing sea surface temperatures, and—as the oceans absorb more of the carbon dioxide that human activities emit to the atmosphere—growing acidification of surface waters. For coastal ecosystems and communities, especially in the developing countries, the repercussions could be considerable, threatening the livelihoods, health, and welfare of millions of people.

Different authors have confirmed that Nigeria's coastal zone is affected by two main types of influences (a) terrestrial and (b) marine, that are considered external to the coastal zone.

Terrestrial influences are mostly anthropogenic in nature, and these include changes in land use and all the consequences of changing hydrological regimes and nutrient loading from sediment transport, runoff, and reduction of sediments through rivers (for example, from dam and channel construction and extraction of river sand upstream).

Marine influences are mostly natural phenomena such as weather events (storms and cyclones), tsunamis, and wave patterns and coastal and ocean currents that affect the processes of nutrient, material, and heat transfer and mediate geomorphologic changes.

Changing Coastal Zone Ecology

Coastal ecosystems are repositories of biological diversity and provide a wide range of goods and services. Pallewata (2010) using the Modified Millennium Ecosystem Assessment Report opined that ecosystem services can be broadly grouped into three types, viz.,

1. *Provisioning*, e.g. food species, water for agricultural and industrial use, timber, fibres, fuel, and genes

2. *Regulating*, e.g. climate regulation; influencing hydrological flows and cycles; regulation of erosion; removal of excess nutrients and wastes; and mitigation/amelioration of natural hazards such as floods, storm surges, landslides, and high winds
3. *Cultural and religious*, e.g. recreational, aesthetic, educational, and scientific opportunities; and spiritual and symbolic values

Multi-Functional Attributes of Nigeria's Coastal System

The Niger Delta extends about 450 km eastwards from Benin river estuary and terminates at the mouth of Imo River. It covers an area about 70,000 km^2 consisting of barrier islands, estuaries, mangroves, creek and fresh water swamps. Finally, the strand coast extends 85 km east of the Niger Delta from Imo River to Cross River estuary at the Nigeria-Cameroun border. The strand coast is characterised by flat beaches backed up by mangrove swamps.

The mangrove also occupies an extensive zone with red soils and salt water. The Nigerian coastal zone is rich in natural resources. For example, the timber from forest, oysters, shellfish, crabs from the mangroves, and aquacultural production—especially fish of different species and minerals (oil and gas).—Sand, gravel and limestone are also solid minerals of the coastal zone. The majority of Nigeria's economic activities are located along the coastal cities of Lagos, Warri, Port Harcourt, Calabar and Bonny, with activities such as agriculture, fishing, mining, manufacturing of textiles, food, wood, pulp and paper production dominating.

The resources within the Nigerian coastal and marine environment have high implications for Nigeria's economy. Oil and gas are the main backbone of Nigeria economy. Some of the renewable resources in the Nigerian coastal and marine environment include plants, mangroves, fish and shellfish, marine mammals and reptiles. The non-renewable resources include oil and gas, solid and heavy minerals, salts, sand and gravel, and clay.

Economic activities in the coastal zone include oil and gas exploration and exploitation, fishing industries, shipping, agriculture and tourism. The zone experiences a tropical climate consisting of a rainy season (April–October) and a dry season (November–March) with diurnal temperature as high as 34–35 °C and high relative humidity rarely below 60 %.

Nigeria's coastal zone is being challenged and threatened by a multitude of environmental problems such as soil and coastal erosion, pollution, population pressure, habitat loss, coastal hazards, marine/beach debris, oil spills, global climate change, over fishing, loss of biological diversity, invasion of non-indigenous/nuisance faunal species (water hyacinth), flooding etc. Soil and coastal erosion adversely affects 80 % of Nigerian land. The ever turbulent Lagos bar beach at Ahmadu Bello Way, Victoria Island and the seaward ends of the Niger Delta at

Okrika in Rivers State are great coastal challenges to Nigeria. The Nigerian petroleum industry located in the Niger Delta has added to the problems of these coastlands. Gas flares have burnt the majority of the mangroves and polluted settlements, plants, and animals. Similarly, oil spillages devastate land, water and vegetation. More so, the canals used by oil companies to aid field transportation in the Niger Delta have caused the intrusion of salt water into the fresh swamps, thus decimating the vegetation. The low elevation over extensive areas of the coast has made it prone to rising sea levels, coupled with widespread erosion and flooding.

Resource Exploitation and Consequences

Exploitation of Fisheries

Fishing and fish exploitation is one of the major activities of the coastal populace in the coastal area of Nigeria. The potential yield of the fish resources from all sectors (waste, brackish water, rivers and lakes aquaculture and off shore fisheries) is estimated at 1,180,12 metric tonnes. Based on the Federal Department of Fisheries (FDF 2006) report, the breakdown is as follows: inshore fisheries (brackish/coastal) 201,300 metric tonnes; offshore fisheries 33,900 metric tonnes; inland fisheries 288,200 metric tonnes and fish farming 1,180,215 metric tonnes.

Coastal and Marine Pollution

As a result of the high population in Nigeria, there has been increased application of technology in the exploration and exploitation of natural resources aimed at producing more food, goods and services. The rise in industrialisation and agricultural activities has led to the release of different categories of wastes into the environment. These wastes sometime reach and exceed toxification level and are thus classified as pollutants (Ajayi 1990).

Oil Spills

These have a major impact on the coastal environment particularly in the Niger Delta area where oil prospecting is extensive. The potential impact of oil spills include among others;

- High mortality of aquatic animals
- Contaminations of human lathered
- Impairment of human health

- Loss of biodiversity in breeding grounds
- Vegetation destruction and other ecological hazards
- Loss of potable and industrial water resources
- Reduction in fishing activation
- Poverty, rural underdevelopment and bitterness among the coastal communities (NDES 1997).

Physical Modification and Destruction of Habitats

In Nigeria, the coastal zones have undergone vast modifications over the last thirty years. This is due to high pressures on coastal resources, conflicting exploitation techniques and increasing population leading to loss of biodiversity, ecosystem and reduced value of coastline. The destruction of mangrove ecosystems has been on the increase since exploitation of oil and gas started in the Niger Delta resulting in replacement of mangrove vegetation by new vegetation like grasses and lumber (NDES 1997).

Fisheries

The mud shore fish resources of the Nigerian waters (0–50 m) include demersal, pelagic shellfish resources. The potential yield from inshore waters is estimated at 201,000 metric tonnes per annum. Small scale fisheries contribute to between 50 and 70 % of total domestic production (Tobor et al. 1977). About 157 species of fish belonging to 71 families in the Nigerian inshore waters were also recorded (Tobor et al. 1977). The pelagic fish resources are mainly from the clupeid family and the most exploited among them are:

Ethmalosa fimbriata, S. maderensis, S. aurita and *Ilisha africana*. Others such as anchovy and the scombrids are not the major targets of the small-scale fishery. Shellfish harvested by the artisanal include white shrimps (*Macrobrachim macrobrachinum), river prawn (M. vollenhovenii)*, and juvenile pink shrimp *Penaeus notialis* and *P. duorarum*. The industrial shellfish fishery targets the adult pink shrimp *P. notiales* and *P. duorarum* (Ibe, 1990).

Mangrove Destruction

The main vegetation in Nigerian coastal areas is the mangrove. In many places and in the estuaries themselves, mangrove have been over exploited and destroyed, e.g. in the Qua Iboe River area, wide areas of cleared mangrove swamp are common. In the Molume areas of the mud coast of Ondo state, massive destruction of mangrove forest has led to the wiping out of many fishing communities through severe flooding and erosion. Mangroves are over exploited for firewood and charcoal, timber, construction of boats, houses and the leaves as fodder for cattle and goats (Umana 2000).

Major Coastal Problems in Nigeria

The major problems of the coastal zone derive from human and natural impacts due to high populations, industrial and agricultural activities aimed at meeting food, energy, goods and other requirements of the populace. A lot of the environmental problems of the coastal zone are caused primarily by land-based activities. The following problems have been identified: 1. Over-exploitation of fisheries; 2. Coastal and marine pollution; 3. Oil spills; 4. Coastal erosion and flooding; 5. Physical modification and destruction of habitats; 6. Climate change and sea level rise; 7. Invasive species.

Nigeria's coastline is being threatened by the following problems:

1. Erosion (these were from coastal and riverbank)
2. Flooding (sea level rise): land degradation, resource degradation, sand mining
3. Fisheries (stock depletion, habitat degradation)
4. Forestry (deforestation, mangrove degradation, biodiversity loss, water hyacinth invasion)
5. Environmental pollution (these sources were from toxic substance, sewage, water contamination, oil spills, solid waste, air pollution).

Suggested Management Strategies for Coastal Management in Nigeria

Over the years different management strategies have been suggested by various researchers. Some of the often discussed strategies are as follows:

1. The need to promote the use of coastal crop agriculture, in order to combat increasing salinity through maize production under the wet bed no-tillage method and "Sorjan" systems of cropping in tidally flooded agro-ecosystems.
2. Encouragement of coastal fisheries through aquaculture of salt-tolerant fish species in coastal areas of the Niger Delta.
3. Reducing climate change hazards through coastal afforestation with public and community participation.
4. Encouragement of research and utilisation of saline-tolerant crop varieties to facilitate further adaptation in the future.

5. Rural development enhancement of communities and provision of essential amenities to rural communities.
6. Enhancing the resilience of urban infrastructure and industries to the impacts of climate change.
7. An integrated approach to coastal management. An integrated coastal resource management approach with the objective of promoting sustainable utilisation of coastal resources, as well as restoring and maintaining the integrity of coastal ecosystems, needs to be adopted to address a wide range of social and environmental issues and move coastal zone towards sustainable development.
8. The practice of sustainable and sound policymaking and decision-making with information systems. The use of geographic information system (GIS) will go a long way towards the collection and provision of information and dissemination of technical data relevant to the coast such as (i) spatial information, particularly land and forest survey (ii) flood and erosion risk assessment (iii) biological inventories, and (iv) socio-economic state of the coastal zones and (v) risk assessment.

Conclusion

Throughout much of the world, coastal areas are over developed, overcrowded and over exploited. Coastal waters are often horribly polluted with untreated (or partially treated) municipal, industrial and agricultural wastes. Rivers bring more pollutants from upstream, including chemicals and heavy metals, along with increasing loads of erosion sediment torn from the hinterlands. In Nigeria there is an urgent need for a watershed-based approach to data collection and analysis, and for a comprehensive review of coastal management programmes and projects to help determine what policies and actions have worked and which have not, in order to build political and community support for coastal management plans and efficient implementation of these plans.

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Author Biography

Yemi Akegbejo-Samsons heads the Department of Aquaculture and Fisheries Management at the Federal University of Agriculture, Abeokuta, where he doubles as a researcher, teacher and coastal resource expert. He is a professor of aquaculture and coastal resources management and has many years of research and administrative experience. Contacts: Room 201, Department of Aquaculture and Fisheries management, College of Environmental Resources Management, Federal University of Agriculture, PMB 2240, Abeokuta, Nigeria. Email: samsons56@yahoo.co.uk

Chapter 8
Disaster Risk Management Through a "Watershed Plus" Approach in the Western Orissa Rural Livelihoods Project (WORLP): Orissa, India

Gala Bhaskar Reddy and Niranjan Sahu

Abstract The Western Orissa Rural Livelihoods Project is a DFID-UK funded project and is implemented by Orissa's Agriculture Department through the Orissa Watershed Development Mission. WORLP has been implemented in the four districts of western Orissa since 2000, namely Bolangir, Nuapada, Kalahandi and Bargarh. These four project districts are among the poorest in India, with 70 % of their population of four million living below the poverty line. On average, the drought in the state happens once in every 3–5 years. Rainfall in the WORLP districts is mostly erratic and punctuated generally by long dry spells. These districts suffer from frequent drought-like conditions resulting in crop failures. The small and marginal farmers, land-less and very poor households are most vulnerable to these conditions. WORLP followed a watershed plus approach to promote sustainable livelihoods. It operates on a watershed platform. Participatory planning with the community analysed the constraints and opportunities faced by vulnerable groups and identified the livelihood needs of the poorest. The community was organised into different grassroots organisations so as to build their social capitals. Investment priorities were identified through such planning to improve the productivity of land and water and improve drinking water and sanitation. For the poorest groups, provisioning of credits through revolving and grant funds and promotion of on-farm and non-farm micro-enterprise activities diversified the livelihood portfolios. Furthermore, the capacity of government organisations, local government, NGOs and community to work together in addressing poverty was strengthened. Widespread Natural Resources Management

G. B. Reddy (✉) · N. Sahu
Orissa Watershed Development Mission, Watershed Mission Complex, Siripur, Bhubaneswar, Orissa 751003, India
e-mail: Bhaskar@worlp.com

N. Sahu
e-mail: niranjan@worlp.com

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(NRM) interventions, augmented agricultural activities, and the evolution of sensitised farming communities indicated a strong resilience against natural disasters like drought. A recent study reveals that 86 % of the marginal and small farmers in the watershed area are able to cope with natural disasters.

Keywords Watershed · Sustainable livelihoods · Participatory planning · Natural disaster

Introduction

The Western Orissa Rural Livelihoods Project operates in the East Indian state of Orissa with the aim of protecting and strengthening the livelihoods of the poorest in the four districts of Bargarh, Bolangir, Kalahandi and Nuapara. Bolangir and Bargarh districts are a part of the "West Central Table Land Zone" and have a hot, sub-humid climate. This zone is situated between 20° 9′ and 22° N latitude and 82° 39′ and 85° 15′ E longitude. Similarly, Kalahandi and Nuapada districts are a part of the "Western Undulating Zone" and have a hot, moist and sub-humid climate. This zone is situated between 19° 3′ and 21° 55′ N latitude and 82° 20′ and 83° 47′ E longitude. Both the agro-climatic zones are located in Eastern Plateau and Hills Zone (Zone Number 7) of India (OWDM 2009).

The project commenced in 2000 and adopted a "Watershed Plus" approach that uses micro-watershed as the basic developmental unit and focuses on building and working with people's existing strengths and resources. The approach is about informing, enabling, initiating and empowering appropriate choices for long-term well-being. It involves all sections of rural society across caste, class, gender, and other divides. The Watershed Plus approach also brings in livelihood improvement, capacity building and an enabling environment. The poor and marginalised left out in normal watershed programmes have been given opportunities to participate in the development process.

The project uses the DFID's Sustainable Livelihoods Framework to analyse all livelihood constraints and opportunities for the target population. The project operated in an area of 1.45 lakh hectares incorporating 545 villages.

DFID'S Sustainable Livelihoods Framework

In keeping with the above, the UK's Department for International Development (DFID) has been promoting a sustainable livelihoods (SL) approach that focuses not just on the needs of the rural poor, but also builds on their existing assets, both at a community and an individual level. The DFID seeks to assist the rural poor to improve their lives and strengthen the sustainability of a people-centred approach, designed to be participatory and with an emphasis on sustainability. The approach first identifies what people have rather than focusing on what people do not have.

> A livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base (DFID 1999).

The key components of the Sustainable Livelihoods Framework for analysing the livelihoods of individuals and communities are:

- capital assets
- vulnerability context and the transforming structures (layers of organisations both in private and public sectors)
- processes (laws, policies, incentives) which shape and influence the livelihood strategies which they adopt.

The DFID distinguishes five categories of assets (or capital): natural, social, human, physical and financial. The vulnerability context of the Sustainable Livelihoods Framework outlines the trends, shocks and seasonality that have direct impacts on people's livelihoods. One way of managing the vulnerability context is to assist people to become more resilient and better able to capitalise on the positive aspects to build up their assets (DFID 1999).

Emphasis is also placed on setting up structures, processes and policies which have a direct bearing on livelihood outcomes.

The important outcomes of the SLF are reduced vulnerability and improved food security by the sustainable use of natural resources. Therefore, watershed is selected as a natural unit of development with this approach. Watershed is a geohydrological unit drained by a system of streams passing through a common point. A micro-watershed, which has an area of 500–1000 ha, forms a part of a mini-watershed. The hierarchy of watersheds, in order, is: micro-watershed, mini-watershed, sub-watershed, watershed, sub-catchments, catchments, basin, and region. A "region" covers millions of square kilometres. It incorporates different resources, namely land, water, and vegetation/forest, in addition to human habitations, livestock and wildlife. Development of land, water and vegetation ultimately contributes to the well-being of the human population.

WORLP Watershed Plus Approaches

The WORLP Watershed Plus approach has adopted the SLF and developed tools and processes to minimise risks to the vulnerable community. The interventions have led to social, financial, natural, physical and human capital accumulation. Better social and human capital has effectively managed natural resources to promote the livelihoods of the poor and vulnerable. Pursuing this approach has led to interventions which address the non-agricultural livelihood needs articulated by poor rural people, including food security, drinking water supply, savings and credit, on-farm and off-farm income generation, and access to health and education services.

The approach manages the disaster risks by addressing issues of vulnerabilities through physical and natural capital accumulation, building response capacities of the communities through promotion of community-based organisations, and capacity building and managing risks through employment and diversification of livelihoods.

The Watershed Plus approach provides a broad framework for inclusive development. The tools, guidelines and processes to operationalise WORLP approaches are discussed below.

Identifying the Poor Through Participatory Microplanning

WORLP adopts a participatory planning process for developing microplans at community level. It involves various stages of rapport building, resource mapping, problem identification, prioritisation, negotiation and development of action plans. The microplans (MLP) in WORLP provide separately for plans and budgets for poor and very poor households. This provides space for inclusion of the needs, aspirations and desires of the poor and vulnerable. WORLP uses the Well-Being Ranking (WBR) tool to classify households into categories: very poor (most vulnerable), poor, manageable, and well-off. Furthermore, the more complex investments are made once resource rights for the excluded have been negotiated. This ensures that the project inputs reach them and their voices are heard. Excluded households are thus enabled to become an important part in both decision-making and execution processes. This bias towards the poor and very poor in the WORLP MLP has succeeded in creating steps to increase social opportunity functions for these groups.

Provisioning for the Poor

WORLP is the first project to implement the "Watershed Plus" concept and components in Orissa. For the "watershed" component, WORLP mainly follows the National Watershed Guidelines of 2001; for the "plus" component, the project developed "livelihoods guidelines" during June 2004. During the course of implementation it was observed that targeting of the poor was still a major challenge and in some instances equity issues remained unresolved. The livelihoods guidelines were accordingly revised, with inputs from all stakeholders including the DFID in the context of a workshop 2006. The main elements of the guidelines are as follows:

Table 8.1 Activities for improving basic living conditions

Preventive health activities	Promotion of mosquito nets, training of midwives, drug distribution centres, health camps, bathing ghats, etc
Sanitation	Promotion of latrines, proper sewage and drainage systems, convergence with district sanitation mission, etc
Drinking water	Decontamination of drinking water, chlorination of open wells, convergence with Swajaldhara scheme, etc
Common infrastructure for productive activities	Common infrastructure for productive purposes may be supported in the poorest communities to supplement income generation activities viz. common facility centres, provisions for collection, storage and grading of agricultural produce, threshing/drying floors, small agricultural/non-timber forest produce (NTFP) processing units for self-helpgroups (SHGs), common weighing machines, etc

Natural Resource Management Budget

Rupees 3600/ha is available for Natural Resource Management initiatives within WORLP watersheds. This involves treating the area with various soil and moisture conservation activities and also providing support to cropping systems initiatives. A budget of Rs. 18.00 lakh/watershed of 500 ha is available for NRM activities.

Community Development Fund

The Community Development Fund is utilised for interventions that benefit large sections of the community in general, and for activities specifically aimed at improving the quality of life of the poorest sections of the community. These are aimed at bringing the community to a common fold. Activities for improving the basic living conditions of the poorest sections of the community are identified and implemented. Rupees 1200/ha (or Rs. 6 lakh/watershed) is available. Some of the activities implemented as common activities for the larger community are as follows: (Table 8.1).

Livelihoods Promotion Budget

Various income generation activities are being promoted under WORLP in the Watershed villages out of the Livelihood Promotion budget. The Project Implementing Agency (PIA) facilitates and supports the very poor, poor and manageable households to identify and develop viable farm and off-farm based income generation activities. As the NRM budget is available for developing both arable and non-arable lands, the Livelihood Promotion budget concentrates more on promoting concentrated off-farm activities and on building up sufficient market scales. The community, with support from the PIA, is identifying a few selected sectors that are area specific and allow a cluster approach. These are strongly related to Watershed activities viz. pisciculture, livestock, Primary Agriculture Processing, NTFP processing, etc. To promote income generation activities WORLP provides assistance from the Livelihood Promotion budget in the form of grants and revolving funds.

Livelihood Promotion Budget (Grant)

To support various income generation activities, grant funds are provided to the “Very Poor” and “Poor” household classes. Rupees 1400/ha are available as a grant component in a watershed. Hence, for a watershed of 500 ha, Rs. 700,000 is available as a grant component. Grant funds vary depending on the area of the watershed.

Special provision to support five vulnerable households per watershed

Some of the weakest and most downtrodden households and individuals are unable to take up any income generation activities and for those individuals the challenge is simply to survive from day to day. WORLP provides grants to these households and individuals from the “Very Poor” class for consumption purposes. A maximum of Rs. 7000 is provided as grants for consumption purposes, limited to five households per watershed.

Livelihood Promotion Budget (Revolving Fund)

To promote microfinance and encourage microenterprise ventures, the Watershed Committee provides revolving funds to various Self-Help Groups and Common Interest Groups among the “Very Poor”, “Poor” and “Manageable” household classes. Rupees 1400/ha is available as revolving funds in WORLP watersheds. The SGH/CIG is eligible for a first instalment of a maximum of Rs. 20,000 of revolving funds. Subsequently, based on the performance of the group and its credit-worthiness, the Watershed Committee can sanction further revolving funds up to a maximum of Rs. 50,000.

Enabling Peoples' Institutions

People's institutions at village level form the base for planning, decision-making and implementation of a sustainable development effort. WORLP has enabled the creation of appropriate and strong institutional delivery mechanisms at various levels. Watershed committees with mandatory representation of very poor and poor, small and marginal farmers, land-less and comprised of at least 30 % women, exist in all watersheds. This is to enable *"voices of all sections to be heard and appropriate decisions to be taken in the committee"*. User groups were also formed as and when the watershed structures were finalised. These groups are comprised mainly of male members largely from land-holding households. Self-Help Groups (SHGs), on the other hand, are predominantly comprised of female members, especially from marginal land-holding families and land-less households. Women SHGs form more than 80 % of the community-based organisations (CBOs) in WORLP, and handle almost all of the revolving funds (OWDM 2010). Common Interest Groups (CIGs) have evolved during the Project to manage livelihoods activities in a group. This has enabled the creation of economies of scale and allowed collective bargaining.

In addition to all this, WORLP has developed a cadre of community link workers (CLW) in the thematic areas of SHG, Agri-Horticulture, NRM and livestock. WORLP has trained them to provide basic technical expertise for the community and to act as a link between the Project, different line departments and the community (Reddy 2006). They build on social and human capital in the community by disseminating technologies and best practices. They play a critical role in facilitating the processes of reaching the poorest. This has been a notable contribution of WORLP, which is now being fast-tracked in other projects as well.

Pro-Poor Strategies

In WORLP there is a strong focus on developing and adopting strategies that can provide maximum benefits for the very poor and poor sections of the community. Given the chronic nature of the poverty and deprivation suffered by these groups, it was realised quite early that the resources of any one agency or institution will not be enough. Thus, a key focus of the project became convergence with institutions, both governmental and non-governmental. Initially, WORLP started with "what they could see" to "what they were presented". Currently, WORLP is in partnerships with government departments, civil society, academic institutions, resource organisations and individuals to help the poor access opportunities for development. The recent publication of "A Compendium of Ongoing Rural Sector Schemes for Convergence with Watersheds" will help rural development efforts to facilitate better access for poor people to programmes managed by various ministries and government line departments.

Western Orissa has a tradition of water harvesting. Soil and water conservation efforts through WORLP have also led to the creation of several seasonal and perennial water bodies. Fish is an important part of the diet of the people in this area. However, traditionally pisciculture was limited to perennial ponds owned by rich individuals or *panchayats* (local self-government bodies) and village ponds which were again taken on lease by the powerful commercial players. In this process, the poor and land-less became excluded from fish production activities. But pisciculture was still found to be a potential livelihood source for those with poor resources in terms of income and nutritional security. "Fish rearing within the project is now contributing to the livelihoods of around 12,000 poor people" ("Fish in our Watersheds", July 2006, WORLP*)*. This was made possible due to a multi-pronged strategy adopted in WORLP involving collaboration with national level research agencies, the state fisheries department, international technical expertise, local NGOs, entrepreneurs and communities. Being able to grow fish profitably has not only helped these poor families increase their income but has also helped the women from these families gain confidence and display increased agency.

Self-help groups, by engaging in thrift and credit activities, have helped their members gain access to much-needed savings and credit facilities, the former sometimes being a greater need. SHGs also serve as a medium for their members to access services and opportunities such as capacity building, skills training, bank linkage, revolving funds, and business planning and enterprise development. Besides these points, SHGs help build social capital for their members. Members grow to show increased self-confidence and awareness to involve themselves with *panchayats* and take over the running of mid-day meal schemes (MDM), Public Distribution Systems (PDS) and the National Rural Employment Guarantee Act (NREGA) from them. They are also able to successfully lease ponds and common land from *panchayats*, which often involves participating in competitive bidding. In short, the SHGs in the Project are acting as important building blocks in the development process.

"Collective marketing" has armed Community Based Organisations (CBOs), primarily SHGs and CIGs, with the knowledge, confidence and processes to operate as non-exploitative channels for the marketing of products. Besides collectivising the produce, these CBOs also get a higher value by conducting a range of value-added activities including drying, sorting, grading, weighing, and packaging. A range of marketing infrastructure has been created in the villages for this purpose.

Addressing food and nutritional security has been one of the objectives of the Project. WORLP has helped create grain banks to counter lean season food shortages. Tuber crops such as cassava, yam, elephant foot yam and sweet potato have been promoted in the watershed area. The twin advantages of tuber crops are that these can be grown in unproductive lands and the crops can be harvested all year round to meethousehold food shortages. Kitchen gardens have been promoted in the Project villages. Drumstick, papaya and lemon, as well as greens, are grown in the kitchen gardens. The existing *laer* (traditional farm) has been transformed

Table 8.2 Sampling overview

Particular	Phase I	Phase II	Control villages
Number of districts	4	4	4
Number of watersheds	50	50	50
Number of villages	100	100	100
Total number of sample households	1400	1400	1400

into an integrated farm by incorporating perennial tree crops such as mango, lemon, custard apple, and drumstick, as well as seasonal vegetables, greens and tuber crops. In some cases livestock rearing is also an integral part of the farming system. This has provided small farmers with increased income from the farm, in addition to food and nutrition security. Families that do not have any land except their kitchen gardens are also eating better than before.

Results and Discussion

A detailed impact assessment study was conducted between January–April 2011. For the household survey, microwatershed was considered as the primary sampling unit and the sample size for the assessment was arrived at using statistical formulae. Households for the study were proportionately selected from the watersheds on the basis of their Well-Being Ranking. The sample distribution of quantitative tools used for the study is presented in the Table 8.2.

For qualitative assessments, Focused Group Discussions (FGDs) were conducted with the watershed communities, including the poor and female representatives. In-depth interviews were held with project personnel and representatives of the Community Based Organisation (CBO) and Panchayati Raj Institutions (PRI).

Some Key Findings of the Study with Respect to Disaster Risk Management

Livelihood Assets

There has been a significant increase in natural capital for almost 65 % of the poor and very poor households in the project area. The project focused watershed activities have meant a significant increase in natural assets. This finding is further reinforced by the fact that the control population shows a relatively low natural capital value. There has also been a noteable increase since the last assessment (2008), primarily owing to activities ensuring, for example, the leasing of water bodies and land, and better health of livestock. A significant increase in financial capital can also be observed for almost 57 % of the poor households and 55 % of the very poor households. Some steps have been taken forward on social capital as well. Mobilising communities into collectives and the capacity development of these collectives have been some of the key project activities, and over the last 3 years it has been reinforced further. This has resulted in a significant increase in social capital for almost 56 % of the poor households and 52 % of the very poor households.

Disaster Coping

There has also been a sharp decline in the rate of overall migration amongst poor households. While at the baseline 47 % of migration of the poor was distress migration (>30 days), this figure has reduced to 6 %. The project has also ensured an overall decrease in the incidence of lean season food shortage days, with approximately 5 % of poor people stating that there have been days/times when they were not able to arrange food, even after using all their resources. At the project baseline, incidence of food shortage days was reported by 25 % of poor people. Almost three-fifths of the marginal farmers in the project watersheds had reported improvement in disaster coping capacity during 2008 (WORLP 2008). This figure has increased to 86 % during the current assessment. There has been a substantial increase in population of marginal farmers suggesting improved disaster coping capacities through these years (i.e. from 74 to 86 % in Phase I and 79 % in Phase II). These differences reflect that positioning of the project activities is better than with the control watersheds (i.e. from 53 to 55 % in control area) and it has also improved with time (WORLP 2011). Enhanced agricultural production, diversification of livelihood activities and access to consumption credit has been delineated as the key factors behind improvement in disaster coping (Fig. 8.1).

Reaching Out to the Poorest

WORLP has been a pioneering project in addressing this critical issue through the Watershed Plus approach. The approach recognises these groups and includes them in interventions, while the Plus component goes further in bringing the poorest to the forefront of interventions. Almost 71 % of the poorest households belong to inclusive groups in the form of SHGs and CIGs. Substantial project investment has also gone into imparting the requisite capacities for group functioning and management so that these groups can function as peer collectives harnessing social capital. Revolving funds and grants are specifically aimed at these groups and adequately address the difficulties faced by people with few or no resources.

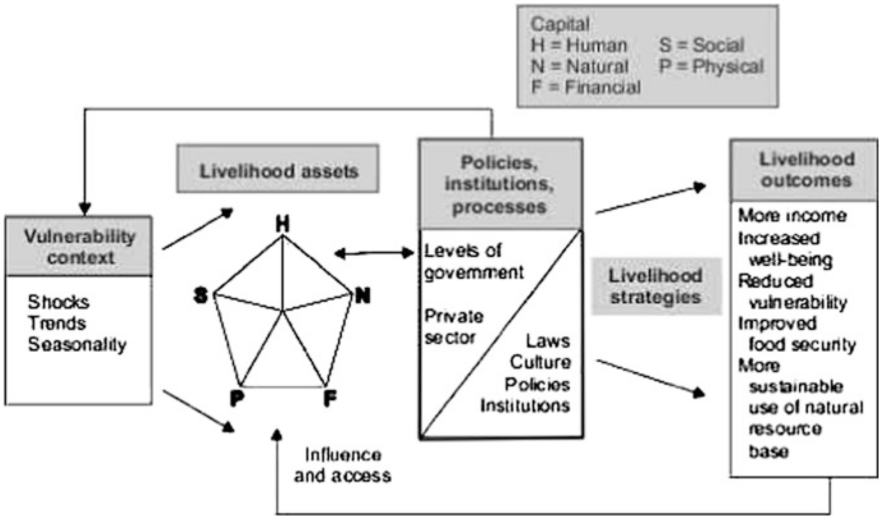

Fig. 8.1 DFID sustainable livelihood framework

Policy Footprints

The WORLP implementation paradigm had a significant influence on the common guidelines for watershed development projects developed by the Indian Government in 2008 according to three parameters: adoption of the Plus component, 19 % allocation for livelihoods, and adoption of WORLP institutional structure. The Watershed Plus approach pioneered by the project is being replicated in 2332 watersheds in the state.

Project Efficiency

The Economic Rate of Return (ERR), which describes the economic performance and desirability of the project over other investments, comes to 25.44 %. At the time of the project design, the expected ERR was approximately 21 %. The ERR at present is higher than the opportunity cost of capital or the real rate of interest on long-term investment. The economic efficiency of the project is therefore very high (WORLP 2011).

Post-Project Sustainability

WORLP has strengthened and established around 6000 community-based organisations. These orgainsations continue to operate beyond the project period. Similarly, community link workers have been engaged and their capacities have been built to provide knowledge services to the community during and after the project. Cluster Livelihoods Resource Centres (CLRCs) have been established with local civil society organisations. They are providing capacity building and other knowledge services to the community. Each watershed has a corpus of approximately one million rupees at the end of the project period. Watershed committees continue to manage these funds to meet the community needs. Post-project management guidelines have been prepared in a consultative process and are in operation to manage the results of these projects after their closure.

Conclusion

There is growing recognition of the role that effective management of natural resources can play in supporting adaptation: increasing the resilience and decreasing the vulnerability of people and their livelihoods to the impacts of natural disasters. This is of critical significance in geographies where the majority of the livelihood portfolio comprises natural resource based livelihoods. Well-managed natural resources have considerable potential for adaptation to climate change; they resist and recover more easily from extreme weather events, and provide an array of benefits to the populations depending on them. Livelihood protection and diversification (non-farm IGA) initiatives that centre on these natural resources therefore have a significant role to play in managing the risks of natural disasters.

Accumulation of both social and human capital in watersheds was stronger, and many group activities could be pursued effectively. Wherever the social capital is high, the community is more resilient and more equipped to handle climate shocks effectively. The livelihood diversification of the landed into multiple crops and for the land-less into non-farm activities reduces vulnerability to climate stress conditions. Convergence among agencies was helpful in dealing with these conditions. The main link between social capital and natural disasters is the role of the former in reducing the vulnerability of livelihoods and reducing shock, thus ensuring a better ability to cope. Since groups are exposed to the participatory planning process they are better able to manage common property resources and are better prepared than communities in areas where such groups are either non-existent or loose.

Watershed-based livelihoods programmes can contribute significantly in this regard. A recent study of WORLP reveals that 86 % of the marginal and small farmers in the watershed area are able to cope with natural disasters.

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Author Biographies

Mr. G. B. Reddy, IFS Director of the Orissa Watershed Development Mission (OWDM), joined the Indian Forest Service in 1981. For the last 30 years, he has worked in various capacities and been actively involved in tribal development, natural resource management, rural livelihoods, food security, microfinance and climate change related issues. As a Director of the OWDM he holds responsibility for managing over 4000 micro watersheds covering an area of two million hectares and containing around 8000 villages. Community resilience is being built through climate change related activities in the watersheds. He also holds responsibility for managing the DFID funded Western Orissa Rural Livelihoods Project (WORLP). Previously he worked on the UNWFP funded World Food Programme (WFP) as Project Director and implemented various food security and livelihood programmes in the tribal pockets of Orissa. He has also worked as Divisional Forest Officer for the State of Orissa and General Manager for the Orissa Forest Development Corporation Ltd. Presently he is also involved in preparing the State Climate Change Action Plan.

Mr. Niranjan Sahu, PSU Coordinator, has 19 years of experience in the fields of teaching, extension, research and development. He experienced an entire project cycle while working at the Danish International Development Agency (DANIDA) assisted bilateral project on watershed development, and has experience working for government, non-governmental organizations (NGOs), civil and tribal society. He worked as PSU Coordinator on the Western Orissa Rural Livelihoods Project. He is passionate about climate change and reducing the vulnerabilities of the poor and marginalised.

Chapter 9
Identifying Drivers, Barriers and Opportunities for Integrating Disaster Risk Reduction and Climate Change Adaptation in Indonesia: An Analysis Based on the Earth System Governance Framework

Riyanti Djalante

Abstract Climate change is expected to increase the frequency, severity and intensity of disasters. Indonesia is known to be one of the countries most vulnerable to natural hazards. It is located in the "Pacific Ring of Fire"—a highly active geological area and scene of many incidents of volcanic eruptions and earthquakes. In addition, more than half of all disaster events in Indonesia are climate-related. There have been increasing and stronger propositions for integrated disaster risk reduction (DRR) and climate change adaptation (CCA) to reduce vulnerability to natural hazards and climate change. This chapter utilises the Earth System Governance (ESG) framework to analyse the integration of DRR and CCA in Indonesia. Journal articles and organisational reports are reviewed. This chapter examines drivers, barriers and, most importantly, opportunities for institutional integration for DRR and CCA in Indonesia. It is argued that the Indonesian government's institutional capacity and arrangements can be both the main barrier and driver for integration. It is established that the main barrier to integration is at the national government level where separation of government organisations and sectoral ministries leads to uncoordinated planning for CCA and DRR. Strong relationships between key government organisations in DRR and non-governmental and international organisations involved both in DRR and CCA hold the key to integration of policy and practice. Moreover, opportunity for integration is even greater at the local government and community level. However, more financial and technical support from the national, international and non-government sectors is needed at the local level in order to make use of this opportunity.

R. Djalante (✉)
Department of Environment and Geography, Faculty of Science, Macquarie University, Building E7A, Sydney 2113, Australia
e-mail: riyanti.djalante@mq.edu.au

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Integration of Disaster Risk Reduction and Climate Change Adaptation: Conceptual Development

Rationale for Integration

Linking Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA) is important because climate change is likely to increase the frequency and severity of hydro-meteorological hazards (IPCC 2007). The simultaneous application of DRR and CCA also results in more efficient use of financial, human and natural resources and therefore increases the effectiveness and sustainability of both approaches. The climate change community is in danger of "wasting time and money in re-inventing the wheel" by conducting CCA activities separately (Schipper 2009; Mercer 2010). Venton and La Trobe (2008) argue that implementation of DRR activities linked with adaptation can result in a reduction of climate-related losses. DRR can contribute to CCA through existing knowledge, approaches and tools that have been tried and tested by the DRR community to address the proximate and underlying causes of hazard vulnerability. The CCA community can also learn from DRR approaches how scientific and traditional knowledge can be integrated (Mercer et al. 2009).

Similarities

There is significant overlap between the theory, policy and practice of DRR and CCA. According to Mitchell and van Aalst (2008), the main synergy between the two is the management of hydro-meteorological hazards, where DRR needs to take into account changing hazards, and adaptation needs to build resilience. Both DRR and CCA emphasise vulnerability reduction and sustainable and flexible long-term strategies to build resilience to adverse impacts. Both also promote approaches that are pro-active, holistic and long-term either before or after hazards occur (Thomalla et al. 2006; Schipper 2009). The Hyogo Framework for Action (HFA) aims to achieve a comprehensive, system-wide risk-reducing approach to CCA (UNISDR 2007). The proactive and progressive risk management approach advocated by the DRR community fits well with CCA purposes (Venton and La-Trobe 2008).

Differences

Schipper (2009) writes that the two fields promote their activities through different actors and institutions, different time horizons, policy frameworks and patterns of works. Thomalla et al. (2006) outline six distinct differences of DRR and CCA, in terms of approach, organisations and institutions, international conferences, assessment, strategies and funding. They argue that the main pragmatic difference between DRR and CCA is the approach toward the issue. DRR traditionally evolved from engineering and the natural sciences. Taking a traditionally short-term perspective, DRR focuses on the hazard event and on exposure to that hazard. CCA has developed from a strong scientific basis, is highly interdisciplinary, focuses on vulnerability and takes a long-term perspective (Thomalla et al. 2006). DRR and CCA are organised by two distinct institutional and strategic frameworks. The UNFCCC and Intergovernmental Panel on Climate Change (IPCC) are the two main bodies for CCA, while the UNISDR and the Global Platform for DRR (GP-DRR) are the main organisations responsible for DRR.

International Progress and Challenges for DRR and CCA Integration

Policies

The need to link DRR and CCA has been gaining stronger international momentum. It was formally initiated at the United Nations Framework Convention on Climate Change (UNFCCC) meeting in Bali. The Bali Action Plan agreed by the parties present at the UNFCCC meeting in Bali recognises that existing knowledge, experience and capacities for reducing vulnerabilities and increasing preparedness to extreme weather events must be harnessed in adapting to climate change. As stated in the UNFCCC Decision 1/CP.13 and UNFCC/CP/2007/6/Add.1, para 1(c) (ii and iii) (2007), both UNFCCC and the UNISDR are actively engaged in activities aimed at linking the two issues. The UNISDR Working Group on Climate Change and DRR were heavily involved in the negotiation of the adaptation pillar of the post-2012 framework under the UNFCCC (Venton and La-Trobe 2008). The 2009 and 2011 Global Platform on DRR reiterates importance of synergies between the two (UNISDR 2009, 2011). The IPCC Working Group II is currently preparing for a special report on “Extreme Events and Disasters: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation” which will provide input for the IPCC’s Fifth Assessment Report (IPCC 2011).

Implementation Progress at International Level

A number of international organisations are actively involved in integrating DRR and CCA in humanitarian and development programmes. The Red Cross Climate Centre supports the International Federation of Red Cross and Red Crescent Societies (IFRC) in understanding and addressing the humanitarian consequences of climate change and extreme weather events (IFRC and The Netherlands Red Cross 2007). Various financial and development agencies (for example the World Bank, USAID, AusAID, and DANIDA) have developed guidelines on climate-proofing their development agendas (Ministry of Foreign Affairs of Denmark 2005; AusAID 2009; The World Bank 2010; USAID 2010). Various organisations and documents have highlighted the need for simultaneous implementation of DRR and CCA. These include (to name but a few): the Vulnerability and Adaptation Resource Group (VARG) (Sperling and Szekely 2005), the UNISDR publication "On better terms" (UNISDR 2006), the World Bank (Burton and van Aalst 2004), Tearfund's report "Linking climate change adaptation and disaster risk reduction" (Venton and La-Trobe 2008), the Global Environmental Change and Human Security (GECHS) report on "DRR, CCA and Human Security" (O'Brien et al. 2008), and a similar DKKV publication (Birkmann et al. 2009). There are also activities that aim to examine how DRR and CCA can be effectively undertaken together. The Nairobi Work Programme on impacts, vulnerability and adaptation to climate change calls in its Call for Action No. 12 for the assessment DRR and CCA (UNFCCC 2008). UNDP produced a climate risk management (CRM) approach and conducted the Caribbean Risk Management Initiative (UNDP 2004, 2010).

The Earth System Governance Framework

Focus on Governance

The author analysis of various organisational reports pointed out that governance is one of major issues driving the possibility for DRR and CCA integration. Governance is broadly defined as the means of interaction patterns of actors, their sometimes conflicting objectives, and the instruments chosen to steer social and environmental processes within a particular policy area (Duit et al. 2010). The shifts from government to governance is generally driven by factors such as increasing decentralisation, growth of public–private partnerships, influences of non-governmental organisations on policy processes and increased impacts on multilateral agreements on domestic policy (Duit and Galaz 2008; Duit et al. 2010). It has been largely acknowledged that current environmental problems have become very complex, such that there is no single approach that serves as the panacea for those complexities, including governance approaches (Ostrom 2008).

A differentiated framework that combines elements of adaptive governance and collective actions is needed. This can be, for example, through a system of multi-level governance (Underdal 2010) or "hybrid modes" of governance (Lemos and Agrawal 2006).

The Earth System Governance Framework

The Earth System Governance framework (ESG) is used as the tool for analysis. This framework has been applied in various cases examining environmental changes. It has been examined within social science perspectives (Biermann 2010), and in connection to its relationship with democracy (Drzek and Stevenson 2010). It has been used to examine floodplain management along the Tisza River in Hungary (Werners et al. 2009) and DRR and CCA integration in the Pacific (Gero et al. 2010). The latest application of the framework includes the ESG project strategy paper in navigating the anthropocene (Biermann et al. 2010).

There are also studies that investigate separate analytical problems of the framework. "Architecture" is examined in terms of the roles of NGOs to fill in gaps in global climate governance (Dombrowski 2010). The issue of "agency" has been closely examined in various contexts (Schroeder 2010; Benecke 2011; Bouteligier 2011; Dellas et al. 2011). "Adaptability" is examined in terms of social learning for water management (Lebel et al. 2010a, b), while "accountability and allocation" are also explored in water and climate governance (Gupta and Lebel 2010; Kanie et al. 2010).

This framework was initially developed by Biermann (2007), and then subsequently refined through the Earth System Governance Project (Biermann et al. 2010). The project (ESGP 2011) defines ESG as:

> the interrelated and increasingly integrated system of formal and informal rules, rule-making systems, and actor-networks at all levels of human society (from local to global) that are set up to steer societies towards preventing, mitigating, and adapting to global and local environmental change and, in particular, earth system transformation, within the normative context of sustainable development.

The Earth System Governance framework is conceptualised into three main analyses of problem structure, governance principles and research challenges, as shown in Table 9.1. *Problem structure* deals with characteristics of earth system transformations. The transformations tend to be uncertain, inter-dependent with functions, time and space, and extreme. These problems' characteristics are unprecedented in the governance of human affairs and therefore they need certain *principles of governance* which are credible, stable, adaptive, and inclusive. *Five research challenges*, of architecture, agency, adaptability, accountability and allocation, can help in guiding the quest for earth system governance (Biermann 2007).

Table 9.1 Conceptualisation of earth system governance (Biermann et al. 2010a)

Problem structure	- Uncertainty
Earth system governance must cope with at least five characteristics of earth system transformation	- Intergenerational dependencies
	- Functional interdependence
	- Spatial interdependence
	- Extraordinary degree of harms
Governance principles	- Credibility
Four core principles of earth system governance	- Stability
	- Adaptability
	- Inclusiveness
Research challenges	- Architecture
Five interdependent analytical problems	- Agency
	- Adaptability
	- Accountability and legitimacy
	- Allocation and access
Crosscutting themes	- Power
Four crosscutting themes have been selected for closer examination within the Earth System Governance Project	- Knowledge
	- Norms
	- Scale

Drivers, Barriers and Opportunities for DRR and CCA Integration in Indonesia: Applying the ESG Framework

Problem Structure: Drivers for DRR and CCA Integration

Biermann et al. (2010a) stated that earth system governance must cope with at least five characteristics of earth system transformation. These problems are uncertain, interdependent and extreme. This chapter argues that problem structure, in terms of Indonesia's vulnerability to natural hazards and climate change, is the main driver for DRR and CCA integration. The underlying aim of those activities is to reduce vulnerability. Everything comes together as a recipe for natural hazards to turn into disasters. Indonesia is highly exposed to danger, is extremely sensitive to shocks and has low adaptive capacity.

Indonesia is the world's largest archipelago with more than 17,000 islands and around 240 million inhabitants, making it the fourth most populous country in the world (BNPB 2011). Its geographical position at the intersection of the Pacific, Eurasian and Australian tectonic plates makes it extremely prone to volcanoes and earthquakes (BNPB 2011). Some of the more recent geological disasters include the 2004 Indian Ocean tsunami, which caused more than 230,000 casualties in Aceh and North Sumatra provinces. In 2010 alone, Indonesia suffered great casualties due to the tsunami which hit the Mentawai Island, flood in Wasior, West Papua and the eruption of Mount Merapi in Yogyakarta (BNPB 2011). The Intergovernmental Panel on Climate Change reported that the number of hydro-meteorological disasters has doubled in the last 5 years, whereas geological hazards have remained the same (IPCC 2007). The increasing impacts of climate

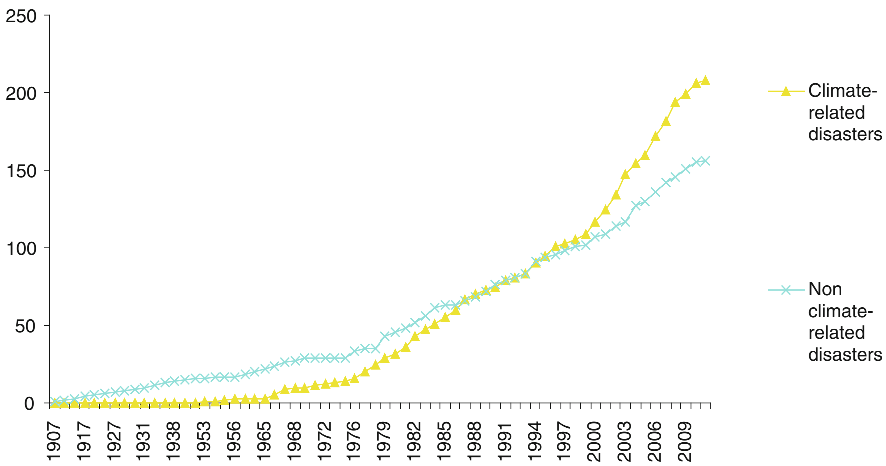

Fig. 9.1 Comparison in (cumulative) numbers of disasters due to climate-related and non-climate related disasters in Indonesia from the period 1907 to 2010 (*Source* modified from EM-DAT)

changes are expected to greatly increase the frequency, intensity and severity of disaster in Indonesia. Climate change will only exacerbate these existing problems in the country (UNDP Indonesia 2007). Several studies reiterate Indonesia's high vulnerability to climate disasters (Yusuf and Francisco 2009), with Jakarta coming only after Dhaka in Bangladesh as the most vulnerable city in WWF's climate vulnerability ranking of major cities in Asia (WWF 2009). Using data from "EM-DAT: The OFDA/CRED International Disaster Database", the numbers of disasters due to climate-related and non-climate related disasters in Indonesia from the period 1907 to 2010 are compared (see Fig. 9.1), and climate-related disasters affected 63 % of the 27 million people affected by climate-related disasters (EM-DAT 2011) (see Fig. 9.2).

Governance Principles: Barriers for DRR and CCA Integration

Biermann et al. (2010a) stated that there are four core governance principles needed to govern the earth system. These are credibility, stability, adaptability and inclusiveness. The second argument in this chapter is that ineffective governance hinders the possibility of DRR and CCA integration. Socially and economically, Indonesia is still struggling to fight poverty and social inequalities (World Bank Indonesia 2011). Lack of credible, stable and adaptive governance has created the underlying risks that lead to vulnerability to natural hazards in the first place (BNPB 2011). Even though strong progress on DRR has been observed in Indonesia, it only happens at the national level (BNPB 2011). Furthermore, while there have been many reports on strong collaboration between governments and NGOs, this tends to

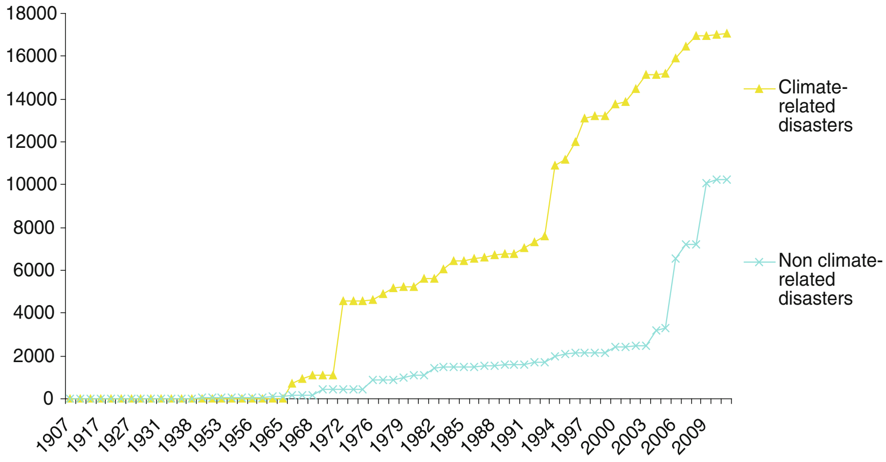

Fig. 9.2 Comparison in (cumulative) numbers (in 000) of people affected by disasters due to climate-related and non-climate related disasters in Indonesia from the period 1907 to 2010 (*Source* modified from EM-DAT)

happen only at the national level. There are few reports informing collaboration between the two at the local level.

There is insufficient support provided to the local governments to manage DRR and CCA, and decentralisation, while it has had some positive outcomes in terms of delegation of power, leaves local governments to fend for themselves. They, as the first respondents to disasters, just do not have the necessary skills and capability to manage disasters and to plan for long-term adaptation. They tend to rely heavily on financial and technical support from national governments (BNPB 2011). The results from the author interviews and the literature review suggest that local governments still have a very low capacity and capability to develop plans for climate change resilience (Thomalla et al. 2009; Thomalla and Larsen 2010; BPBD Makassar City, October 2010). The so called 'big-bang' of decentralisation in Indonesia has created difficulty in coordinating and aligning national and local planning and policies (Sudarmo and Sudjana 2009). Local governments tend to view climate change as an additional burden on top of more pressing problems such as education, social and economic development, and poverty alleviation.

Research Challenges: Barriers and Opportunities for DRR and CCA Integration

Biermann et al. (2010a) proposed five interdependent analytical problems in a quest for a better governance of the Earth System. They are architecture, agency, adaptability, accountability and legitimacy (the "Five As"). Furthermore, within each of these analyses, issues of power, knowledge, norms and scale need to be considered. The last argument in this chapter is that in Indonesia, the Five As can be analysed as both the barriers to and opportunities for DRR and CCA integration.

Architecture: Nested Arrangements and Policy Frameworks

Biermann et al. (2010a) define governance architectures as the overarching system of public or private institutions, principles, norms, regulations, decision-making procedures and organisations that are validly active in an issue. Architecture is defined as the structure and the interlocking web of principles, institutions and practices that shape decisions by stakeholders at all levels. It spans global, regional, national and local governance and concerns the emergence, design and effectiveness of the systems. There are several questions to be answered when analysing architecture. One needs to understand how environmental institutions functions through their nesting and multi-level actions within larger or smaller architectures; how non-environmental governance systems affect the environment; how instances of "no governance" can be observed; and signs of overarching and crosscutting norms of earth system governance.

Table 9.2 shows the architecture for DRR and CCA at global, regional, national and local levels. As can be seen from the table, the architecture of these institutions has been established, and can continue to provide opportunities for integration. International organisations and NGOs (internationally and locally) have a crucial role in planning and implementing integrated activities.

In Indonesia, policies, plans, activities and institutions for DRR and CCA have traditionally evolved separately, as shown in Table 9.3. It can be seen that DRR activities have been formally conducted by the government since Indonesian independence in 1945. International influences on DRR and CCA policies have also come at a later stage. Indonesia was a signatory to the Climate Convention in 1992 and its subsequent actions clearly describes how international activities influence national policies for CCA. The 2004 Indian Ocean tsunami also strongly influenced international and Indonesian efforts in DRR. The "Hyogo Framework for Action: Building the Resilience of Nations and Communities to Disasters" was agreed during the World Disaster Reduction Conference in 2005 in Japan (UNISDR 2007). HFA is a ten-year plan to make the world safer from natural hazards and a first systematic and comprehensive approach in reducing disaster risks and losses (UNISDR 2007).

Agency: Review of Indonesia Key Policies and Institutions

The next issue to be analysed is "agency". Agency encompasses all stakeholders from government agencies, non-government organisations, and private and community organisations. Biermann et al. (2010a) have stated that to effective

Table 9.2 Key institutions for DRR and CCA in Indonesia, from global to local level

Level	DRR	Integrated DRR and CCA	CCA
Global	- UNISDR - GFDRR - Global platform for DRR	- Bali action plan on DRR and CCA - Nairobi plan - Cancun agreement (CCA also for DRR) - SREX report - International organisations and NGOs (international) initiating integrated DRR and CCA projects	- UNFCCC - IPCC
Regional	- Asia DRR - ADRC - Asean DRR	- Fourth Asian ministerial conference on disaster risk reduction through climate change adaptation (4AMCDRR) - Incheon REMAP - International organisations and NGOs (international) initiating integrated DRR and CCA projects	- Asian adaptation platform
National	- Bappenas - BNPB - National platform for DRR	- Funding agencies - UN organisations - International organisations and NGOs (international and national) initiating integrated DRR and CCA projects	- Bappenas - DNPI - Ministry of eEnvironment
Local	- Bappeda - BPBD - NGOs - CBOs	- International organisations and NGOs (international) initiating integrated DRR and CCA projects - CBDRM (include CC issues)	- Bappeda - Environmental department - NGOs - CBOs

understanding earth system governance requires understanding of agents that drive it and that needed to be involved. Furthermore, Biermann et al. (2010b) suggested several core questions in ESG project such as what agency is, who the agents of earth system governance (especially beyond the nation state) are, how different agents exercise agency in earth system governance and how we can evaluate their relevance.

While the need to link the two approaches has been highlighted by many researchers, the operationalisation and implementation have so far been limited. Mitchell and van Aalst (2008) outlined several obstacles for convergence of international policy processes, multi-lateral and bi-lateral institutions, financing mechanisms, and implementation at national level. In developing countries, adaptation and disasters issues are usually managed by different institutions, each with their own inter-sectoral coordination groups (Mitchell and van Aalst 2008). This is also the case in Indonesia. Despite acknowledgement that disasters and climate change are one of the nine Indonesian development priorities, there has been little integration of sectoral agencies. While DRR is managed by the National Agency for Disaster Management (BNPB), CCA is managed by the National Council for Climate Change (DNPI) and the Ministry of Environment (MoE). There has been recognition of the integration of DRR and CCA by these agencies (Bappenas 2010; BNPB 2010; DNPI 2010b), but there has been little formally

Table 9.3 Policy frameworks for DRR and CCA in Indonesia

Guidelines, policies, strategies and activities relating to DRR and CCA		
Years	DRR	CCA
2011	- Third Global Platform for DRR - Indonesia named Global Champion for DRR	- UNFCCC COP 17 (to come) - SREX report to be published
2010	- National Guidelines for Disaster Management (Renas PB) 2010–2014 - National Action Plan for Disaster Risk Reduction (RAN PRB) 2009–2012	- UNFCCC COP 16: Cancun agreement - Indonesia Second National Communication (SNC) to the UNFCCC
2009	- Second Global Platform for DRR - Indonesian National Platform for Disaster Risk Reduction (Planas PRB)	- UNFCCC COP 15: Copenhagen Accord - Indonesia Climate Change Sectoral Map (ICCSR) - Indonesia Climate Change Trust Fund (ICCTF)
2008	- National Disaster Management Agency (BNPB) - Sub-National Disaster Management Agency (BPBD)	- UNFCCC Nairobi Work Programme - National Council for Climate Change (DNPI) - National Development Planning: Indonesia Response to Climate Change
2007	- Disaster Management Law No 24 Year 2007 - First global platform for DRR	- UNFCCC COP 13 in Indonesia - The Bali Road Map/Action Plan - National Action Plan Addressing Climate Change (RAN-PI) - First Sub-National Task Force on Climate Change Adaptation
2006	- National Action Plan for Disaster Risk Reduction (RAN PRB) 2006–2009	–
2005	- The National Coordinating Board for Disaster Management (Bakornas-PB) - Tsunami relief, rehabilitation and reconstructions started - Hyogo Framework for Action (HFA) - World Conference on Disaster Reduction (WCDR)	–
2004	- Indian Ocean Tsunami hit Aceh and Nias Island	- Indonesia ratified the Kyoto Protocol
2001	- The National Coordinating Board for Disaster Management and Refugees (Bakornas PBP)	–
1999	–	- First Indonesia's National Communication to UNFCCC
1997	–	- The Kyoto Protocol - Adaptation Fund established
1994	–	- Indonesia ratified the UNFCCC
1992	–	- Indonesia signed the Climate Convention

(continued)

Table 9.3 (continued)

Guidelines, policies, strategies and activities relating to DRR and CCA

Years	DRR	CCA
1990	–	- National Committee on Climate Change (KNPI)
1979	- The National Coordinating Board for Disaster Management (Bakornas PBA) and similar provincial agency (Satkorlak PBA)	–
1967	- The National Coordination Team for Disaster Management (TKP2BA)	–
1966	- The National Board for Disaster Management (BP2BAP)	–
1945	- The National Board for War Victim Supports (BPKKP)	–

managed collaboration. BNPB is not a formal member of the DNPI Adaptation Group while DNPI is not part of the National Platform for DRR (DNPI 2010a, 2011) nor be active in any BNPB-led DRR activities (BNPB 2010).

The latest figures from the United Nations Technical Working Group on DRR (UNTWG-DRR 2011) show that there are currently 154 organisations working on DRR in Indonesia, as set out in Fig. 9.3. As Fig. 9.3 shows, the organisational landscape for DRR is dominated by national and international NGOs. This indeed shows their significance and importance in driving DRR and also in initiating climate change issues within their DRR activities. To enable better coordination of a large number of agencies, several initiatives such as the UNTWG-DRR or Convergence Group for DRR, or lately, the National Platform for DRR are formed (Bappenas 2010). CCA activities should start with these DRR establishments.

Adaptability

Biermann et al. (2010a) stated that adaptability means a condition by which a state is able to adapt internally and externally to large-scale transformations of its natural environment. They explained that earth system governance must respond to the inherent uncertainties in human and natural systems, through combining stability to ensure long-term governance solutions with the flexibility to react quickly to new findings and developments. Some issues to be explored in understanding adaptability are: the politics of adaptability; the governance processes that foster it; the attributes of governance systems that enhance capacities to adapt; and, lastly, how, when and why does adaptability influence earth system governance. In Indonesia, adaptability seems to be driven by non-government organisations. These organisations have been involved in various pressing issues such as poverty alleviation, environmental management, gender strengthening and governance (IFRC 2010; Mercy Corps 2011;

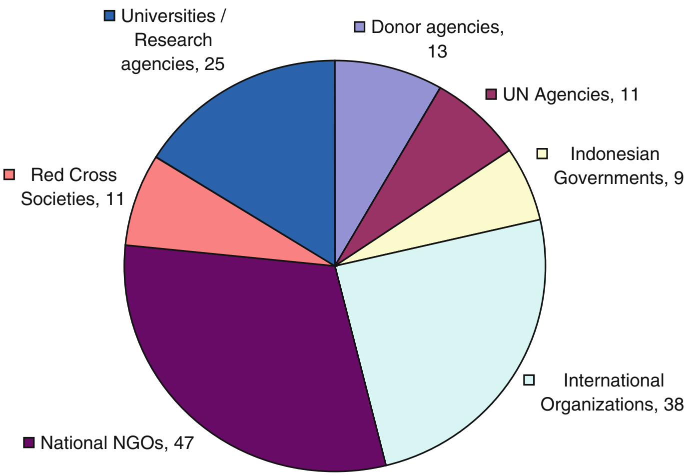

Fig. 9.3 Agencies and organisations involved in DRR and CCA in Indonesia (*Source* UNTWG-DRR 2011)

Oxfam 2011; PMI 2011). These experiences equip the organisations to be flexible yet robust enough to respond to changes and uncertainties. Interviews with these organisations revealed that there is strong collaboration and coordination happening at local and national level (IFRC 2010b; Mercy Corps 2010; PMI 2010). They have also acknowledged that DRR and CCA need to be practised together in the field. However, barriers still exist; organisations working traditionally for DRR generally have this understanding about integration. Furthermore, DRR has been on the whole better developed and implemented than CCA in Indonesia. Therefore any CCA activities should utilise the existing knowledge, practices, and networks.

Accountability

In understanding accountability, Biermann et al. (2010a) suggested that the complex character of earth systems confronts accountability and legitimacy of governance. Some key questions to be explored are the sources of accountability and legitimacy in earth system governance, the effects of different forms and degrees of accountability and legitimacy for the performance of governance systems, the mechanisms of transparency in ensuring accountable and legitimate earth system governance, and how institutional designs can produce the accountability and legitimacy of earth system governance in a way that guarantees balances of interests and perspectives. It is observed that decentralisation in Indonesia creates difficulty in coordinating and aligning national and local policies for DRR and CCA (Sudarmo and Sudjana 2009; BNPB 2011).

Allocation and Access

The last research challenge is that of allocation and access. Biermann et al. (2010a) suggested that earth system governance and other means of governance are basically concerned with distribution and allocation of goods. Governance is therefore a system that makes sure that these distributions are justifiable, fair and equitable. Questions to be answered include how can we reach interdisciplinary conceptualisations and definitions of allocation and access, what (overarching) principles underlie allocation and access, and how allocation can be reconciled with governance effectiveness. In Indonesia, allocation and access seems to be more of a problem at local government level. Indonesia's mid–term review of HFA stated that, while the national government was progressing quite well in DRR, local governments lagged behind. The reason for this is the lack of technical and financial support received by local governments from the national government or international organisations (BNPB 2011).

Discussions and Conclusion

Drivers, barriers and opportunities of DRR and CCA integration in Indonesia have been analysed in this chapter. The problem structure analysis shows that uncertainty and increasing extremity of climate-related disasters are the key drivers for integration. Examination of governance principles needed for effective integration of DRR and CCA shows that most principles still act as barriers to that integration. Next, the Five As are examined closely in this chapter. Accountability and allocation still act as barriers, while architecture, agencies and adaptability serve both as barriers to and opportunities for DRR and CCA integration. It is very important that Indonesia uses these identified opportunities to push integration forward. Roles of non-governmental organisations and international agencies have been successful in helping DRR and CCA at national level and these efforts should be directed more at the local government level.

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Author Biography

Riyanti Djalante is a PhD candidate at the Macquarie University in Australia, undertaking research on "Promoting Resilience to Natural Hazards and Climate Change: a Case study of Indonesia". Riyanti graduated with a Bachelor's degree in Engineering from the University of New South Wales and a Master's in Project Management from The University of Queensland, Australia. In Indonesia, she works for the local government of Kendari City, South East Sulawesi Province. Her research interests and work expertise include local development planning, poverty alleviation, institutions and governance, and, currently, vulnerability and resilience to natural hazards and climate change.

Chapter 10
Environmental Performance and Vulnerability to Climate Change: A Case Study of India, Nepal, Bangladesh and Pakistan

Medani P. Bhandari

Abstract Relatively little scholarly work has focused on a comparative evaluation of South Asian countries' environmental performance (EP) in addressing issues of vulnerability to climate change. It is an accepted fact that climate change induced problems in South Asia have been increasing over many years, but their effects have largely been blamed on extreme poverty and uncontrolled population growth. Scholarly works and government reports indicate that the countries are both individually and collectively aware of the severity of climate change and have taken some initiative aimed at adaptation and mitigation. However, it is still unknown how effective those initiatives are and how they are being implemented. This research broadly examines these countries' EP by modelling a comparative matrix in the global as well as in the regional context. The author is interested in how India, Nepal, Bangladesh, and Pakistan actually engage in addressing environmental severity caused by climate change. This research utilises (plot) various years' data from the public domain, e.g. Environmental Sustainability Index (ESI); Environmental Performance Index (EPI). EP is presented in the framework of comparative scores on (1) environmental burden of disease; (2) water resources for human health; (3) air quality for human health; (4) air quality for ecosystems; (5) water resources for ecosystems; (6) biodiversity and habitat; (7) forestry; (8) fisheries; (9) agriculture; and (10) climate change respectively. The specific findings of this research will reflect on the efforts of the respective countries and also provide an opportunity to evaluate the cause of success or failure.

Keywords Evaluation · South Asia · Governance and environmental performance (EP) · Vulnerability · Climate change · Problems · Risk

M. P. Bhandari (✉)
Maxwell School of Citizenship and Public Affairs, Syracuse University, 302 Maxwell Hall, Syracuse, NY 13244, USA
e-mail: mbhandar@syr.edu

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Short Introduction

The research evidence shows that economic growth is a function of governance performance as well as socio-economic competiveness; whereas governance is the sum of the many ways individuals and institutions, public and private, manage their common affairs. Governance is a continuing process through which conflicting or diverse interests may be accommodated and cooperative action may be taken. This research exhibits comparative overviews on environmental performance in addressing issues of vulnerability to climate change based on the cases of India, Nepal, Bangladesh, and Pakistan, which have differing socio-political and economic status. The overall systems of governance in these countries are not able to cope with changing global competitiveness and are not able make significant progress based on indicators of good governance. To cope with the climate change induced problems, emphasis must be placed on increasing the responsibilities of all stakeholders, and instigating more cooperative efforts towards ensuring a healthy environment for the future. Increased awareness of ecosystems and new market-based systems will prove to be important mechanisms in dealing with environmental issues.

Introduction

This study provides comparative overviews of environmental performance in addressing issues of vulnerability to climate change based on the cases of India, Nepal, Bangladesh, and Pakistan, which have differing socio-political and economic statuses. Performance measurement is an ongoing process of ascertaining how well, or how poorly, a government programme is being conducted. It involves the continuous collection of data on progress made towards achieving the programme's established objectives. Performance indicators, or measures, are developed as standards for assessing the extent to which these objectives are achieved. The author utilises the EP measurement method, which is one of most widely applied tools of country situational analysis developed with the aim of shifting environmental decision-making to firmer analytic foundations using environmental indicators and statistics. This paper shows the strengths of the governance of four countries, highlights the major evidence of climate change induced risk and causality, and examines environmental performance with regard to minimising risk.

Among the four nations studied, India is the largest in area. It is the seventh largest country in the world, comprising of 2.1–2.3 % of the planet. Also studied are Pakistan, which is 36th in size globally, Nepal, which is 93rd, and Bangladesh, which is 94th (CIA 2010). Table 10.1 below summarises the countries' positions in terms of their territory, demographics, economics, and health profiles.

Table 10.1 A brief comparative account of four countries (territory, demographics, economics, and health profiles)

Category	Indicators	IND	PAK	BGD	NPL
Population	Territory (land surface in 000 km^2)	3287	796	144	147
	Population density (per km^2) 2008	361	210	1120	195
	Total (million)	1181.4	184.4	160	28.9
	Rural (% of total)	71	64	73	83
	Over 65 years (% of total)	5	4	4	4
	Young	50	63	50	63
	Old	8	7	6	7
Economy	GNI/capita (USD)	1,220	1,000	580	440
	PPP GNI/capita (USD)	3,280	2,680	1,550	1,180
	Annual growth GDP (%)	7.3	2	6.2	5.3
	Male 15 years and older (%)	81	85	84	76
	Female 15 years and older (%)	33	21	58	63
	Extreme Poverty (% < USD 1.25 PPP)	41.6	22.6	49.6	55.1
Health indicators	Mortality rate, infant (per 1,000 live births)	52	73	43	41
	Maternal mortality ratio (per 100,000 live births)	450	320	570	830
	Crude death rate (per 1,000 population)	7	7	7	6
	Life expectancy (years)	64	67	66	67
Health services	Hospital beds (per 10,000 populations)	7	10	3	2
	Physicians (density per 10000 population)	6	8	3	2
Health financing	Total expenditure on health (% of GDP)	4	2.9	3.5	4.9
	General government expenditure on health (% of total)	28	29.7	35.7	39
	Per capita total expenditure on health (USD	43	24	17	20

BGD Bangladesh, *IND* India, *NPL* Nepal, *PAK* Pakistan; *population data sources* World Bank, World Development Indicators, 2010. Data for health services are from World Health Statistics, 2009. *Original data sources include*: ILO, WHO, UNICEF, UNFPA, and World Bank, Maternal Mortality in 2005 (maternal mortality ratio); and WHO National Health Accounts (health financing data). Note: data are for 2008 except for extreme poverty (2002–2005), maternal mortality ratio (modelled estimates, 2005), hospital beds (2000–2008), and physicians (2000–2007) per 10,000 people as in World Bank Data 2011, p. 21)

It is worthy of note that in addition to having the seventh largest territory globally, India has the second largest population, whereas Bangladesh has the largest population density in the world, 1120 per square kilometre. Among the four, India has the highest annual growth in GDP (7.3 %) and Pakistan has the lowest, only 2 % annually (CIA 2010; World Bank Data 2011).

Governance Performance

Governments often are described as standing on three legs—economics, politics, and administration—whereas governance is the sum of the many ways individuals and institutions, both public and private, manage their common affairs. It is a continuing process through which conflicting or diverse interests may be accommodated and cooperative action may be taken. It includes formal institutions and regimes empowered to enforce compliance, as well as informal arrangements that people and institutions either have agreed to or perceive to be in their interest (as in UNDP 1999, p. 29).The efficacy of administration depends on civil service and public financial management, government policy-making procedures, leadership, and service delivery systems (UNDP 1997).

Table 10.2 below summarises the standing of the four countries of this study with regard to overall governance performance in terms of six universally applied parameters (Kaufmann et al. 2010). India holds the best position, followed by Bangladesh on Voice and Accountability, Political Stability and Absence of Violence, and Rule of Law (second among the four); Pakistan in Government Effectiveness and Regulatory Quality (second among four); and Nepal, which is second among the four in Control of Corruption. In the category of Political Stability and Absence of Violence, Pakistan scores lowest and Nepal eighth lowest in the world.

Summary of the Results on Governance Performance

2.1. *Voice and Accountability*. One of the major measures of governance performance, where India's performance increased by 6 points from 1996 to 2008; in contrast Nepal appeared one of the worst by dropping 21 points, followed by Bangladesh with a drop of 11 and Pakistan with a drop of 8 points. The reason for such a drastic fall in Nepal's performance was the Maoist insurgency, which kept the country in turmoil for about 11 years over that period. In the case of Bangladesh and Pakistan, the reasons are the direct or indirect militarisation, internal violence and power struggle.

2.2. *Political Stability and Absence of Violence*. The performance of all four countries was unsatisfactory within a global context. To some extent India is stable; in comparison, Nepal was the best performing country among the four in 1996, with a rank of 42, but dropped by 34 points by 2008 and was eighth among the 10 weakest performing nations; Pakistan ranked the worst and Bangladesh tenth.

2.3. *Government Effectiveness*. India remained almost constant over the 12 years studied, whereas, again, Nepal's performance dropped by 25 points (from 49 to 24), while Pakistan dropped by 6 and Bangladesh by only 3 points.

2.4. *Regulatory Quality*. India's performance increased by 7 points, Pakistan's by 6 points, Nepal by 4 points; in contrast Bangladesh quality dropped by 14 points.

2.5. *Rule of Law*. Bangladesh gained 3 points in 12 years, whereas Nepal appeared a major loser with a drop of 25 points, followed by Pakistan with a drop of 16 points and India with a drop of 6 points.

Table 10.2 Governance performance

Year	2008 % Rank	2008 Est.	1996 % Rank	1996 Est.	2008 % Rank	2008 Est.	1996 % Rank	1996 Est.
Country	Voice and accountability (rank and estimation)				Political stability and absence of violence			
India	59	0.45	53	0.12	17	−0.99	16	−0.99
Bangladesh	31	−0.61	42	−0.23	10	−1.54	20	−0.80
Nepal	25	−0.79	46	−0.06	8	−1.69	42	−0.09
Pakistan	19	−1.01	27	−0.71	1	−2.61	9	−1.44
	Government effectiveness				Regulatory quality			
India	54	−0.03	57	−0.15	47	−0.21	40	−0.01
Pakistan	26	−0.73	32	−0.54	35	−0.47	29	−0.38
Nepal	24	−0.75	49	−0.25	27	−0.66	23	−0.72
Bangladesh	23	−0.77	26	−0.65	21	−0.82	35	−0.22
	Rule of law				Control of corruption			
India	56	56	56	56	44	−0.37	38	−0.38
Pakistan	27	27	27	27	29	−0.68	64	0.35
Nepal	25	25	25	25	25	−0.77	15	−1.04
Bangladesh	19	19	19	19	11	−1.10	33	−0.51

Source Kaufmann et al. (2010)
Note WGI measures the standard normal units of the governance indicator, ranging from around –2.5 (low performance) to 2.5 (high performance), and in percentile rank terms ranging from 0 (lowest) to 100 (highest) among all countries worldwide. The column labelled "Est." provides the point estimate (The governance indicators presented here reflect the statistical compilation of responses on the quality of governance given by a large number of enterprise, citizen and expert survey respondents in industrial and developing countries, as reported by a number of survey institutes, think tanks, non-governmental organisations, and international organisations as in Governance Matters VIII: Governance Indicators for 1996–2008)

2.6. *Control of Corruption*. This has been considered as a major problem in the region (UNDP 1999). In this category Pakistan gained 10 points and India 6 points, whereas again Nepal was the worst among the four, dropping 35 points (from 64 to 29) and Bangladesh 22 points (from 33 to 11).

To sum up, Table 10.2 shows that the overall situation is that all four countries are performing poorly in relation to the global scenario governance performance. Among the four, India's situation is either stable or improving incrementally. However Nepal's performance dropped drastically in all categories followed by Pakistan and Bangladesh. This table also reveals that regardless of international effort, a country's position in governance performance could not be improved until or unless the norms of governance are functioning. The case of Nepal, for example, is a frustrating picture in the sense that it instituted a democratic system of government in 1990, but has not yet been able to institutionalise democratic norms. Instead of keeping pace with the global scenario, Nepal's performance has been deteriorating further every year in all six governance performance measures.

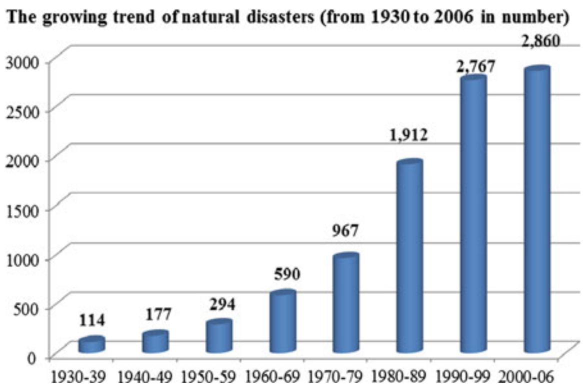


Fig. 10.1 Natural disaster growing trend (*Data source* EM-DAT (2011). *Note* Natural disasters include: drought; earthquake (seismic activity); epidemic; extreme temperature; flooding; insect infestation; mass movement dry; mass movement wet; storm; volcano; wildfire. Since 1988 the WHO Collaborating Centre for Research on the Epidemiology of Disasters (CRED) has been maintaining an Emergency Events Database EM-DAT. EM-DAT was created with the initial support of the WHO and the Belgian Government. EM-DAT contains essential core data on the occurrence and effects of over 18,000 mass disasters in the world from 1900 to present. The database is compiled from various sources, including UN agencies, non-governmental organisations, insurance companies, research institutes and press agencies (EM-DAT 2011). The figure shows that during 1930–1939 there were only 114 major natural disasters, which reached 1912 during 1980–1989 and 2860 by 2000–2006. It is evident that the extreme climatic events are increasing over the years)

Environmental Problems and Impacts

In terms of environmental challenges, all four countries are on the same trajectory. In these countries, environmental degradation has been playing a critical role in triggering some disasters, and making others worse. As these countries have been facing problems caused by deforestation, erosion, over cultivation and over grazing of marginal lands, they also are the hardest hit by the catastrophic events. The empirical evidence suggests that the countries which suffer most from natural disasters are those in which environmental degradation is most severe, i.e. those with severe deforestation, soil erosion, over cultivation and over grazing (UNEP-DA 2008; World Bank 2007; Kelkar and Bhadwal 2008). For example, annual floods in Nepal are mainly caused by deforestation and alterations to natural catchment drainage patterns, which reduce the attenuation of run-off, and concentrate high run-off volumes over a short period of time even though the actual intensity of the rainfall may not have been particularly severe. Furthermore, the effects of environmental degradation can also transcend national boundaries. It has been claimed that the increasing soil erosion in the hills of Nepal is resulting in heavy siltation of river beds in India and Bangladesh, which is raising river bed levels and causing more frequent flooding. The region also experiences the tremors

Table 10.3 The four Asian countries' situations in terms of change in temperature and change in precipitation

Countries	Change in temperature	Change in precipitation
India	0.68 °C increase per century, increasing trends in annual mean temperature, warming more pronounced during post monsoon and winter	Increase in extreme rains in north-west during summer monsoon in recent decades, lower number of rainy days along east coast
Nepal	0.09 °C per year in Himalayas and 0.04 °C in Terai region, more in winter	No distinct long-term trends in precipitation records for 1948–1994
Pakistan	0.6–1.0 °C rise in mean temperature in coastal areas since early 1900s	10–15 % decrease in coastal belt and hyper arid plains, increase in summer and winter precipitation over the last 40 years in northern Pakistan
Bangladesh	An increasing trend of about 1 °C in May and 0.5 °C in November during the 14-year period from 1985 to 1998	Decadal rain anomalies above long term averages since 1960s

Source IPCC (2007, p. 475); (also in Government of India 2010, p. 30)

of global ecological changes (UNEP 2007). For instance, the loss of natural vegetation, particularly forests around the world, is also a major cause of preventable natural disasters that afflict South Asia. These problems are not recent phenomena; however, in recent years they have increased due to climate change (see Fig. 10.1).

Climate Change

Related to the environmental degradation issue, the IPCC Fourth Assessment Report (2007) provides a foreboding picture of global climate change and its impacts, particularly in the developing world (IPCC 2010). It notes that "climate change is already having significant impacts" in certain regions, particularly in developing countries, and on most ecosystems. It will affect developing countries' ability to achieve the Millennium Development Goals (MDGs). "Impacts of climate change will vary regionally", with the most significant impacts expected in the Arctic, the Asian mega-deltas, Small Island Developing States (SIDS) and sub-Saharan Africa. Climate change will further constrain water resources, already stretched by growing demand from agriculture, industry and cities. Rising temperatures will further diminish the mountain snow pack and increase evaporation, thus altering the seasonal availability of water (IPCC 2010, pp. 1–2). One of the indicators of climate change is the incremental trends of natural disasters; Fig. 10.1 below shows an alarming scenario.

The IPCC's four-country analysis of change in temperature and precipitation clearly indicates that the temperature in South Asia is increasing slowly but steadily. The report shows the region's vulnerability and the urgency of implementing mitigation tools and policies (Table 10.3).

Adverse impacts of climate changes have already been noted in individual South Asian countries, especially as the main source of GDP in these countries is agriculture. For example in Bangladesh, which is a major rice producing country in the region, the production pattern is changing, ranging from −6 % decreases to a 14 % increase over a 14-year period due to increased vulnerability of agricultural areas to floods, cyclones and storm surges, increasing salinity of soils due to reduced upstream freshwater supply and salt-water intrusion in aquifers (see Table 10.3) (IPCC 2007). Similarly, in Nepal, vulnerability is increasing due to the effects of climate change on disruption of the irrigation system, decreased availability of glacier melt water, increases in domestic and irrigation water demand, disasters (floods, droughts, extreme temperatures, windstorms, glacial lake outbursts), and increased variability of hydropower production. In Pakistan, observed effects of climate change include a drastic decline in agricultural production, shortening of the crop life cycle, destruction of irrigation infrastructure and crops attributed to increased flooding, increase in run-off (which boosts hydropower production, but will also causes flooding, waterlogging, and salinity), loss of mangroves, which has serious implications for fisheries export, and increase in erosion and landslides attributed to excessive rainfall (Asia Forest Network and RECOFTC 2006; IPCC 2007). In India, it has also been noted that the frequency of hot days and multiple-day heat waves has increased in the past century, and deaths due to heat stress have increased in recent years (NATCOM 2010). Climate change impacts have been noticed in all sectors i.e. land, air, water and biodiversity (UNEP-DA 2008).

It is clear that the South Asian nations are in a climate prone area and the adverse impacts of climate change have changed the ecosystem of the region. However, the region is not well prepared to tackle the changed environment (UNDP 1997). These nations lack the resources to mitigate the process and also are technologically unable to forecast the impact of climate change hazards. In addition to a weak technical capacity, there is also lack of trust among the countries which has impacts on mitigation. For example India and Pakistan have a fair weather forecast mechanism but still lack of an information-sharing mechanism (AIT-UNEP RRCAP 2011). The IPCC and various other studies have shown the severity of the impact and forecast the future consequences of climate change in the region. For example UNEP-DA (2008, p. 53) notes that the glacier melt in the Himalayas is projected to increase flooding and will affect water resources within the next two to three decades; climate change will compound the pressures on natural resources and the environment due to rapid urbanisation, industrialisation, and economic development; crop yields could decrease up to 30 % in South Asia by the mid-twenty first century; mortality due to diarrhoea primarily associated with floods and droughts will rise in South Asia; and sea level rise will exacerbate inundation, storm surge, erosion and other coastal hazards. The consequences of such environmental changes include: decreased water availability and water quality in many arid and semiarid regions; an increased risk of floods and droughts in many regions; reduction in water regulation in mountain habitats; decreases in reliability of hydropower and biomass production; increased incidence of waterborne diseases such as malaria, dengue, and cholera; increased damage and deaths caused by extreme weather events; decreased agricultural productivity; adverse impacts on fisheries; and adverse effects on many ecological systems. As a result of these changes, climate change could hamper the achievement of many of the Millennium Development Goals (MDGs), including those on poverty eradication, child mortality, malaria and other diseases, and environmental sustainability. Much of this damage would come in the form of severe economic shocks. In addition, the impacts of climate change will exacerbate existing social and environmental problems and lead to migration within and across national borders. In sum, climate change is clearly not just an environmental issue but one with severe socio-economic implications in South Asia (World Bank 2007; ICIMOD-UNEP 2009; Armstrong 2010; Ives et al. 2010; Desai et al. 2011).

Climate Change Induced Risk

According to the recent publication of Global Climate Risk developing countries are relatively more vulnerable to global climate change. The report shows that in terms of the geography, population and economic conditions, the top ten developing nations suffering adverse climate events that occurred from 1990 through 2008 were Bangladesh (the most vulnerable), followed by Myanmar, Honduras, Vietnam, Nicaragua, Haiti, India, Dominican Republic, Philippines and China. The annual global human loss resulting from adverse climate events was 34,782, and in 18 years, the world faced a total of 626,079 human deaths and USD 1,881,537.48 million of property loss. This scenario shows an alarming threat of extreme weather events.

According to Maplecroft (2010), the countries with the most risk are characterised by high levels of poverty, dense populations, exposure to climate-related events; and reliance on flood and drought-prone agricultural land. Africa also features strongly in this group, as the continent home to 12 out of the 25 countries most at risk. However, from 1990 to 2009, Bangladesh was ranked first, Nepal 11th, India 12th, and Pakistan 37th on the global scale; Fig. 10.2 gives a snapshot of the four countries in terms of lives lost.

Overall, the four countries in this study are threatened not only in terms of climate change impact, but also by poverty, uncontrolled population growth, weak mitigation options, and due to their geographical location and variation. Among them Bangladesh is recognised worldwide as one of the country's most vulnerable

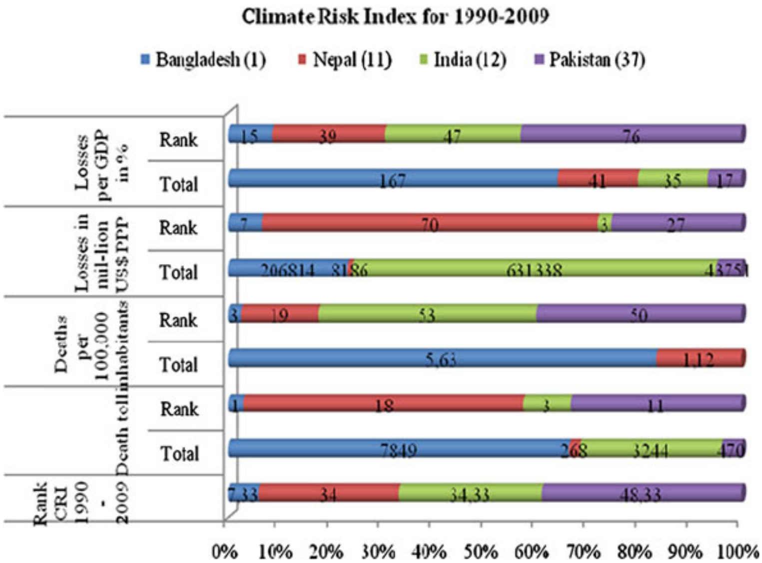


Fig. 10.2 Impact of climate change [*Source* German Watch (Harmeling et al. 2010, pp. 17–19)]. *Note CRI* Climate risk index; *GDP* gross domestic product; *PPP* purchasing power parity; in the India and Pakistan column, deaths per 100,000 inhabitants is not shown because of the lower number in comparison to the population ratio and the share percentage. The actual number in the CRI, deaths per 100,000 inhabitants for India is 0.31 and for Pakistan 0.35. The figure gives only a brief picture of risk index in terms of human loss and the sense of vulnerability, where Bangladesh (ranking first in death toll, third in deaths per 100,000 inhabitants, and 15th in loss of GDP) is in extreme risk, followed by Nepal (ranking 18th in death toll, 19th in deaths per 100,000 inhabitants, and 39th in GDP loss), India (third in death toll and 47th in GDP loss) and Pakistan (11th in death toll and 76th in GDP loss)

to the impacts of global warming and climate change. This is due to its unique geographic location, dominance of floodplains, low elevation from the sea, high population density, high levels of poverty, and overwhelming dependence on nature for its resources and services.

In addition to loss of lives and effects on the population, natural disasters have damaged tens of thousands of houses and infrastructure (roads, railways, electricity, bridges, monuments etc.), and devastated large swathes of farmland; Fig. 10.3 provides a brief overview of such losses.

As shown in the figure, each year each of the four countries loses millions of dollars' worth of property. Among the four countries, Bangladesh has suffered most severely as a victim of natural disasters (ND). For example during the period 1991–95 it faced economic losses of more than USD 9.014 billion; in 1996–2000, USD 7.996 billion; in 2001–05, USD 15.599 billion, and in 2006 alone it faced economic losses of more than USD 3.390 billion. Of the remaining three countries, the impact of natural disasters has been most severe in India, followed by Nepal and Pakistan.

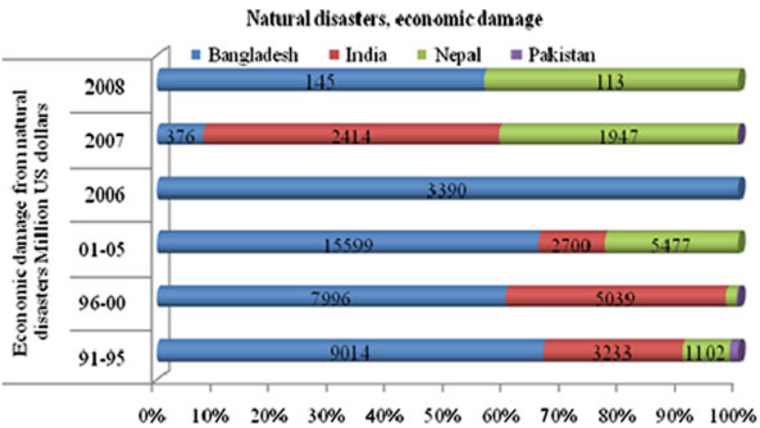


Fig. 10.3 Economic damage due to disasters (*Source* Data compiled from ESCAP 2010, pp. 221–223) *Note* Estimated economic damage (millions US dollars): the economic impact of a disaster usually consists of direct (e.g. damage to infrastructure, crops, housing) and indirect (e.g. loss of revenues, unemployment, market destabilisation) consequences on the local economy. For each disaster, the registered figure corresponds to the damage value at the moment of the event, i.e. the figures are shown true to the year of the event

With the realisation of these facts, the governments of the respective countries individually and collectively are aware of the severity of climate change impacts and have taken some initiatives for the mitigation of the impact (UNEP-DA 2008). However, these initiatives are not sufficient to address the issues due to a lack of expertise, infrastructure, technology, and economic resources, combined with uncontrolled population growth, extreme poverty and to some extent conflicts and violence, instability in the government and the low priority assigned to addressing the issue (Government of India 2010; Kelkar and Bhadwal 2008).

The Environmental Performance of India, Nepal, Bangladesh and Pakistan

The Environmental Performance measurement is one of the most commonly applied tools of country situational analysis, developed with the aim to shift environmental decision making to firmer analytic foundations using environmental indicators and statistics, such as those generated by Yale University's Center for International Earth Science Information Network, Yale Center for Environmental Law & Policy and Columbia University, USA, in collaboration with the World Economic Forum, Switzerland and the Joint Research Centre of the European Commission, Italy, which produces the Environmental Sustainability Index (ESI) and the Environmental Performance Index (EPI) annually. To evaluate the

Table 10.4 Selected countries of Asia and their ESI score in 2005 and 2010

Country	ESI rank (2005)	ESI score (2005)	ESI rank (2010)	ESI score (2010)
Nepal	85	47.7	38	68.2
India	101	45.2	123	48.3
Pakistan	131	39.9	125	48
Bangladesh	114	44.1	139	44

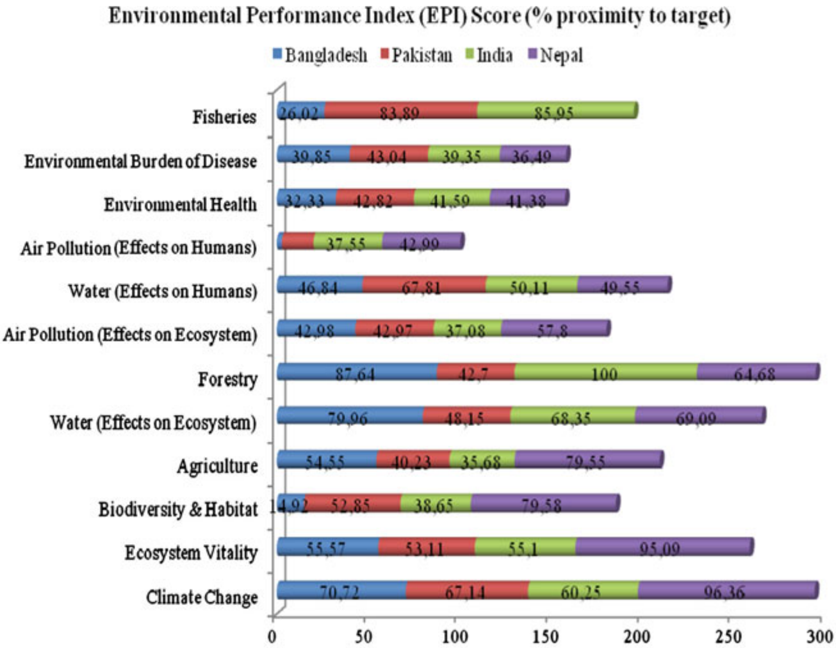
Note the ESI was measured in 10 major categories: (1) 32.1−38.3; (2) 38.4−44.4; (3) 44.5−50.5; (4) 50.6−56.7; (5) 56.8−62.8; (6) 62.9−68.9; (7) 69.0−75.1; (8) 75.2−81.2; (9) 81.3−87.3; and (10) 87.4−93.5 respectively [Scores are calculated for each of the ten core policy categories based on two to eight underlying indicators. Each underlying indicator represents a discrete data set (whereas category 1 shows the lowest and 10 is the highest performance indicator)]

Environmental Performance of India, Nepal, Bangladesh and Pakistan, the present research utilises data (in the public domain) from the 2005 and 2010 Environmental Sustainability Index (ESI) and Environmental Performance Index (EPI), respectively.

According to the ESI and EPI database, Nepal has been the best performing country among the four nations studied, followed by India, Pakistan and Bangladesh (Table 10.4):

The 2010 Environmental Performance Index (EPI) evaluated 163 countries on 25 performance indicators tracked across ten policy categories covering both environmental public health and ecosystem vitality. The ten categories are as follows: (1) Eenvironmental burden of disease; (2) Water resources for human health; (3) Air quality for Human health; (4) Air quality for ecosystems; (5) Water resources for ecosystems; (6) Biodiversity and habitat; (7) Forestry; (8) Fisheries; (9) Agriculture; and (10) Climate change. These indicators provide a gauge at a national government scale of how close countries are to established environmental policy goals. The EPI's proximity-to-target methodology facilitates cross-country comparisons as well as an analysis of how the global community is doing collectively on each particular policy issue. The overall EPI rankings provide an indicative sense of which countries are doing best against the array of environmental pressures that every nation faces. From a policy perspective, greater value derives from drilling down into the data to analyse performance by specific issue, policy category, peer group, and country. Such an analysis can assist in refining policy choices, understanding the determinants of environmental progress, and maximizing the return on governmental investments. More generally, the EPI provides a powerful tool for steering individual countries and the world toward environmental sustainability (copied from EPI 2010; 2005 data are drawn from Khan 2006 and World Economic Forum 2005).

The 2005 and 2010 EPIs show that Nepal has been the best performing country and Pakistan remains the lowest among the four in the present study. In Asia and the Pacific, New Zealand is the highest performing with a score of 73.4, followed by Japan with 72.5, Singapore with 69.6, and Nepal with a score of 68.2. Other



	Climate Change	Ecosyste m Vitality	Biodiver sity & Habitat	Agricult ure	Water (Effects on Ecosyste m)	Forestry	Air Pollution (Effects on Ecosyste m)	Water (Effects on Humans)	Air Pollution (Effects on Humans)	Environ mental Health	Environ mental Burden of Disease	Fisheries
Bangladesh	70,72	55,57	14,92	54,55	79,96	87,64	42,98	46,84	2,78	32,33	39,85	26,02
Pakistan	67,14	53,11	52,85	40,23	48,15	42,7	42,97	67,81	17,38	42,82	43,04	83,89
India	60,25	55,1	38,65	35,68	68,35	100	37,08	50,11	37,55	41,59	39,35	85,95
Nepal	96,36	95,09	79,58	79,55	69,09	64,68	57,8	49,55	42,99	41,38	36,49	

Fig. 10.4 Environmental performance index [Plotted from EPI 2010 (Environmental Performance Index)]

countries in this study are way below in EPI performance, i.e. India ranks 20th with score of 48.3, Pakistan ranks 21st with a score of 48.0, and Bangladesh ranks 24th with the score of 44.0. In terms of improvement, all four performed better in 2010 than 2005; however, Nepal has taken the highest jump in rank, from 85th to 38th (or 47.7–68.2 in score). Nonetheless, nations do not perform consistently across all categories. For example, in terms of climate change, ecosystem vitality, biodiversity & habitat, and agriculture, Nepal is the best performing country in the global context (see Fig. 10.4), whereas in environmental burden of disease and environmental health it is in the lowest categories. In forestry management, India is the best with a perfect score of 100 and is good in fisheries management with a score of 85.95 (EPI 2010). In contrast, Bangladesh, one of whose main sources of livelihood is fisheries, scores only 26.02, the worst in the world. Figure 10.4 below provides an overall picture of performance in the major categories listed above and the following table under the figure provides the details within sub groups.

Conclusion

The data above shows that environmental performance frequently contrasts with the governance performance. But why is this?

Firstly, environmental performance was evaluated on the basis of anthropogenic disturbances in the environment. For example, urban particulates, indoor air pollution, sulphur dioxide emissions, nitrogen oxide emissions, volatile organic compound emissions and ozone exceedance are the major environmental hazards created through anthropogenic activities and such activities occur only if there is any substantial growth in the economy.

The empirical evidence shows that economic growth is a function of governance performance as well as socio-economic competiveness; whereas governance is the sum of the many ways individuals and institutions, public and private, manage their common affairs. Governance is a continuing process through which conflicting or diverse interests may be accommodated and cooperative action may be taken. In terms of sustainable growth, countries can only be successful when the government is capable of exercising economic, political and administrative authority to manage affairs at all levels. As UNDP (1997) notes, governance comprises the mechanisms, processes and institutions through which citizens and groups articulate their interests, exercise their legal rights, meet their obligations and mediate their differences. To be successful on the six measures noted above, a government must apply effective and equitable participatory, transparent and accountable mechanisms to improve performance. For this to be possible, a government must promote the rule of law and focus equally on its three branches: economic, political and administrative (UNDP 1997, p. 13). In the case of Nepal all three branches are effectively wounded due to instability in the government, frequent violence, and a weak administrative system, but mostly due to institutionalised corruption, which has largely hampered its socio-economic growth.

Nepal's good environmental performance is due in part to its efforts to maintain the environment. However, it is at least equally—or more so—due to its lack of economic development and competiveness. As seen in the governance performance indices in the regional and the global context, Nepal ranks almost at the bottom as a "non-competitive power" country, because none of the governance functions are working properly. When a country lacks functional governance, the economic development process falters, industry cannot advance, and emissions into the atmosphere are minimised. Emerson et al. (2010, p. 31) have drawn similar conclusions, noting that undeveloped nations perform very poorly on environmental health indicators but well on climate change indicators due to their low greenhouse gas production per capita. Low income helps explain poor health infrastructure and limited fossil fuel based development, which perfectly fits with the Nepalese case: on climate change, Nepal scores the highest, with a 96.36 percentile rank, in contrast with health, where it scores only a 41.38 percentile rank (see Fig. 10.4).

Secondly, to some extent, when a country lacks capacity in building infrastructure, geography also hampers industrial development. Extensive and efficient infrastructure is critical for ensuring the effective functioning of the economy, as it is an important factor in determining the location of economic activity and the kinds of activities or sectors that can develop in a particular economy (World Economic Forum 2010). For example, in Nepal, the lowest elevation is 70 metres above sea level (Kanchan Kalan, Jhapa), ranging upward to 8,850 metres (Mount Everest); 76.9 % of the land surface is hillside (41.7 % land surface with only 12.9 % road networks) and mountain (35.2 % land surface with 1.4 % road network), and the remaining 23.1 % is formed by the Terai (plain) areas. Even in the Terai, the road network covers only 25 % (ADB 2010) of the region. One consequence is that overall only 39.39 % of households in Nepal are connected by the electricity grid, and have to suffer more than 12 load shedding events (power cuts) in dry seasons. The effect of these conditions is to limit potential industrial emissions. In addition to the biophysical situation, constant violence and instability are also barriers to the economic growth.

Good environmental performance in Nepal also is due to the concentration of efforts of other governments, international conservation organisations, donor agencies and civil society efforts to address environmental issues, in comparison to other countries of the region. With the support of these stakeholders, Nepal's government has undertaken environmentally sound initiatives, as noted in the policy categories of biodiversity and habitat conservation (score 79.58), whereas Bangladesh scores only 14.92, India 38.65 and Pakistan 52.85 (Fig. 10.4). In this context, Nepal holds a strong position because about 23 % of its total land surface is under a protected area system, which is the highest percentage in the region after Bhutan. Finally, Nepal has some good indicators in terms of human development. For example the Human Development Report (HDR) 2010 identified Nepal as one of the top ten performers in human development globally, especially in health and education, in the last 40 years. As HDR 2010 notes, "Nepal emerges as one of the world's fastest movers since 1970, coming in third out of the 135 countries studied. A child born today in Nepal can expect to live 25 years longer than a child born in 1970; more than four of every five children of school age in Nepal now attend primary school, compared to just one in five 40 years ago (…) This is perhaps surprising in light of Nepal's difficult circumstances and record of conflict

(…) But Nepal's impressive progress in health and education can be traced to both public policy efforts and substantial remittance inflows from emigrant workers over many years" (UNDP 2010, p. 1).

This does not mean that Nepal is capable of tackling its climate-change-induced challenges alone. As the UNEP-DA notes, to address environmental challenges in South Asia it is essential to focus on diverse response options and instruments for possible solutions. Emphasis must be placed on increasing responsibilities of all stakeholders and more cooperative efforts towards ensuring a healthy environment in the future. Increased awareness of ecosystems and new market-based systems will prove to be important mechanisms in dealing with environmental issues. To some extent, in Nepal the awareness of ecosystems has increased due to improvement in the education system, however, it remains far behind overall in managing its affairs successfully.

In terms of overall performance, Asian countries are still way behind the developed world. India's performance in the socio-economic sector is improving incrementally, but Nepal's position has slipped in the recent years. Similarly, Bangladesh and Pakistan's positions seem unimproved. Furthermore, among the four, Pakistan constantly has been facing intervention in governance by the military regime, including regional conflicts and trans-boundary tension. In the same way, Bangladesh has been the victim of the natural disasters, indirect militarisation and domestic power conflicts. In recent years, at least Pakistan and Bangladesh have stability in the government; however, Nepal is still in turmoil.

The above analysis clearly shows that, overall, the governance systems in South Asia are not able to cope with changing global competitiveness and are not able to progress significantly on indicators of good governance. Further investigation is needed to explore the causes and consequences of this situation.

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Author Biography

Medani P. Bhandari (a Nepali national) leads an active academic and professional life. He has earned several Master's degrees, achieved ABD status in 2009, and is finalising his PhD from Maxwell School, Syracuse University NY, USA. He is also currently a member of the United Nations Convention of Biological Diversity's Expert Group Meeting on Biodiversity for Poverty Eradication and Development. Having served extensively as a research and professional consultant, and having played a leading role in various international NGOs over the past 20 years, he has gained expertise in fields ranging from environmental, organisational and political sociology, international organisations, climate change, biodiversity conservation, global public/social policy and other areas related to sustainable development and environmental change. He is the author or co-author of numerous professional publications ranging from journal articles and research reports to books. He aims to cultivate a multidisciplinary knowledge-based network to minimise conflict over natural resources, catalyse action across the global community for a sustainable world by changing public attitudes on global climate change, increase public awareness of North–South differences and tensions, and analyse risk, policy, and behaviour. He can be reached by email (mbhandar@syr.edu) and by post (302 Maxwell Hall, Syracuse University, Syracuse, NY 13244, USA).

Chapter 11
Institutions Matter for Urban Resilience: The Institutional Challenges in Mainstreaming Climate Smart Disaster Risk Management in Bangladesh

Md. Zakir Hossain and Nazmul Huq

Abstract The core issues of this chapter are institutions, climate smart disaster risk management, adaptive capacity, and the institutional adaptation capacity. Our main focus is to review policies and strategies and institutional settings in order to identify institutional challenges to mainstream climate smart disaster risk reduction strategies in cities of Bangladesh. Therefore, the key contributions of this chapter are that we (a) identify possible entry points for mainstreaming climate smart risk management strategies, and (b) recognise some broad institutional constraints to address effectively climate change risks. Cities are at risk of the impacts of climate change on infrastructure, human lives, human health, and environmental quality. These effects will deepen in coming decades. Climate smart disaster risk management (CSDRM) approach can be considered as a holistic approach, because it provides guidelines to build adaptive capacities of local people and also local institutions. This chapter deals with some important core concepts such as institution, climate smart disaster risk management, adaptation capacity, and the institutional adaptation capacity. This chapter focuses particularly on the institutional challenges to mainstream climate smart strategies in cities of Bangladesh. For this, the chapter reviews policies, institutional settings, and legal frameworks underway in Bangladesh that respond to climate change, and discusses what currently constrains this. The review reveals that national as well as local level institutions in Bangladesh are already grappling with large deficits

Md. Z. Hossain (✉)
School of the Built Environment, Heriot-Watt University, Room 4.36, William Arrol Building, Riccarton, Edinburgh, EH14 4AS, UK
e-mail: zakir_urp9913@yahoo.com

N. Huq
Action Research on Community Adaptation in Bangladesh, Bangladesh Centre for Advanced Studies (BCAS), House 10, Road 16A, Gulshan-1, Dhaka, 1212, Bangladesh
e-mail: nhrussell@gmail.com

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which limit capacity of these institutions to mainstream climate smart risk reduction strategies.

Keywords Urban resilience · Climate Smart Disaster Risk Management · Institutions and institutional challenges

Introduction

The IPCC's report identifies that it is extremely likely that the poor countries in Africa, Asia, Latin America and the Caribbean are at risk from the impacts of climate change and extreme disasters (Satterthwaite and Moser 2008). Urban centres in developing countries, with concentrations of large populations, are particularly at risk (Sharma and Tomar 2010). Among the urban poor, the risks of natural disasters include earthquakes, floods, landslides, windstorms, volcanic eruptions, wild fires, water surges, and droughts (Wamsler 2007). Several underlying factors contribute to the vulnerability of the urban poor to climate change and variability, such as the lack of assets, substandard housing, poor waste management, lack of drainage facilities and sewerage systems (Wamsler 2007). While poverty reinforces people's vulnerability to climate change and extreme disasters, the poor communities regularly experience disproportionately high levels of social disruption and economic loss. In response to this vulnerability, we need comprehensive risk management strategies in order to boost resilience and to be able to cope with anticipated impacts of climate change and extreme natural disasters.

The link between climate change and disasters is now widely recognised in the process of building urban resilience to people's risks. The DFID 2006 white paper has recognised this and states that disaster risk reduction is a crucial part of adaptation, particularly for vulnerable communities in developing countries (Mitchell and van Aalst 2008; Mitchell et al. 2010). The Climate Smart Disaster Risk Management (CSDRM) approach integrates the policies and programming related to climate change adaptation and disaster risk management, which enhances adaptive capacities of cities in developing countries. Therefore, disaster risk management includes risk management strategies in face of non-climatic disasters, such as earthquakes, whereas adaptation addresses long-term impacts of climate change and especially climatic variability, such as loss of biodiversity, and poverty reduction (Mitchell and van Aalst 2008). Thus, we should focus on robust institutional processes for mainstreaming climate smart disaster risk management strategies.

Institutions are rules of the game in a society, or more formally, the humanly devised constraints that shape human action (North 1990). It is understood here that formal and informal structures of rules are consciously designed and voluntarily agreed between different actors. Both the formal and informal rules structure the roles, rights and responsibilities of different actors and, in turn, shape the social practices of different stakeholders in a society (Ostrom 2005). However, institutions and institutional processes are mentioned rarely in climate change literature (Dovers and Hezri 2010). The literature only proposes policies, but rarely discusses how those policies will be implemented within each local socio-environmental context. Implementation mainly depends on how institutions include “win–win” interventions, in order to mitigate the impacts of climate change and extreme disasters. Similarly, it also involves trade-offs, political conflict and redistribution of risks among the stakeholders (Lebel et al. 2011). Therefore, the efficacy of mainstreaming climate smart strategies actually depends on successful institutional performance within each local socio-cultural context. This is influenced by institutional structure and capacity. Problematic institutional structures and insufficient institutional capacities place strain on implementing policies effectively (Batterbury 2002). The chapter’s main focus is to examine the role of local institutions in mediating the adaptive capacities of the urban areas in response to the risks of climate change and extreme disasters.

The key contributions of this chapter are that we offer a conceptual framework that links several important core concepts, such as institution, climate smart disaster risk management, adaptation capacity, and the institutional adaptation capacity. Moreover, it presents the role of institutions in promoting adaptive capacities of the households and communities. Furthermore, we assess policies, institutional settings, legal frameworks in order to identify possible entry points for mainstreaming climate smart policies, strategies and programmes, and also recognise some institutional barriers that will limit the capacity of city governments, civil society and private businesses to address climate change risks.

This chapter is organised as follows: (1) “Climate Change Risks in Urban Areas”; (2) Then, “From Climate Change Risks to Urban Resilience” presents the concept of urban resilience and also presents how urban resilience links with climate smart disaster risk management; (3) “Conceptual Framework”—discusses institutions, climate smart disaster risk management, adaptation capacity, and the institutional adaptation capacity. (4) “Methodology”; (5) “Institutionalising Climate Smart Disaster Risk Management Strategies” reviews policies, the legal framework and institutional settings in Bangladesh, in order to find out possible entry points for mainstreaming climate smart disaster risk management. This section also presents some broad institutional barriers. (6) In closing the chapter, “Conclusion” highlights some policy issues to enhance or improve existing practices.

Climate Change Risks in Urban Areas

Bangladesh is at high risk of increased natural disasters, such as floods, cyclones, storm surges, flash floods, drought, tornadoes, earthquakes, riverbank erosion, and landslides. It is the geographical setting of this country makes the country vulnerable to those climatic events. Climate change and variability increase the frequency and intensity of natural disasters, heat waves and the increasing seasonality and vulnerability of Bangladesh. This scenario has already been noticed in various studies. According to the Germanwatch Long-Term Climate Risk Index (CRI) 2011, Bangladesh has been the most vulnerable country to extreme climate events during the period 1990–2009 (Harmeling 2011).

Urbanisation and urban primacy are the major features of contemporary urbanisation in the developing countries, and Bangladesh is no exception to this phenomenon. Its urban population already exceeds 40 million and is growing at 3.4 % per annum (Banks et al. 2011). While population growth is expected to stagnate or reduce, urban population growth will increase or continue at the same rate in upcoming years (ibid.). However, the urban centres in Bangladesh have experienced an uneven trend of urbanisation, with remarkable variations throughout the twentieth century. Of the total urban population in this country, nearly 50 % of the population concentrate in the four largest metropolitan cities (Dhaka, Chittagong, Khulna and Rajshahi), and this four-city primacy situation that has grinded has been monitored in every census (Islam 1999). Actually, global climate models, which are downscaled to Bangladesh, show the fact that many climate change impacts are likely in those four major urban areas (SMRC 2003; IPCC 2001). Among those four major urban centres, Dhaka, the capital of Bangladesh, is at high risk of climate change and climate variability. The IPCC has projected impacts on urban areas, of changes in extreme weather and climate events (UN-Habitat 2011). The Table 11.1 shows projected impacts on urban areas of changes in extreme weather and climate events.

Climate change has direct effects on the physical infrastructure of a city—its network of buildings, roads, drainage and energy systems—which, in turn, impacts on the welfare and livelihoods of its residents (UN-Habitat 2011). The increasing frequency and intensity of extreme climatic events and slow-onset changes will increase the vulnerability of urban economic assets and, subsequently, the cost of doing business (ibid.). The example of Dhaka shows that extreme events such as floods, drainage congestion and waterlogging due to excessive rainfall, cause very serious damage to such infrastructure as roads and railways, formal and informal housing and educational institutions (Alam and Rabbani 2007). In major flood events of 1988, 1998 and 2004, according to available literature, the eastern part of Dhaka was 100 % inundated and in the west of Dhaka, 75 % was submerged (ibid.). Consequently, both inter and intra-city bus links from eastern Dhaka were shut down because of inundation, and most small-, medium- and large-scale industries and factories were affected by floods. Both flooding and waterlogging, due to excessive rainfall, caused very serious damage in the trade and commercial sectors (ibid.). Furthermore, public utility organisations failed to manage the solid waste and sewerage network, and it was estimated that the total cost to repair and rehabilitate the damage of the sewerage system, after the 1998 flood, was more than USD 9 million. Another estimate calculates that the total damage to the water, sewerage, electricity, gas and telephone services, after the 1998 flood, was more than USD 20 million (ibid.).

Urban poverty persists at a high level in the big cities of Bangladesh and the situation will worsen in the upcoming years. In 2005, nearly 35 % of Bangladesh's

Table 11.1 Projected impacts on urban areas of changes in extreme weather and climate events

Climate phenomena	Likelihood	Major projected impacts
Fewer cold days and nights	Virtually certain	Reduced energy demand for heating
Warmer and more frequent hot days and nights over most land areas	Virtually certain	Increased demand for cooling
Warmer temperatures	Virtually certain	Reduced disruption to transport due to snow, and ice effects on winter tourism Changes in permafrost, damage to buildings and infrastructures
Warm spells/heat waves; frequency increases over most land areas	Very likely	Reduction in quality of life for people in warm areas without air conditioning; impacts on elderly, very young and poor, including significant loss of human life Increase in energy usage for air conditioning
Heavy precipitation events; frequency increases over most areas	Very likely	Disruption of settlements, commerce, transport and societies due to flooding Significant loss of human life and injuries; loss of, and damage to, property and infrastructure Potential for use of rainwater in hydropower generation increased in many areas
Areas affected by drought increase	Likely	Water shortages for households, industries and services Reduced hydropower generation potential Potential for population migration
Intense tropical cyclone activity increases	Likely	Disruption of settlements by flood and high winds Disruption of public water supply Significant loss of human life, injuries, loss of, damage to property Potential for population migration
Increased incidence of extremely high sea levels	Likely	Costs of coastal protection, costs of land-use relocation increases Decreased freshwater availability due to saltwater intrusion Significant loss of human life and injuries; loss of, and damage to, property and infrastructure Potential for movement of population

Source UN-Habitat (2011), p. 20

urban population lived in poor urban settlements in the six biggest urban centres in Bangladesh (Banks et al. 2011). They mainly live with multiple deprivations, such as food insecurities, inadequate asset bases, health stresses, the difficulties in getting proper health care and keeping children in school. These poor urban households are particularly vulnerable to the damaging effects of the erratic behaviour of present climatic and extreme events, such as floods, drought, and heat stress. Climate change and climate variability sharpen the damaging effects of extreme events for the urban poor. Climate change related disasters destroy livelihood assets and thereby directly affect urban livelihoods of the urban poor (UN-Habitat 2011). These include stocks of natural resources (natural capital), social relationships (socio-political capital), skills and health (human capital), infrastructure (physical capital) and financial resources (financial capital) (ibid.). For instance, floods hit nearly half of the total area of Dhaka City. Around 40 % of the population live in slums and squatter settlements; they are severely affected by floods, waterlogging and other relevant problems (Alam and Rabbani 2007). The study, during the 1998 flood, found that at least 7.2 % of people had changed their occupation, while 27.4 % were unemployed as a result of the flood (ibid.).

From Climate Change Risks to Urban Resilience

In response to climate risks in urban areas, urban resilience strategies should be adopted. Urban resilience is the capability of an urban centre or an urban system to resist a wide array of shocks and stresses, which are caused by climate change and extreme disasters (Leichenko 2011). Therefore, urban resilience is an outcome or a goal, which means the urban system and urban population, will bounce back as quickly as possible from climate-related shocks and stresses, through incorporating appropriate policies and strategies. While undergoing changes, the urban system will be able to retain the same functions, and will structure those functions in order to provide feedback for further intervention. In an urban system, resilience reduces urban risks and, through enhancing the adaptive capacity, this allows an actor to adapt to climatic risks. Therefore, it is a product of "planned" strategies undertaken in the light of shocks, such as climate-resistant building materials for the urban residents, and also of "spontaneous or premeditated" adjustments in response to stresses, such as access to health facilities for the poor, through subsidising cost (Pelling 2003, p. 48). It especially involves policies, programming and thinking around climate change adaptation ("adaptation") and disaster risk reduction (DRR) (Bahadur et al. 2010).

There is a significant overlap between the practice and theory of disaster risk reduction and climate change adaptation (IDS 2008). For example, both disciplines aim to lessen the impacts of climate change, and especially climate variability. The major convergence between the two disciplines is the management of hydro-meteorological (i.e. natural) hazards, whereby disaster risk management needs to take into account the immediate risks of environmental hazards, and adaptation will build an adaptive capacity to lessen the impacts of the frequency and intensity of hazards, such as heavy rainfall, drought, high sea levels, and possibly cyclones (Mitchell and van Aalst 2008). Moreover, the two key distinctions between the two disciplines are that disaster risk reduction considers, in addition, the risks of geophysical hazards (like volcanoes and earthquakes) along with natural hazards, such as floods, cyclones, etc. However, adaptation only tackles the impacts of natural hazards and looks at the long-term adjustment to changes in climatic condition, whereas disaster risk reduction focuses particularly on extreme events (Mitchell and van Aalst 2008).

However, there is limited coherence and convergence in institutions, organisations and policy frameworks (IDS 2008). Both these two disciplines are struggling to be incorporated into regular developmental planning (ibid.).

In 2010, a consortium led by the Institute of Development Studies, with Christian Aid and Plan International, launched the Strengthening Climate Resilience initiative with the aim of developing a new approach, by integrating climate change adaptation and disaster risk management for governmental and civil society organisations in developing countries, in order to build the resilience of communities to disasters and climate change (Polack 2011). A draft approach—Climate Smart Disaster Risk Management (CSDRM)—was developed through an extensive literature and expert reviews process (ibid.). It focuses on a climate smart development approach rather than a disaster-focused approach, because the DRM community has not been effective at looking at long-term timeframes or capacities to enhance people's ability to progress over longer terms (Mitchell et al. 2010). Adaptive capacity issues are at the centre of the Climate Smart Disaster Risk Management approach, whereas other frameworks have not yet been considered (ibid.).

Conceptual Framework

The conceptual framework is organised around several core concepts: institution, climate smart disaster risk management, adaptation capacity, and the institutional adaptation capacity. Our main focus is on studying the institutions and their role in facilitating the CSDRM, in order to build adaptive capacities.

Institutions are understood here as "regularised patterns of behaviour between individuals and groups in society" (Leach et al. 1999, p. 5), whereas organisations are defined as "the players, or groups of individuals bound together by some common purpose to achieve objectives" (North 1990 cited from Nunan 2006, p. 1319). Institutions are formal rules as well as informal rules, which mediate legitimate effective command over productive assets or resources (i.e. entitlement). In response to climate change and extreme disasters, institutions facilitate the building of the adaptive capacity of the urban residents. Institutions at multiple levels provide incentives to the local people in adapting to the impacts of climate change and extreme disasters (Young et al. 2005). Linking climate change adaptation and disaster risk management strategies at the local level, in the form of CSDRM, is influenced by the socio-environmental context of the local level. The local institutions are the most important component to change behaviour at this level, in order to enhance the adaptive capacity of the people.

Climate smart disaster risk management (CSDRM) provides a guide to strategic planning, programme development and policymaking, in order to assess the effectiveness of existing DRM policies, projects and programmes in the context of a changing climate (Polack 2011). The rationale for the CSDRM approach rests on the relationship between climate change and disaster risks (ibid.). Therefore, CSDRM is "an integrated social development and disaster risk management approach that aims simultaneously to tackle changing disaster risks, enhance adaptive capacity, address poverty, exposure, vulnerability and their structural causes and promote environmentally sustainable development in a changing climate" (Mitchell et al. 2010, p. 9). The approach has been built using three main pillars. The discussions of the three main pillars have been synthesised from Strengthening Climate Resilience Discussion Papers (Mitchell et al. 2010, pp. 9–10; Polack 2011).

Pillar One: Tackle Changing Disaster Risk and Uncertainties

Pillar one supports the priority areas of the Hyogo Framework of Action (HFA). It enhances the importance of collaboration between multiple actors. It conducts multiple risk assessments by using an improved information base. It also highlights the importance of providing access to information to all stakeholders through education, early warning and the media. The CSDRM approach treats climate change as a key consideration and attempts to insert climate change into the most critical, climate–sensitive development approach.

Pillar Two: Enhance Adaptive Capacity

Adaptive capacity refers to the ability to manage changes. In order to promote adaptive capacity, institutions and networks should learn and use knowledge and experience to create flexibility in decision-making processes. Promoting diversity, creating flexible, effective institutions, accepting non-equilibrium, adopting multi-level perspectives, integrating uncertainty, ensuring community involvement, promoting learning, advocating equity, recognising the importance of social values and structures and working towards preparedness, planning and readiness—these factors can be considered as key characteristics which enhance adaptive capacity. Enhancing adaptive capacity is a key strategy for people and organisations to respond to shocks and unexpected events more effectively.

Pillar Three: Address Poverty and Vulnerability and Their Structural Causes

CSDRM treats root causes, dynamic pressures, unsafe conditions and hazards as all contributing to disaster risk for the poor. Root causes underscore the importance of access to power, structures and resources.

The CSDRM approach recognises the complexities and interdependencies of each intervention (Mitchell et al. 2010). Thus, it enhances the interrelation of the three pillars. However, successful implementation of the CSDRM approach needs to consider institutional dynamics in the case of developing countries.

The institutions are not directly exposed to climate risk; thus, the adaptive capacity of an institution should be understood as the ability to perform functions that facilitate the adaptive capacity. We therefore defined the institutional adaptive capacity as the ability to adapt its institutions, in order to address a policy issue, such as climate change (Willems 2004).

Climate change and extreme disasters are multi-level problems, so the institution dealing with climate smart disaster risks is also multi-level. The linkage of multi-level institutions by the method of subsidies is very important in building adaptive capacities. The household and community receive the incentives from the policy designed by government and the driving forces from biophysical and socio-economic contexts (Li 2010). The local institutions will shape these outside forces and will organise the CSDRM, which will effect on the level and distribution of livelihoods and human behaviour (ibid.). These will also be the incentives when redesigning policies and institutions (ibid.).

Methodology

It is a desk review study involving different scholarly literatures. The review has been divided into two parts. The first part studies institution, climate smart disaster risk management, adaptation capacity, and the institutional adaptation capacity to build a conceptual framework showing the role of institutions to the adaptive capacities. For this, the chapter reviews journal articles, edited books, books and research reports. For the empirical part, we have reviewed the governance system of Bangladesh, institutional settings, climate change as well as development policies and strategies, in order to find out possible points for mainstreaming climate smart development policies. It is a matter of fact that the climate smart disaster risk management approach is very new, so it is necessary to identify the flaws which will be revisited at the time of implementation. For this, we study some experiences of climate change adaptation as well as disaster risk management programmes, in order to identify institutional challenges (Fig. 11.1).

Institutionalising Climate Smart Disaster Risk Management Strategies

The legal and institutional framework and the capacity of Bangladeshi cities to implement CSDRM strategies should be considered a great importance. It needs to identify some possible avenues for the implementation of CSDRM strategies.

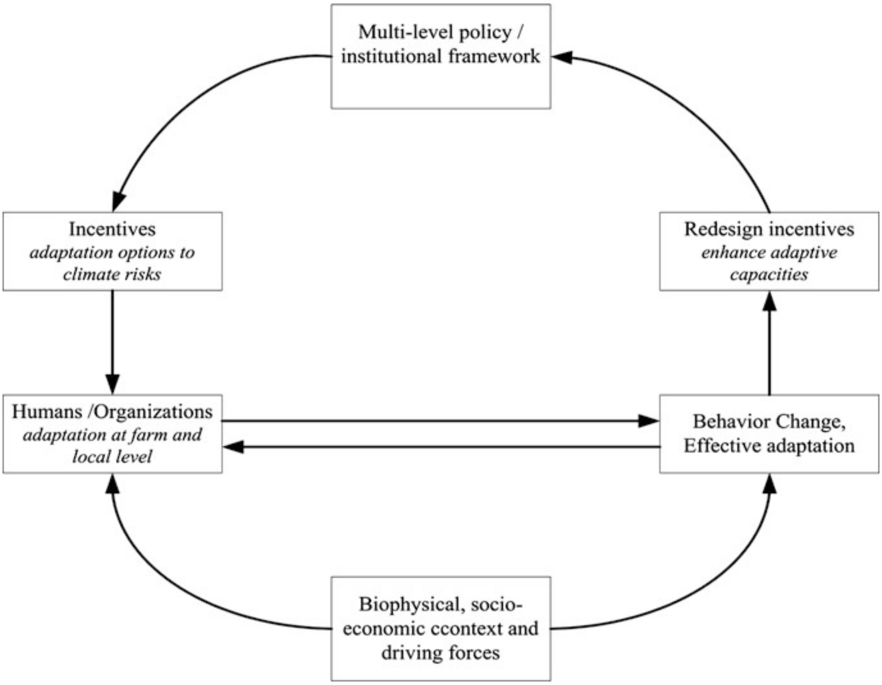

Fig. 11.1 The role of institutions in promoting adaptive capacities of the households and the communities. *Source* Li (2010), p. 3

State of City Governance: Decentralisation and Autonomy

The governance of Bangladeshi cities is structured around the Municipal City Corporations and the City Development Authorities, which constitute urban local bodies (Tanner et al. 2009). The concept of decentralisation in urban local government was introduced as a government strategy when the country became independent in 1971. The aim of introducing decentralisation at that time was to place popular representatives in charge of local government institutions, in order to periodically publicise local level planning. Forms of decentralisation in Bangladesh are administrative in the sense that, here, decentralisation is mainly implemented by diffusion and delegation, which are the two subforms of administrative decentralisation; it is also seen in the evolution of decentralisation in Bangladesh. Furthermore, diffusion involves spreading the decision-making authorities and financial and management responsibilities among different levels of the central government (Hossain 2005).

In urban Bangladesh, two types of local government exist: municipalities (pourasabhas) and city corporations. 309 pourasabhas are categorised into three groups, depending on the magnitude of revenue generated (Paul and Goel 2010). Six city corporations operate in Dhaka, Chittagong, Rajshahi, Khulna, Barisal and

Sylhet. These six city corporations comprise executive and administrative wings, of which only the executive wing is made up of elected representatives (Tanner et al. 2009). These municipalities and city corporations are responsible for a set of functions, which cover the key aspects of urban planning, service delivery and infrastructure development. Besides this, these municipal governments have the ability to make decisions and implement them across a range of responsibilities and services. This autonomy creates avenues for city government to build their own climate smart disaster risk management strategies by incorporating local perceptions and needs, in order to build adaptive capacities of local people.

In Bangladesh, urban development falls under the purview of the development authorities, which, in turn, delegate the responsibility of preparing an urban development plan (Master plan), as envisaged under the ordinance of each development authority (e.g. Khulna Development Authority Ordinance, 1984) and the Ministry of Public Works and Housing is the nodal agency for providing policy guidelines to the development authority, as well as financial support in priority areas. Each development authority has the legal authority to make a development plan and implement the plan. For example, Section 22 (1) of Khulna Development Authority Ordinance signifies the necessity of preparing a Master Plan and is approved by the government (KDA 2000). Section 22 (1) says that the authority shall "(…) prepare and submit it to the government for approval of a Master Plan for the Municipality and the areas in its vicinity indicating the manners in which it proposes that the land should be used (whether by carrying out thereon of development or otherwise) and the stages by which any such development should be carried out" (KDA 2000, p. 53). This also reveals that each development authority has the responsibility to coordinate the multiple sectoral institutions to implement a development plan. While institutionalising climate smart disaster risk management (CSDRM), it is important to coordinate the multiple sectoral institutions relevant to the CSDRM planning and implementing. Therefore, planning provisions of development authority ordinance can be considered as the important step in planning and implementing the CSDRM strategies.

Lack of financial capacity and control can be considered as one of the greatest struggles for municipal corporations in developing countries (Fernandes 2007). Big municipal corporations have some sort of capacity and financial autonomy. For example, Chittagong City Corporation raises 55–65 % of its revenues from its own sources (85 % come from taxes) and a further 35–45 % is channelled to the corporation through line ministries (Tanner et al. 2009). On the other hand, the Chittagong Development Authority (CDA) owns a huge number of plots of land, which provides its major source of income as well as renting markets and land transformation fees (ibid.). This financial autonomy of the Chittagong City Corporation and the Chittagong Development Authority suggests that institutionalising the CSDRM has possible avenues at local level, and it will require special attention to the partnerships of these two major institutions and other institutions related to the CSDRM planning and implementation.

Possible Nodal Points for Mainstreaming CSDRM in Bangladesh

In the light of the institutional structure and challenges, a few initiatives and institutions can be considered as the entry points for mainstreaming CSDRM strategies in Bangladesh.

Climate Change Policies and Strategies in Bangladesh

The climate change adaptation policies have made some progresses in Bangladesh. The government of Bangladesh has recognised climate change and extreme disasters as major impediments in achieving sustained economic growth. The climate change agenda has been recognised adequately in different policy documents whilst some attempts to incorporate potential response measures in response to climate change and variability have been made to the overall development planning process (Government of Bangladesh 2005). All political governments during the last 10 years in Bangladesh have shown sufficient commitment to formulate climate change policies. To this end, Bangladesh has already prepared quite a significant amount of climate change and disaster management policy documents such as climate change strategy, adaptation plans, environmental management plans and also established a Comprehensive Disaster Management Programme (CDMP) with donor assistance, which embedded a goal of launching an integrated approach to climate change and disaster management (Ayers and Huq 2009). A list of national efforts by the Bangladesh government to address climate change and extreme disasters are given in Table 11.2.

National Steering Committee on Climate Change

The Government of Bangladesh recognises the need to strengthen the institutions, in order to respond effectively to the enormous challenges of climate change (MoEF 2008). A National Steering Committee on Climate Change has been established to coordinate and facilitate national actions on climate change. It links to the secretaries of all climate-affected ministries and divisions, as well as representatives of civil society and the business community (ibid.). It also provides guidance on international climate change negotiations, including bilateral, multilateral and regional programmes for collaboration, research, exchange of information and development (ibid.). A Climate Change Secretariat will be set up in the Ministry of Environment and Forests, in order to support the National Steering Committee on Climate Change. It will work with climate change cells in all ministries. This structure will be considered as the entry point to facilitate

Table 11.2 National efforts to address climate change and extreme disasters

Name	Key areas and institutional arrangements
National Environmental Management Action Plan (NEMAP)	The government has developed the National Environment Management Action Plan (NEMAP) in 1996 and has prioritised 57 actions on the environmental front. The Department of Environment (DoE) under the Ministry of Environment and Forest (MoEF) is responsible to take necessary steps for ensuring compliance to environmental protection
Sustainable Environment Management Programme (SEMP)	The Sustainable Environment Management Programme (SEMP) had 26 projects (components) to enhance environmental management in Bangladesh. The Ministry of Environment and Forest (MoEF) was the lead public institution and those projects were designed to be implemented by 22 government and non-government agencies. The SEMP was successful in mainstreaming mitigation in the national policy discourse
Bangladesh National Capacity Self-Assessment (NCSA) for Global Environmental Management	The overall goal of NCSA is to identify priority capacity needs of Bangladesh in order to effectively address crosscutting global environmental issues. The Ministry of Environment and Forest (MoEF) is responsible for the execution of these plans
National Adaptation Plan of Action (NAPA), 2005	Bangladesh has completed a NAPA, which has been submitted to the United Nations Framework Convention on Climate Change (UNFCC) in 2005. A list of key areas of this policy document are: Forestry, Bio-diversity and Land-use, Agriculture, Fisheries and Livestock, Water, Coastal Areas, Natural Disasters and Health, Livelihood, Gender, Local Governance and Food security, Industry and Infrastructure, Institutional and Policy issues. The policy document has critically evaluated different sectors and proposed 15 specific projects. This plan links mitigation and adaptation strategies for Bangladesh; however, it specifically focuses on mitigation measures. The Ministry of Environment and Forest (MoEF) is the focal point and Department of Environment (DoE) will be the lead public organisation. The projects will be implemented by 15 different public organisations and the DoE will coordinate with other implementing organisations and supervise their activities.

(continued)

Table 11.2 (continued)

Name	Key areas and institutional arrangements
Bangladesh Climate Change Strategy and Action Plan 2009	The vision of the Government of Bangladesh (GoB) is to eradicate poverty and achieve economic and social well-being for all people through implementing a pro-poor climate change strategy. This policy document prioritise climate change adaptation, disaster risk management and mitigation measures. Climate change strategy has built on six pillars: (a) Food security, social protection and health, (b) comprehensive disaster management, (c) infrastructure, (d) Research and knowledge development, (e) Mitigation and low carbon development and (f) capacity building and intuitional strengthening. Under these six pillars 44 programmes have been listed. The Ministry of Environment and Forest (MOEF) is the focal point and one Climate Change Cell under this ministry has been developed by the GOB for coordination and management of the programmes. The Climate Change Focal Points in all ministries have been constructed to plan and implement programme activities within their remit
National Strategy for Accelerated Poverty Reduction (NSAPR), 2009–2011	In Bangladesh, the PRSP for the 2009–2011 period is known as the National Strategy for Accelerated Poverty Reduction (NSAPR). It is major development policy framework of this country. It describes the macro-economic, structural and social policies and programmes that a country will pursue over several years to promote broad-based growth and to reduce poverty. The NSAPR identifies climate change strategies as the pillars of the Bangladesh poverty reduction strategy. This policy document prioritises 18 strategies to address climate change, environmental management and extreme disasters. The PRSP has designed a broader institutional framework to implement each of the strategies and actions, e.g. one strategy is to improve the living environment of the urban poor. Here, it prioritises the Ministry of Environment and Forest (MOEF) as a lead responsible organisation and associate responsibilities are performed by relevant ministry with that action, CBOs, NGOs, city corporations, municipal authorities and media

(continued)

Table 11.2 (continued)

Name	Key areas and institutional arrangements
Comprehensive Disaster Management (CDMP)	Bangladesh established a Comprehensive Disaster Management Programme (CDMP) in 2003 with assistance of multi-donors such as UNDP, DFID, European Commission and Sida. It is an appropriate mechanism to address convergence of climate change and disaster risk management. It translates the hard science of climate change into tangible and community level actions. Key priorities are: collaborative partnerships with regional, local and national organisations, reforming existing policies, acts, rules and regulation regarding disaster management, mainstreaming disaster risk management into development policy framework, capacity building of disaster management committees, local community empowerment, urban risk reduction, climate change database development and modelling and emergency response and information management. The host organisation is the Ministry of Food and Disaster Management, with the support of a technical management team from UNDP

Source Ayers and Huq (2009), General Economics Division (2008), Government of Bangladesh (2005), MoEF (2008)

institutionalising climate smart disaster risk management strategies at city level in Bangladesh.

Challenges and Issues Involved in Institutionalising Climate Smart Disaster Risk Management at City Level in Bangladesh

Having discussed the possible entry points for institutionalising CSDRM strategies in the municipalities and city corporations of Bangladesh, it reveals that a stronger, much clearer institutional structure needs to be considered by the policy-makers, donors and local level implementers. They need to address institutional challenges in order to tighten the possible entry points for institutionalising CSDRM effectively at local level:

- *constraints relating to understanding emerging scientific information about climate change hazards and their impact on cities* (Fünfgeld 2010, p. 156; Sharma and Tomar 2010, p. 461).

In the context of climate change, the analysis of the impacts of climate change involves different analyses, such as the type of climate hazards, their spatial extent, and the expected frequency and intensity of impacts on urban areas. However, city authorities need to accommodate immanent changes to hazard exposure, rather than focus only on historical data, local experiences and institutional memory. The changes to hazard exposure caused by geographic shifts of climate hazards, emerging global hazards, such as sea level rises, pose qualitatively new challenges for urban planning and development, due to the changing levels of intensity and frequency of existing events. Therefore, the biggest impediment is the lack of understanding of the changes to hazard exposure. Without considering this, it is impossible to build adaptive capacity of the city population in Bangladesh.

- *city government has limitations regarding the understanding of how broader socio-economic processes influence urban vulnerabilities* (Fünfgeld 2010, pp. 156–157).
  The changes in hazard exposure, the sufferings of city dwellers and city governments are increasing. The case studies of the implementation of different adaptation programmes in various parts of the world confirm that climate change risk in cities is constituted, to a significant extent, by the vulnerability of urban populations. Broader socio-economic trends, such as global population growth, urban poverty, migration, decreasing food security and rapid urbanisation, need to be considered in the planning and implementation of the CSDRM. These factors particularly underpin the inability of many governments to provide adequate protection from natural hazards. In turn, it leads to increased vulnerability for some groups. Therefore, broader socio-economic processes should be addressed, in order to improve city governments' understanding of urban vulnerability.
- *constraints regarding integrating information about hazard exposure and vulnerability into local planning processes and development agendas* (Fünfgeld, 2010, pp. 156, 158; Roberts 2010, p. 408).
  At city government level, climate smart development strategies need to consider knowledge about changes in hazard exposure and climate change vulnerability, and should incorporate existing risk management policy and practice, land-use planning, as well as political agendas and development priorities. The case study of institutionalising climate change in the city administration of Durban, South Africa, showed that broad engagement with current climate change science was considered essential. It is very important for the transfer of climate smart development or a disaster management approach into planning and decision-making practice. Therefore, incorporation of climate change knowledge is the highest priority or high institutional challenge, which needs to be addressed when implementing a climate resilient development approach at local level.
- *limitations in administrative competences and fragmentation can be considered as institutional challenges* (Heinrichs et al. 2011, p. 221).
  The institutional settings related to service delivery are complex, and services are delivered by a mix of central government as well as local government

institutions. They have been operating with insufficient institutional capacity, limited resources and a lack of coordination. Firstly, we map out the institutional arrangements in urban local governments in Bangladesh. Then, we assess the existing institutional structure, in order to identify the factors which constrain or enable the adaptive capacity of the poor.

In response to climate change and extreme disasters, the Government of Bangladesh focuses more attention on central government institutions. The Ministry of Environment and Forests (MoEF) is the focal ministry for implementing all programmes or projects on climate change, and the Department of Environment (DoE) is the responsible organisation under the ministry. For disaster management, the government follows a completely different institutional framework. The Ministry of Food and Disaster Management (MoFDM) is responsible for disaster management and planning, and the Disaster Management Bureau is the apex organisation which is responsible for coordinating national level disaster interventions across all agencies. There are also 35 other ministries, which are responsible for the activities of climate change and disaster management.

The evidence shows that central government institutions are fragmented and uncoordinated. Both bureaucratic competition and separatism can lead to fragmentation and lack of coordination of central government institutions (Lebel et al. 2011). Bureaucratic competition and institutional incapacities have disrupted disaster management interventions, and the new policy on climate change is also hampered by separatism and the institutional gaps of central government public institutions (Lebel et al. 2011). Competition amongst the actors leads to poor coordination amongst actors, as well as institutional incapacities and gaps in service provisions (Lebel et al. 2011). However, local level institutions play an important role in implementing climate change and disaster risk management interventions at the local level.

At the urban local government level, central government institutions are responsible for delivering different basic services, such as education, health, judiciary, policing, land registration, etc. A fair number of urban local government institutions have been operating in the big cities of Bangladesh, such as city corporations and development authorities. Urban local institutions in the metropolitan cities (Dhaka, Khulna, Chittagong and Rajshahi) are also fragmented and uncoordinated, similar to central government institutions. For example, while RAJUK—the development authority in Dhaka City—has planning and management responsibilities, it has not maintained its strategic planning functions. Its primary function is now new land development and planning. In a similar way, other urban institutions in Dhaka City have been diverted from their functions and all those institutions are competing with one another to gain power at the local level. Another reason for fragmentation and insufficiently coordinated efforts is that there is no strategic policy leadership or lead institution at the metropolitan level. Other institutions may take initiatives without referencing RAJUK. Similar to central government institutions in Bangladesh, urban local institutions have institutional incapacities and gaps, which disrupt service provisions. The current fragmented institutional structure is one of the major struggles for central government as well as local government, in order to plan and implement climate smart disaster risk management strategies, as these strategies involve a large number of national level as well as local level institutions.

- *lack of transparency and autonomy within urban local governments in Bangladesh* (Tanner et al. 2009, p. 29).
  The climate smart urban development relies on a municipal system that maintains a relationship of accountability to its citizens. This is open in terms of financial management, information on the use of funds, and adherence to legal and administrative policies. There is lacking of adequate financial transparency in all city governments. In turn, this kind of institutional structure will encourage rent-seeking behaviour among local level implementers, while implementing climate smart urban development strategies. Therefore, we need to attempt to drive dramatic improvements in the capacity of citizens, in order to hold their elected representatives accountable.
- *anti-urban poor development policies in Bangladesh*
  A review of those milestones (as shown in Table 11.2) reveals that none of the priority actions or programmes in two major climate change policy documents (such as NAPA, 2005, and Climate Change Strategies and Acton Plan, 2008) target the problems faced by the urban poor. This means that the government maintains a rural focused policy continuum. However, Bangladesh has been showing a significant awareness in making climate change adaptation policies, and has created a National Adaptation Programme of Action (NAPA); the priority actions identified have not been implemented. In contrast to the failure of the implementation of NAPA, Bangladesh has responded to the call from the Copenhagen Summit for a new policy document (i.e. Climate Change Strategy and Action Plan) to get the attention of the donor community. The review reveals that all climate change policy documents recommended costly projects, rather than building and expanding on the current initiatives and community level adaptations (Banks et al. 2011). The lure of international finance particularly motivates the policy makers to identify the costly projects (ibid.).
  Nonetheless, whilst there is a demand to increase the resilience of urban infrastructure, the NAPA only recognised one urban infrastructure project. This does not have any direct or indirect link to the urban poor. Other policy documents, such as the Climate Change Strategy and Action Plan, outline some infrastructure projects that do not have any clear link to the urban poor. It outlines 18 urban infrastructure projects under two thematic areas, which will improve the drainage and infrastructure of the urban areas in Bangladesh. However, the infrastructure development reduces the expenditure provisions of the urban poor and also increases the threat of evictions.
  The neglect of urban poverty is also visible in the PRSP of Bangladesh. Banks (2008) identifies a rural bias in governmental policy and programmes for poverty reduction. Empirical evidence identifies three main obstacles in the way of more effective urban policy making: a rural bias in Bangladesh's PRSP; a lack

of coordination among relevant departments and ministries; and a common resignation that urban poverty reduction is impossible (ibid.). The initial draft of the PRSP totally neglected the agenda of urban poverty reduction. Indeed, urban poverty reduction policies were added into the final draft, which are very minimal, in the face of high demands. The climate change agenda has been incorporated into the PRSP policies and strategies, as a measure to initiate climate change mainstreaming into current development planning practices. One strategy, as mentioned in the PRSP, is to improve the living conditions of urban slum dwellers. However, the programme has not made any progress in the last 2 years. The Annual Development Programme (ADP) in the last 2 years (2009–2010 and 2011–2012) did not mobilise any financial resources for that programme.

The urban poor in Bangladesh experience a "double-whammy" of neglect (Banks et al. 2011, p. 17). They are neglected both by national policy on poverty (e.g. PRSP) and also by national policy on climate change (e.g. NAPA and CCSAP). This confirms that poor urban households have little adaptive capacity with which to cope with shocks resulting from climate change and extreme disasters. The climate change policies produce disincentives for the urban poor that constrain building their adaptive capacity to urban vulnerability.

- *constraints to achieve pro-poor governance*

  The municipal governments in Bangladesh are constrained by a number of factors (Tanner et al. 2009, p. 20):

1. Municipal boundaries often do not include areas where the poor reside;
2. City governments are often not responsible for many public services including land allocation, housing, water and other public services;
3. Legal restrictions may prevent municipal governments from being able to act, for example, by not being able to supply those populations which do not pay property taxes;
4. Weak managerial and technical capacities at the local government level;
5. Lack of financial resources in order to increase service provision and build infrastructure. This is often exacerbated by international donors and development banks who reinforce the power of national governments and pay little attention to governance and needs at the local or municipal level;
6. Lack of financial management capabilities and low financial incentives for staff resulting in corruption.

It is a question of how city governments or public institutions in Bangladesh address the urban poor people's vulnerability to climate change and climate variability. Without recovering from those constraints, it is not possible for city governments in Bangladesh to achieve institutional capacity to implement climate smart strategies.

Conclusion

Institutional mainstreaming of climate smart disaster risk management is an essential milestone in adapting to climate change and extreme disasters in the cities of Bangladesh. In this, the chapter explores the nodal points of institutionalising climate smart disaster risk management, and also identifies some institutional constraints, which withstand the institutional mainstreaming processes in the cities of Bangladesh. The review reveals that climate change adaptation is growing in prominence in the national policy discourse. However, current policy discourses as well as practices in Bangladesh are insufficient and particularly problematic in the case of institutional mainstreaming of climate smart disaster risk management. The case study identifies different institutional constraints that will limit the capacity of city governments, communities, civil societies and private businesses to adequately address climate change and extreme disaster risks.

The climate smart disaster risk management framework for cities requires the initiation of an integrated intervention that includes urban development and growth coupled with environmental safety and sustainability. This will mean re-directing development interventions and their investments towards climate change adaptation and disaster risk reduction planning. Therefore, the integrated interventions call for a link between different levels of institutional intervention. However, this is not an easy task. Urban local governments in Bangladesh are neither the best equipped nor are they efficient entities. In addition, they often lack the necessary capacity to provide basic services in their jurisdiction. Thus, it is necessary to incorporate some of the adaptive and risk reduction actions into municipal functions. It has some brighter sides: (a) it reduces the implementation cost; (b) it provides some co-benefits, for instance, it allows for development that considers climate smart development strategies and also environmental aspects, which is sustainable in the long run; (c) it offers some environmental benefits such as reduced air pollution, restored water bodies and land use planning.

There is a strong need to understand what climate smart development planning entails and how its components are in line with the development priorities of the municipalities in Bangladesh. It is necessary to mainstream climate risk assessments and climate scenario-based planning across sectors of the city government and in the development of projects, as this helps to build resilience. After this, the city governments often fail to ensure benefits for all city residents, especially for the poor. For this, accountability mechanisms in city planning and the participation of city residents in planning processes need to be ensured that make the city's capacity to implement meaningful and pro-poor climate smart disaster risk reduction programmes. National government should come forward and motivate city governments into undertaking climate smart development strategies. Thus, the national government can launch some intensive training and capacity building programmes in order to sensitise municipal officials to the issues and impacts related to climate change and extreme disasters. The city government would be given instructions of how they could involve them and also other actors to implement climate smart development priorities in the cities of Bangladesh. External donors can be included in this process by providing technical support as well as funding at city level. Additionally, it is essential to involve the research institutes/universities for outsourcing research to understand the impacts of climate change and also evaluate the effectiveness of different climate smart development actions in responding to current and future climate risks.

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Author Biographies

Md. Zakir Hossain is Lecturer in Urban and Rural Planning, researching poverty, inequality, and social development, with a particular interest in climate change adaptation. Previous professional experience included working as a research assistant at the Transparency International Bangladesh work in a multidisciplinary team working with Corruption, Governance and Development and also working as a development worker in a national NGO in Bangladesh. He completed his first degree at Khulna University in Urban and Rural Planning and he did his Master's at the Institute of Development Policy and Management (IDPM), University of Antwerp with distinction in Governance and Development. Since 2011, he has been working for a PhD at Heriot-Watt University in Edinburgh. He is working on institutionalising pro-poor urban adaptation to climate change in his PhD.

Nazmul Huq has a Master's in Advanced Studies in Human Ecology and a BA in Urban and Rural Planning. He is a senior researcher at the Bangladesh Centre for Advanced Studies, the leading environmental think-tank in Bangladesh. His major research focuses are community based adaptation to climate change, social dimensions of climate change, development cooperation & climate change adaptation and green economy. He can be reached at nazmulhuqrussell@gmail.com.

Chapter 12
Management of Climate Change and Disaster Risk: The Malaysian Perspective

Ching Tiong Tan and Joy Jacqueline Pereira

Abstract Interactions between the climate change and disaster management communities in Malaysia have brought about significant progress in recent years. With the anticipation of increasing and changing nature of disaster risks due to climate change, the need for a holistic and integrated approach to climate and disaster management is recognised at the policy and institutional levels. As the top–down initiatives are progressing, local level studies, including case-specific research areas are being pursued to provide bottom-up inputs in laying adaptation roadmaps for national and sector-specific responses to mainstream climatic hazards. Future bridging of the climate change and disaster management communities in the country through the institutional and research platforms would require addressing several issues. Considering the uncertainty within climate projection, examining the biophysical sensitivity under exposure of projected future climates may be inadequate in gaining insight into their current adaptive capacity, and whether such adaptability will transform or facilitate actual adaptation in the future. As more adaptation initiatives will be implemented in the future, it is important to ensure adaptive capacity is drawn upon and translated into action by identifying and removing barriers to ensure successful adaptation. The provision of appropriate and easily understood information regarding vulnerable areas in the future will aid local stakeholders in making decisions that could incorporate elements of climate change adaptation and disaster risk reduction.

C. T. Tan · J. J. Pereira (✉)
Southeast Asia Disaster Prevention Research Institute (SEADPRI-UKM), Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia
e-mail: joy@ukm.my

C. T. Tan
e-mail: tanct@ukm.mytctiong@gmail.com

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Introduction

Climate change is any change in the climate over time that directly and indirectly affects humans and their activities as well as natural systems and processes (NRE 2010). It is a process that influences all hydrometeorological hazards (Pereira et al. 2010). While the outcome is unknown, it is expected to intensify the hazards that affect human livelihoods, settlements and infrastructure as well as weaken the resilience of livelihood systems in the face of increasing uncertainty and frequent disasters (Masika 2002; O'Brein 2006). A holistic and integrated approach is therefore crucial in managing the risks of climate change and disasters. Although the relationship between climate hazards and disaster risks is increasingly being recognised, the interaction between the national agencies on climate change and disaster management is still limited in Malaysia. While this is attributable, to a certain extent, to the economic situation in recent years that has intensified competing financial requirements for different agendas, it is also still acknowledged that the implications of climate change for disaster management are still uncertain, and efforts to integrate disaster risk reduction and climate change adaptation are still at their initial stage. This chapter aims to provide an insight into the challenges of managing the risks and of promoting resilience to climate change and disasters in Malaysia.

Risks of Disasters and Climate Change

Globally, there is an increasing trend of loss of lives and monetary loss due to hydrometeorological disasters over the past decade. Population growth and urbanisation have contributed to increased vulnerability and exposure to hazards. In Malaysia, the most common hydrometeorological disaster is flooding. Compared to other disasters, floods have affected the greatest number of people over the last century. Floods generally occur during the high rainfall seasons, affecting major rivers, particularly on the east coast of Peninsular Malaysia. Recent major flooding events include those impacting the southern parts of Peninsular Malaysia between the end of December 2006 and early January 2007, as well as those that took place nationwide in late 2010 and early 2011. Besides the loss of lives and displacement of thousands of people, the country also incurs a large expenditure on response measures particularly for the rescue, transfer and relocation of victims, rehabilitation of infrastructure and subsequent long-term recovery efforts.

Malaysia's climate shows similar trends that have been encountered globally. The average temperature in the country has been increasing since the middle of the last century (MOSTE 2000). The prognosis at the national level is mixed with models yielding projections that are variable. Localised climate modelling projected that the country may become warmer by the middle and end of the twenty-first century (NAHRIM 2006), that there would be a substantial increase in monthly rainfall over the north east coastal region of Peninsular Malaysia, and a decrease in monthly rainfall on the west coast may also be expected. Simulated future river flows of several watersheds on the east coast of the peninsula have shown increases in hydrologic extremes when compared with their historical levels. By the end of the century, a more significant change in the annual rainfall may be expected in the western regions of Sabah and Sarawak. Higher rainfall and extreme flows increase the risks of floods in both the presently affected (in terms of consequences) and unaffected areas (in terms of likelihood), which could result in the failure of water control structures including dams, barrages and bunds (NRE 2010).

Insights into the potential implications of future climate scenarios on several key economic and resource sectors were first gained during the preparation of Malaysia's Initial National Communication (MOSTE 2000) and later the Second National Communication (NRE 2010). Every 1 °C temperature rise may cause a 10 % reduction in rice yields and prolonged drought conditions may adversely affect the current flooded rice ecosystem, putting national food security at greater risk (MOSTE 2000). The oil palm plantation may be negatively affected in two possible scenarios: rising temperatures that cause droughts, or increased rainfall that leads to flooding (Ramadasan et al. 2001). The increase in flood intensity and frequency would incur additional costs in water resources management due to the need to adjust future flood mitigation plans as well as the existing flood mitigation schemes and drainage systems (Low and Ahmad Jamaluddin 2001). The rise in sea levels will lead to tidal inundation, shoreline erosion, increased wave action and saline intrusion, which in turn will lead to the submergence of corals, loss of fisheries resources, plantation lands, mangrove forests, and a possible relocation of coastal infrastructure (Lee and Teh 2001).

Policy Scenario and Institutional Arrangement

Climate Change

Further to the ratification of the United Nations Framework Convention on Climate Change (UNFCCC) in 1994, Malaysia established the National Steering Committee on Climate Change (NSCCC) for guiding national responses on climate change. Over the years, interests on climate change remained limited at project level, including national communication and clean development mechanism (CDM) activities. A survey conducted in 1998, during the preparation of Malaysia's Initial National Communication, found that the awareness of the general public on climate change was low, with some ordinary Malaysians not even being aware of the existence or functions of the UNFCCC (MOSTE 2000).

However, politicians and government officials are more aware of the issue, given their participation in the negotiation process. With growing concern about the impacts of climate change, especially after the several extreme weather events and natural disasters in the last 5 years, a greater need for adaptation was also recognised.

The increasing importance of climate change at the national level is reflected in the formulation of the National Policy on Climate Change (NRE 2010). The policy is broader and holistic, promoting balanced adaptation and mitigation to achieve climate resilient development. It encompasses principles, strategic thrusts and key actions on climate change mitigation and adaptation including elements of disaster risk reduction, which provide a framework for concerted actions to steer the nation towards sustainability. Its implementation is coordinated and facilitated through the National Green Technology and Climate Change Council, which was established in 2010 and chaired by the Prime Minister of Malaysia. The Council is supported by several Working Committees to address issues in industry, transportation, human resources, research, communication, urban development as well as adaptation.

Disaster Risk Reduction

Malaysia adopted the Hyogo Framework for Action (HFA) in 2005. The National Security Council in the Prime Minister's department is the national focal point to the HFA and coordinates its implementation within the country. There are several existing mechanisms that support disaster mitigation and management in Malaysia (Pereira et al. 2010). The National Security Council's Directive No. 20 on "Policy and Mechanism on National Disaster and Relief Management", issued on 11 May 1997, guides disaster management in Malaysia. The Directive is complemented by other sectoral legislation in forming a comprehensive framework. It prescribes the management mechanism according to the level and complexity of disasters and determines the roles and responsibilities of various agencies to ensure effective coordination and mobilisation of resources when handling disasters. Many government agencies are responsible for different aspects of disaster management while maintaining their core responsibilities (Pereira et al. 2010). For example, the Malaysian Meteorological Department provides information and early warnings on adverse weather, sea, and seismicity conditions as well as for tsunamis. The Department of Drainage and Irrigation oversees aspects related to flood mitigation, including monitoring of river flows and local rainfall. Relief and rehabilitation come under the purview of the Social and Welfare Department, while search and rescue is conducted by the Special Malaysia Disaster Assistance and Rescue Team (SMART).

Disaster risk reduction is a priority for the Malaysian Government in view of the severity of its potential impact on lives and livelihoods as well as on the development of the nation. The country has been adopting several strategies to advance progress in mainstreaming DRR. Disaster planning and prevention is integrated into the overall national development plans and projects for sustainable development, in collaboration with the district and state disaster management committees and authorities in the development, testing and implementation of the overall emergency response plans. There are also several non-government and civil society organisations that work closely with the National Security Council focusing on disaster relief including search and rescue operations. Existing laws and policies are sectoral in nature and the need for comprehensive legislation and law enforcement to minimise disaster impacts and encourage preventive measures has been acknowledged by the government.

Interactions in the Management of Climate Change and Disaster Risk

The national policy on climate change seeks to mainstream climate resilient development into national, state and local levels of government. Climate-resilient development is defined in the policy as "development that takes into account measures to address climate change and extreme weather in line with national priorities" (NRE 2010). The broadened definition enables the policy to serve as an instrument to harmonise and integrate developments to the furthest extent possible in line with national priorities, measures on climate change adaptation, mitigation and disaster risk reduction.

In order to effect mainstreaming of climate change adaptation and disaster risk reduction in the country, there has to be a formal link created between the custodians of both these issues in order to facilitate routine interaction. There should also be coordination and clarification of roles and responsibilities. Interactions between the national focal points of climate change and disaster management in Malaysia used to be on an ad hoc basis (Pereira et al. 2010). Such gaps are being filled through different policy and institutional mechanisms. The synergies created from such interactions are expected to facilitate informed planning on climate change adaptation and disaster risk reduction at the national level, which could then be channelled to state and local levels. From the climate change perspective, this has been facilitated through the Working Committee on Adaptation, established in early 2011, within the National Green Technology and Climate Change Council. The Working Committee is anchored by the National Focal Point on climate change, i.e. Ministry of Natural Resources and Environment. The National Security Council, which is the coordinating agency for disaster management, is the member in the Working Committee which provides leadership on disaster risk reduction in the country.

The Melaka Declaration on Disaster Risk Reduction in Malaysia 2011 is a testament to the increasing awareness of climate change among disaster risk reduction practitioners in Malaysia. The declaration makes a call to galvanise the establishment of a national platform and comprehensive legal framework for disaster management in Malaysia with other stakeholders. In addition, the declaration also makes a call to support implementation of the national policy on climate change through appropriate actions on disaster risk reduction.

Establishing a national platform for disaster management would facilitate stakeholder engagement to address the gaps and enhance implementation of climate change adaptation and disaster risk reduction activities in the country. The benefits of the platform are manifold and include among others advocating disaster risk reduction at different levels, increasing levels of knowledge and skills related to disaster risk reduction, acting as a catalyst for national consultations and consensus building, and coordinating, analysing and advising on areas that require concerted action (Pereira et al. 2010). Furthermore, the platform will consider hazards and disasters in a more holistic manner, especially cascading hazards that would increase with the onset of climate change and if left unchecked, could increase the risk of further disasters.

Towards Successful Integration of Climate Change Adaptation and Disaster Risk Reduction

Improving Adaptive Capacity of the Present Day

While the level of confidence in the global and localised climate models is increasing progressively, there is a need to begin addressing adaptation through the enhancement of the present adaptive capacity to cope with and respond to stressors, and to defend security of livelihoods. Addressing present day vulnerability will reduce vulnerability under future climate conditions (Burton et al. 2002). However, current initiatives on climate change adaptation mainly consider vulnerability as the end point of a sequence of analyses beginning with projections of future emission trends, moving on to the development of climate scenarios, thence to biophysical impact studies and the identification of adaptive options (Kelly and Adger 2000; MOSTE 2000; NRE 2010). It has been pointed out the limited consideration for the capacity of the water sector in Malaysia, at both its current and future ability, to cope with future climate change as the proposed adaptation responses may not have been driven directly towards enhancing adaptive capacity to climate change. Considering the uncertainty within climate projection, examining the biophysical sensitivity under exposure of projected future climates may be inadequate to gain insight into their current adaptive capacity and whether such adaptability will transform or facilitate actual adaptation in the future. As more adaptation initiatives will be implemented in the future, it is important to ensure adaptive capacity is drawn upon and translated into action, by identifying and removing barriers, to ensure successful adaptation (Arnell et al. 2001; Adger and Barnett 2009). Future research on adaptive capacity in the pursuance of climate change adaptation in Malaysia should examine a range of carefully selected factors, which are generally context specific, to ensure the country's capacity for coping in the present day could be adapted to address future climatic and disaster risks.

Tackling Institutional Challenges

Climate change responses to date have been implemented in a disjointed manner with emphasis on mitigation and mainly at the federal government level. Actions to balance adaptation and mitigation will now have to be implemented at all levels. This will be a very challenging task at the state and local levels because land, forests, water and other resources come under the purview of the state government. State governments and local authorities are generally constrained by limited knowledge, capacity and resources. Urban areas under the management of local authorities pose the biggest challenge as many are unaware not only of climate change issues, but also of existing hazards that may undermine development in the short term.

If climate change adaptation measures are to be efficient and effective they must build on and expand existing disaster risk reduction efforts. Similarly, sustainability of disaster risk reduction approaches will be affected without considering the impacts of climate change. The disaster management community has a long history of dealing with disaster events, and therefore such experience with disaster risk reduction should be capitalised on for climate change adaptation (O'Brien et al. 2006). Institutional measures typically associated with addressing disaster risk reduction can be optimised to reduce long-term vulnerability and to influence development potential. The Intergovernmental Panel on Climate Change (IPCC) special report on "Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation" (SREX), which is due for release in December 2011, is expected to provide policy guidance in this respect.

Enhancing Spatial Planning

Engineering approaches, such as the flood mitigation projects in urban areas, are the most common way to address hazards in the country. Although such projects have served to lessen impacts of flooding events, they cover limited parts of the cities and the cost effectiveness of such measures is being increasingly questioned. Calls have been made to identify new approaches to integrate climate and disaster risks, particularly into local development planning.

The provision of appropriate and easily understood information regarding vulnerable areas in the future will aid local authorities in making decisions regarding applications for planning permission. Terrain assessment can support planning tools to incorporate elements of climate change adaptation and disaster risk reduction (Pereira et al. 2006; Halimaton et al. 2007) and ensure land use that supports the aspirations of climate resilient development. In order for terrain assessment to be more relevant, the current information on susceptibility, which represents the intrinsic weakness of a system, has to be expanded to include potential interaction with climate related stressors (Pereira and Ng 2010). The priority should be to identify highly susceptible areas. Based on this initial screening, socio-economic dimensions such as exposure, coping capacities and adaptive capacities have to be assessed. This is not currently done by any organisation in the country.

Generating Policy Relevant Knowledge

The current contribution of science in the implementation of policies to facilitate good governance is generally not very encouraging (Pereira and Komoo 2003). Knowledge generation to bridge the science-governance interface requires integrative scholarship involving multidisciplinary, interdisciplinary and transdisciplinary approaches (Nordin 2004). Climate change adaptation and disaster risk reduction requires such integrative scholarship to generate and apply science for informed decision-making in governance (Pereira et al. 2010). There are many pressing issues in climate change adaptation and disaster risk reduction that should be the focus research questions. Such areas need to be identified particularly if they are host to human settlements. Many developed countries are investing in research activities to identify areas that are susceptible to such risks in the event of flooding due to increased precipitation. The findings of such work will form the basis for their national adaptation action plan to prepare for the impacts of climate change. Malaysia should embark on a similar path. In addition, systems must be developed to identify, monitor, provide early warning and take measures to reduce risk of disasters upon the onset of climate change. In order to have these systems in place, gaps in scientific knowledge need to be addressed jointly by both researchers and practitioners (Fig. 12.1).

Currently, the government has initiated research on adaptation measures in several sectors. Unfortunately, at present there has been no study linking climatic hazards and climate change adaptation. Such a study would be critical as any impact on human settlements and infrastructure may not only cause loss of life, but could also have the potential to trigger a national crisis if economic and civil activities are disrupted. The goal of such a study should be to enhance the resilience of vulnerable communities in Malaysia to present and future hazards. This requires an integrated approach to hazards and risk management under different climatic regimes, and the establishment of a vulnerability assessment methodology and development of early warning systems taking into account social, cultural, ethical, political, economic and legal considerations. The availability of various technologies for adaptation and disaster risk reduction to promote human well-being and security should also be looked into.

In view of the need to encourage knowledge-based decision making in support of climate resilient growth strategies, the government is galvanising the

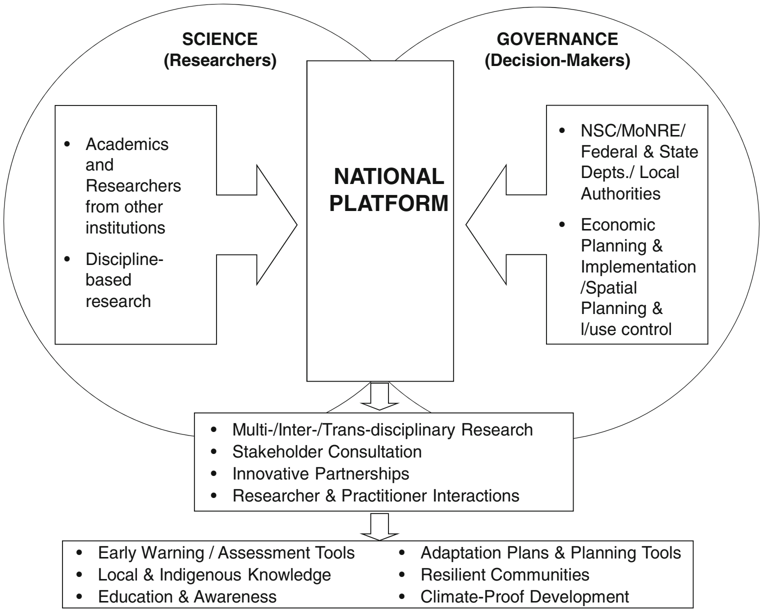

Fig. 12.1 Conceptual framework of the national platform to link climate change adaptation and disaster risk reduction (*Source* Pereira et al. 2010)

institutional arrangements for driving and coordinating policy-science linkages and initiatives. In early 2011, the Working Committee on Adaptation was established under the National Council on Green Technology and Climate Change. With several key disaster risk reduction players in the government and research institutions as key main members in the working committee, relevant disaster risk reduction elements will be promoted and are expected to be integrated while pursuing an R&D agenda on climate change adaptation enhances the understanding of costs and benefits associated with adaptation responses. On the other hand, a national platform on disaster management will be established to improve the effectiveness in multi-stakeholder mobilisation and drive more proactive and comprehensive multi-hazard approaches in identifying, preventing, mitigating and preparing for disaster risks (National Security Council 2011).

Strengthening Local Level Initiatives

A number of constructive initiatives for integrating climate change adaptation and disaster risk reduction have been undertaken at the local level. For example, cities such as Putrajaya and Kuala Lumpur take into consideration planning response and emergency preparation for hazards such as floods and fires. Both cities received recognition by being nominated as the three "Role Model Cities" in the national level campaign on "Resilient Cities: My City is Getting Ready" to inspire its emulation by other local authorities in the country. Notwithstanding that recognition, the capacity to integrate multi-hazards including climate and disaster risks into development planning still needs to be reinforced. The implementation and enforcement of laws, policies and guidelines that promote DRR at the local level are still inadequate despite the numerous provisions that are available in the country (JKR 2011; JPBD 2011). Therefore, the competence and aptitude of most local authorities in adapting and exercising DRR have to be enhanced.

Research in collaboration with local level institutions will be crucial towards improving the ability to integrate climate and disaster risks into local development planning. Fundamental issues on disaster risk reduction and climate change adaptation that need to be addressed surround the potential impacts and vulnerabilities associated with climatic hazards at the local level. New approaches and multi-stakeholder partnerships need to be mobilised to address interventions for adaptation as part of the disaster risk reduction process. This is important as the intensity of disasters associated with climate variability is anticipated to increase in the near future. The framework in Fig. 12.1 provides the possible direct and indirect opportunities for strengthening local level initiatives. Local stakeholders may play active roles as decision-makers to directly interact with the research community or provide input and sharing indigenous knowledge during consultation processes and through partnerships formed.

Concluding Remarks

The onset of climate change and its effects on disaster risks are inevitable but difficult to project precisely. Unless there is serious intervention to reduce vulnerability and build resilience in a changing climate, the socio-political consequences and increases in economic costs of hazards and disasters are unavoidable. A strong and effective institutional basis is critical to ensure successful adaptation to climate change and reduction in disaster risk at different authority levels in Malaysia. While consensus on climate projections for the country is underway, careful consideration should be given to any proposed measures in order to avoid maladaptation. Interactions and synergies in managing climate change and disaster risks should be enhanced when implementing the national policy on climate change and Melaka declaration on disaster risk reduction in Malaysia 2011, as well as in developing a national platform and comprehensive legal framework for disaster management in Malaysia.

The country must prepare to adapt to living in a changing climate, particularly at the local level where the impacts are faced directly and specific actions are most needed. Impacts of climate change will vary spatially; adaptation measures will thus need to be developed accordingly and implemented at the appropriate level. The ability to implement and enforce laws, policies and guidelines that promote disaster risk reduction at the local level has to be reinforced. The provision of appropriate information regarding vulnerable areas will also serve to strengthen spatial planning at the local level. The existing terrain mapping programme will have to be expanded to take into account climate related stressors and other factors that affect vulnerability. The capacity of local authorities needs to be improved to institute multi-stakeholder partnerships and to encourage community-based actions that will subsequently improve resilience.

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Author Biographies

Tan Ching Tiong is Research Officer at the South East Asia Disaster Prevention Research Institute (SEADPRI-UKM) and a PhD candidate at the Institute for Environment and Development (LESTARI), UKM. Tan supports the Climatic Hazards Programme in SEADPRI-UKM in conducting research on climate change adaptation and disaster management targeted at regional, national and local levels. He also provides technical support to the national focal points on climate change and disaster management in international negotiations and conferences.

Joy Jacqueline Pereira is Professor and Deputy Director of SEADPRI-UKM as well as Principal Fellow at LESTARI-UKM. She helms research activities on climatic hazards and chairs the Malaysian Network for Research on Climate, Environment and Development (MyCLIMATE). She is one of the coordinating lead authors of Chap. 24 ("Asia") in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report, as well as review editor of Chap. 7 of the IPCC special report on "Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation".

Chapter 13
Mitigating the Impacts of Climate Change on Disaster Risks Through Soil Ecosystem Services

Marcela C. Pagano

Abstract Global change will cause marked climatic alterations on a local scale; however, it remains intensely debated and new insights into their impacts on soil biota are needed. Responses of soil ecosystem to climate change can also have a substantial impact on the carbon (C) cycle (soils are estimated to contain more than double the amount of C than in vegetation). Biodiversity and ecosystem functions are influenced by climate change and species ranges are shifting. Predictions for the agricultural land area (mainly for food, fibre and fuel) showed increases by 23 (cropland) and 16 % (pastures). The ecosystem services of soils are often not recognised and the impact of agriculture e.g. on soil structure (essential for facilitating water infiltration, success of sustainable agriculture, and preventing erosion) is an issue urgent to study. As biodiversity in all biomes is sensitive to global changes in environment and land use, as well as to mitigate the problems of climate change, ecosystem services of soils which are under high mismanagement and declining soil fertility (that have allowed water pollution in urban river basins) must be taken into account and more widely discussed. Communities living near waterways extensively modify riparian zones (important for reducing floods) and, in order to alleviate the problems of climate change taking into account biodiversity in riparian systems, changes in land use must be controlled. This chapter addresses this issue by drawing on soil properties, soil biota and on current thinking regarding ecosystem services, in order to attain a better understanding of ecosystems and disaster risk, especially in Brazil. For this purpose, a case study in the south-eastern region of Brazil has been analysed.

M. C. Pagano (✉)
Department of Zootechny, Federal University of São João del Rei, Av. Visconde do Rio Preto, s/n° Colônia do Bengo, 36301-360 São João del Rei, MG, Brazil
e-mail: pagano@netuno.lcc.ufmg.br

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Keywords Climate change · Tropical ecosystem services · Soil quality · Disaster · Floods

Introduction

It is probable that climate change (resulting from rising greenhouse gas emissions) results in increasing temperatures and changing rainfall patterns that can cause natural hazards such as hurricanes and other disasters (Schipper and Pelling 2006). To mitigate the problems of climate change, modifications in the agricultural matrix are necessary in order to achieve more sustainable production such as in agroecology (Souza et al. 2009). There is growing evidence that biodiversity and ecosystem functions are influenced by climate change and that species ranges are shifting (Parmesan and Yohe 2003). This is also the case for agrosystems, which depend on non-renewable energy and monocultures (technologies with environmental and social problems) (Souza et al. 2009). It is known that agrosystems are managed by people mainly for food, fibre and fuel and that predictions for the agricultural land area showed increases by 23 (cropland) and 16 % (pastures) (Tilman et al. 2001). Therefore, agriculture must take into account soil biota biodiversity in agroecosystems within an ecological framework, to benefit from ecosystem services of soils (Table 13.1) which are often not recognised and certainly not well understood.

Ecosystem services recognise the benefits people obtain from them and can be categorised in provisioning services (e.g. food and timber), regulating services (e.g. climate and flood regulation), cultural services (e.g. recreation), and supporting services (e.g. soil formation and nutrient cycling), which are necessary for the production of all other services (Millenium Ecosystem Assessment 2003). It is known that management policies rely on scientific information. Thus, it is essential to include the ecosystem services of soils in the information for decision-making and environmental policies (see Dominati et al. 2010) relating to disaster risk management for example.

Ecosystem Services of Soils

Among the ecosystem services of soils, the biological control of pests and diseases (Dominati et al. 2010) and nutrient cycling (Quijas et al. 2010) are the most known. Soils can support symbiotic plants (mycorrhizae, *rhizobium*) and control the proliferation of pests and damnific disease vectors by providing habitat to beneficial species. These services depends on soil properties, soil conditions (e.g. moisture and temperature) and on the biological processes driving species interactions (symbiosis, competition), as well as on the ecosystem management (tillage) which selects the type of organisms present (Dominati et al. 2010; Pagano

Table 13.1 Database survey conducted in September 2011 (SCOPUS) for journal articles dealing with ecosystem services, soil, mycorrhizas and climate change/disaster risk

Keywords	Number of journal articles
Ecosystem services	6,979
Ecosystem services + soil	958
Ecosystem services + climatic change	130
Ecosystem services + soil + climatic change	34
Ecosystem services + soil quality	227
Ecosystem services + AMF	5
Ecosystem services + soil quality + AMF	1
Ecosystem services + AMF + climatic change/disaster risk	0

AMF arbuscular mycorrhizal fungi

2011). With regard to mycorrhizal fungi, it is known that they respond to disturbances, while other organisms do not (Baar 2010; Pagano et al. 2011a). Moreover, arbuscular mycorrhizal fungi (AMF) are necessary for the sustainable management of agricultural ecosystems and soil health (For a review see Gianinazzi et al. 2010) as well as for the restoration of soil ecosystem services (Turnau and Haselwandter 2002).

Studies have revealed that soil carbon (C) plays a major role in soil structure, increasing soil fertility. Moreover, soil aggregation resulted from decomposition products such as polysaccharides and especially from the role of the AMF mycelium (for more exhaustive reviews, see Rillig 2004; Pagano et al. 2011b), which produce a very stable hydrophobic glycoprotein, glomalin. Soil aggregation enhances infiltration, soil water retention, porosity, and aeration, which promote microbial activity and plant growth, providing a service to the cropping system (Swinton et al. 2007). Additionally, the form of recycled organic matter (composting of recycled plant residues) used for cropping systems affects ecosystem services (nutrient cycling), for example, clover green manure without composting can inhibit the AMF benefit (Kahiluoto et al. 2009). Therefore, special attention should be paid in particular to AMF, whose form symbioses with most plants including most agricultural crops (Smith and Read 2008), enhancing the uptake of nutrients such as phosphorus (P) and nitrogen (N). These soil fungi are present in all terrestrial biomes, generally found in soils with low water availability, low nutrients or polluted soils, but also associate with some aquatic plants. Urban ecosystems such as streams contribute to the quality of urban life (Bolund and Hunhammar 1999); however, their degradation has resulted in polluted environments, especially in South America.

As changes occurring above ground (in the atmosphere) will affect microbial biodiversity below ground, AMF are increasingly of interest for the restoration of degraded lands and conservation of natural ecosystems; however, studies on how global changes affect plant community structure and soil symbionts along different ecosystems are scarce (Table 13.1). This is due to the fact that the microbial populations involved in soil functioning, and particularly the contribution of microbial diversity in ecosystem processes, are difficult to measure. Nevertheless,

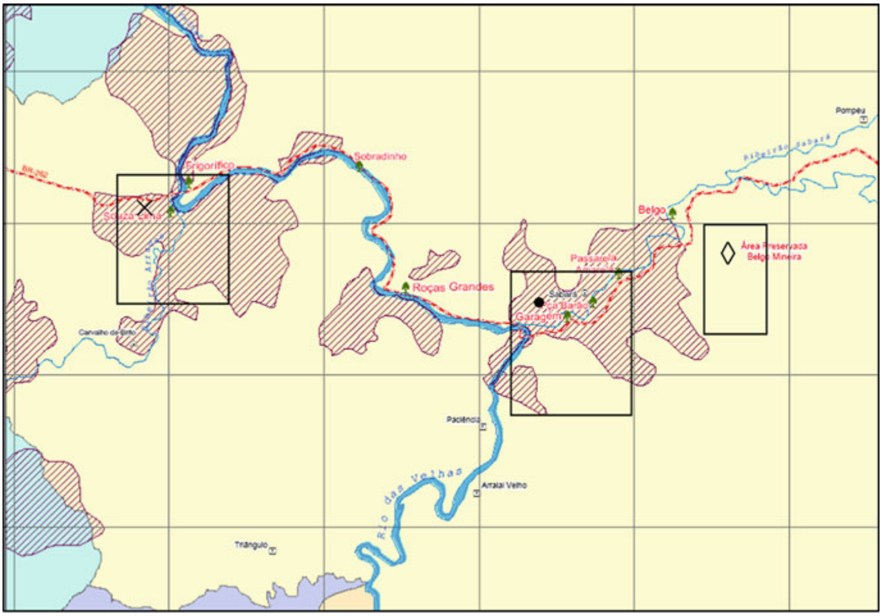

Fig. 13.1 Studied riparian sites.◇ = Preserved site, • = Sabará River and × = Velhas River

recent reviews (Bellgard and Williams 2011) focused on AMF and climatic change mentioned the ecosystem services. It is known that AMF can be affected indirectly by altered C allocation from the host (e.g. atmospheric changes, against which soil serves as a buffer); however, AMF can be directly affected by warming or altered precipitation (Rillig et al. 2002).

Case Study: Riparian Restoration

In the State of Minas Gerais, at the transition between Atlantic Coastal Forest and Cerrado savannahs, Brazil, Pagano et al. (2007, 2008a, b, c, d, 2009) and Marques et al. (2008) have been working with riparian forest (RF) in the Velhas River basin (Fig. 13.1) to improve their restoration within an ecological framework to help prevent flood disasters.

The case study considered here showed (see below) that all plant species (mostly leguminous trees) presented symbioses with AMF.

In one of the experimental areas (Sabará River), also rich in leguminous trees (Fig. 13.2), the treatments tested were: 1 = AMF inoculum, and 2 = AMF inoculum plus phosphate rock (both treatments consisted of reduced chemical fertilisation and organic matter addition). Treatments were replicated three times in a randomised complete block design. Plot size was 10 × 15 m, with 2 × 2.5 m spacing (Fig. 13.2).

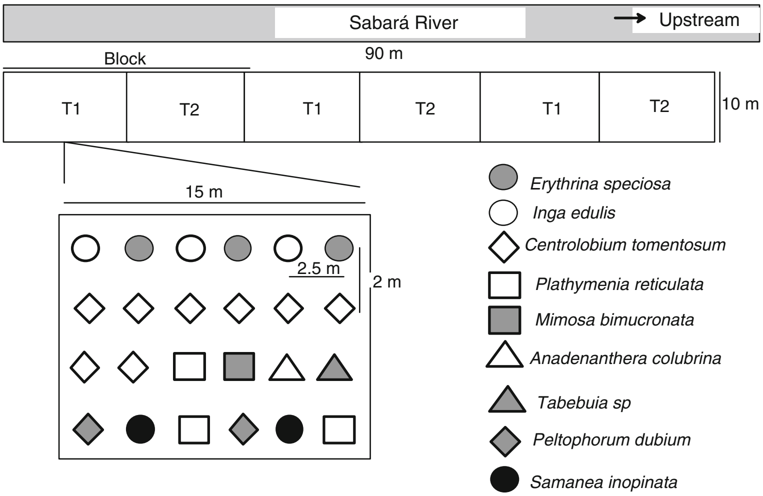

Fig. 13.2 Model of revegetation in Sabará River Brazil

The objective was to develop ecosystems with minimal dependence on high agrochemical and energy inputs outside the area; therefore, biodiversity and occurrence of symbioses are vital. These systems are essential for reducing floods (RF act as sponges, which decrease the severity of floods and maintains stream flows during dry periods), playing an important role in the movement of water and pollutants to surface-water bodies and groundwater, thus decreasing land erosion by water (Shultz et al. 2004).

In 2006, the experiments of reforestation on degraded riparian lands were started (results were presented mostly in conferences). The growth of native tree species used in these systems, their symbioses and associated soil properties (Marques et al. 2008; Pagano et al. 2007, 2008a, b, c, d, 2009) and the AM root colonisation (AMC) and species richness (SR) were estimated over 2 years. Glomalin was extracted from 1 g soil samples with citrate buffers using the methods of Wright and Uphadyaya (1996, 1998). Extracts were autoclaved at 121 °C for 60 min, then centrifuged to remove soil particles. Protein in the supernatant was determined by the Bradford dye binding assay using bovine serum albumin as the standard, and denoted as easily extractable Bradford-reactive soil protein. Soil aggregate stability was determined following the procedure described by Lax et al. (1994) that measures the percentage of soil aggregates between 0.5 and 2 mm that remains stable after being submitted to a simulated rainfall of 150 ml.

As the spontaneous regeneration of RF is insufficient to meet the increasing human impact, management protocols to accelerate their restoration using AMF inoculation of seedlings were accomplished. More than eight species of native trees were planted in the riparian systems, such as *Centrolobium tomentosum*, *Anadenanthera colubrina*, *Erythrina speciosa*, *Inga edulis*, *Mimosa bimucronata,* and *Peltophorum dubium* (leguminous trees), *Samanea inopinata*, and *Croton urucurana* (non-legume trees).

The average temperature in the region varied between 22 and 23 °C (tropical Aw) and the natural vegetation cover was a transition between Atlantic Forest and the Cerrado (Rizzini 1997). Rainfall was unimodal, most coming between November and March (more than 400 mm per month), followed by a prolonged dry season without or with few precipitations between May and August (Pampulha Meteorological Station, Belo Horizonte, Minas Gerais State, INMET). Therefore, the riparian zone is frequently flooded in the wet period, which can be increased with climate change, unless we test revegetation models. Considering trees (reforestation) in the riparian zones, the flooded zone can then decrease. The impact changes from natural sites to polluted sites, were reflected by a decrease in native tree cover vegetation and increasing herbaceous cover including exotic vegetation (most grasses) (Pagano and Cabello 2011), and also by frequent wildfires (crown fire) in the dry season, such as the fire that occurred in Velhas River riparian site in October 2007.

The riparian vegetation of Sabará and Velhas Rivers (São Francisco River basin) in Brazil, have been used for cattle and agriculture practices and have long been negatively influenced by human activities. Unfortunately however, there is no ideal extension for RF (it depends on site characteristics and the benefits expected from the buffer zone) (Klapproth and Johnson 2009). Moreover, in despite of designation for permanent preservation according to Brazilian law, the riparian habitats often have reduced plant cover compared with pristine rivers.

The long-term treatment of vegetation is the simplest solution for land restoration, allowing natural or artificial succession (Bradshaw 1987); however, AMF inoculation improved the chances of plant survival. In this regard these fungi, present in the RF (Pagano et al. 2010), play a role in element sequestration by AMF in different conditions of disturbance.

Riparian systems with diversified native trees increased the soil biodiversity and soil properties, and therefore also, the environmental services. This can be seen in the high similarity of AMF species (Table 13.2) found between the preserved site (upstream) and the Sabará stream (middle stream) followed by the Velhas River site (downstream) (Fig. 13.1). Low AMF diversity was found in the degraded sites studied along rivers, and the highest density of different species was found in the preserved area (Gaia stream). For example, few species of *Scutellospora* and none of the *Gigaspora* were found in the degraded sites, thus contrasting with the preserved site. Results from these studies demonstrate that native trees and herbaceous species Asteraceae, Malvaceae and Poaceae favoured different AMF species richness, and soil that disturbance (cattle, human impact) decrease AMF species diversity, which in turn decreases the soil environmental services.

Soil pH is the most sensitive quality indices for agricultural soils, since the use of amendments and waste waters may affect its value (Bastida et al. 2008). Due to the fact that plants shows different tolerances of drought or waterlogging, and soil pH affects the viability of plants as well as influencing the nutrient supply (Haynes and Naidu 1998), soil pH correction must be accomplished so as not to impede the

Table 13.2 Similarity in AMF soil communities among different riparian sites in Brazil

Riparian sites	Similarity
Sabará River—Gaia stream	0.37
Velhas River—Gaia stream	0.33
Velhas River—Sabará river	0.28
Degraded—Gaia stream	0.16

Gaia stream preserved riparian forest (upstream), *Degraded* zone of grasses, *Sabará River* reforested tree cover, *Velhas River* reforested tree cover in steep vertical stream bank of ≥2 m (downstream), *Similarity* similarity index based on AMF communities

Table 13.3 Soil properties, soil aggregates and AM colonisation in riparian ecosystems from Brazil

Ecosystem	Soil pH[a]	SOM[a]	C[a]	M[a]	Sand[b] (%)	Clay[b]	AS[a] (%)	G[a]	AMC	SR
RF (undisturbed)	4.9	5.74	3.32	30.2	53	37	88.8	1.55	66.21	8
Urban[c] RF	6.7	0.99	0.57	10.6	65	15.6	52.8	0.66	48.30	7

[a] Mean of two measures from one composite sample; pH (H_2O) 1:1
[b] Particle size distribution = sand 2–0.02 mm and clay < 0.002 mm
[c] Mean of data from Sabará and Velhas Rivers
RF riparian forest, *SOM* soil organic matter (%), *C* carbon (%), *M* soil macroporosity, *AS* aggregate stability (%), *G* Glomalin content (mg/g soil), *AMC* arbuscular mycorrhizal colonisation (%), *SR* species richness. *References* Pagano and Scotti (2008), Pagano et al. (2009), Pagano and Cabello (2011)

growth of native species from Brazilian Cerrado, which occurs naturally in acidic soils (Haridasan 2000). In riparian sites from Minas Gerais, soil pH decreased to 6.5 after 18 months, but this value was higher than those of adjacent preserved riparian forest fragments (pH 4.9, Table 13.3), which reflects their higher soil organic matter content, considered to be a key attribute of soil quality (Schoenholtz et al. 2000).

The restoration of riparian sites from Minas Gerais increased the soil macroporosity (Table 13.3) in relation to more disturbed sites (~7 %, data not shown). This speaks in favour of an increasing soil quality as macropores enable rapid drainage through the soil profile and most trees grow best in well-aggregated, well-drained soils with bulk densities less than 1.5 mg/m^3 (Craul 1985). Glomalin content was higher in the undisturbed site, which agrees with a higher AS (Table 13.3), thus providing a useful indicator of soil health.

Additionally, *M. bimucronata* and *S. inopinnata* showed fast growth and the high tolerance to fire of *M. bimucronata* confirmed their role in isolating the riparian zone from external disturbances (the adjacent highway). From a practical point of view, in riparian forests degraded by cattle and subjected to fire, selected seedlings should be planted under organic matter or with reduced chemical fertilisation, but it this will still depend on the previous use of the site. It is also known that the combination of rock phosphate, AMF and P-solubilising fungi is an alternative to the use of fertilisers (Velázquez and Cabello 2010).

AMF colonisation and lower AMF diversity were found in the degraded riparian sites and the highest richness was found in preserved sites. The results from Brazil highlight the importance of the effects between environmental (pH, organic matter, soil porosity, fire) variables and symbioses on the establishment and growth of native trees. These findings agree with Baar (2010) who developed soil quality metrics using AMF (root colonisation and species richness or number of taxa). As this author states, the AMC and SR in RF from Brazil were higher in undisturbed sites, and lower in disturbed sites; however, the soil type (sandy or clay) must also be taken into consideration. With regard to physical, chemical or biological soil properties as key tools to provide ecosystem services, all will be useful indicative values for recognising the effects of climate change; however, the cost and understanding of the methodologies for researchers and policy makers is still limited.

Conclusions

In Brazil there are communities living near waterways that extensively modify riparian zones, leading to changes (increased inputs of nutrients, sediments, and contaminants) which impact freshwater ecosystems substantially (Sala et al. 2000). Current information suggests that to mitigate the problems of climate change, whilst taking into account biodiversity in riparian systems, land-use change must be controlled and undisturbed sites are needed to maintain microbial biodiversity upstream. The use of legumes can facilitate the riparian buffer function and propitiate future establishment of more exigent plant species. The results of studies on RF in Brazil were interpreted in order to recommend procedures for optimising seedling establishment and growth of native species in restoration programs.

It can be concluded that conservation of upstream and middle stream biodiversity is important to preserve downstream soil ecosystem services. Thus, models promoting better draining and soil aeration through de humus formation against the lignified vegetal biomass in litter, and which increase the soil aggregation and nutrient retention, as well as decrease the water eutrophication must be prioritised. Plants provide the following ecosystem services: food for animals, erosion control, invasion resistance, and soil fertility regulation (Quijas et al. 2010). Riparian plants also contribute by shading and by producing nutrients for aquatic systems. AMF participates in services such as increasing soil structure, protecting soil C against mineralisation, and protecting tree roots against disease or drought (Simard and Austin 2010). Moreover, it is known that AMF contributes to the resilience of ecosystems to climate change (Bellgard and Williams 2011) and that a higher glomalin content can be associated with higher abundance of AMF.

It should however be remembered that the complexity of the interactions (nutrients, moisture, temperature, plants, fungi, etc.) involved, requires interdisciplinary work and coordination to design and implement the necessary measures to reduce the negative effects of climate change on environmental sustainability. It is required to assess the impact of climate change on the main biological factors that play a key role in the cycling of nutrients (particularly C, N and P) between the environment and organisms, resulting in the ecosystem services from soils in order to contribute to disaster management.

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Author Biography

Dr Marcela Claudia Pagano (http://lattes.cnpq.br/9865729952546245; SCOPUS Code 26325767800). BSc in Biology. Major in Botanic at the Faculty of Natural Sciences and Museum, National University of La Plata (UNLP), Argentina. MSc in Ecology, Conservation and Wildlife Management (1999). PhD in Applied Botany from the Federal University of Minas Gerais, Brazil (2007). Postdoctoral researcher at the Department of Biology Federal University of Ceará, Brazil (2009–2011). Assistant Professor, Federal University of São João del-Rei, Brazil. Editorial board: *European Journal of Soil Biology*, *Journal of Biophysical Chemistry*, etc. Research interests: agroforestry, agroecology, ecology of plant and soil microorganisms, and ecosystem services.

Chapter 14
The Contributions of Climate Change Mitigating Policies to Poverty Reduction in the Sahel Region

Labintan Adeniyi Constant, Mignouna Babatima Djana and Ituma Chibueze Calistus

Abstract Although there is a relationship between climate change and poverty reduction, some countries in the Sahel region of Africa are yet to incorporate a climate change risk management strategy into their poverty reduction programme. The aim of this research is therefore to evaluate the subjective and quantitative analysis of climate change risk management strategies in all the nine countries that constitute the Sahel region. Both a qualitative and a quantitative approach were used in the investigation. The qualitative approach was used to make a subjective analysis of the climate change mitigating framework with regard to poverty reduction issues at country level. It was based on a scoring system methodology by assessing the following criteria:

- The consideration of climate change scenarios and the vulnerabilities of the countries;
- The analysis of poverty-climate links;
- The climate change institutional framework of each country.The quantitative approach was based on Data Envelopment Analysis (DEA). This was done by applying DEA Solver to evaluate the efficiency of climate change mitigating frameworks and their impact on poverty reduction. The results of the investigation revealed that none of the Sahel countries, excluding Burkina Faso, included climate change risk management in their Poverty Reduction Strategy

L. A. Constant (✉) · M. B. Djana · I. C. Calistus
Doctoral Research Scholar in Agricultural Economics, Business Administration,
Zhongnan University of Economic and Law, 01 Nanhu South Lake, 430073 Wuhan, Hubei, China
e-mail: donconstant@yahoo.fr

M. B. Djana
e-mail: mignon_001@yahoo.fr

I. C. Calistus
e-mail: ezembeke@gmail.com

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and Policies (PRSP). Burkina Faso's National Adaptation Policies Action (NAPA) performs well. Burkina Faso is considered a model country which has included climate change policies in its PRSP. However, as with most countries in the region, the Burkina Faso climate change risk management policy is not comprehensive. This is a result of inadequate climate change risk management projects, exclusion of real needs and other exogenous parameters. However, in Senegal, more efforts are required in response to climate change risk management in order to reduce poverty. This is paramount for the following reasons: the inclusion of climate change risk management into PRSP important in increasing its understanding several challenges require to be addressed for good implementation and to ensure a good monitoring system. Stakeholders in the sector will be more effective and efficient in developing action plans for climate change management strategies and poverty reduction programmes.

Keywords Sahel · Climate change · Poverty reduction · Adaptation strategy · Biosketches

Introduction

The African Sahel region is located in the southern part of the Sahara Desert. The region stretches about 4,500 km, from Cape Verde through Senegal, Mauritania, Mali, Burkina Faso, Niger and Chad (Serigne 2006). The region consists of nine West African countries. Since 1973, these nine countries have formed the Permanent Interstates Committee for Drought Control in the Sahel (CILSS) (Serigne 2006; Integrated Regional Information Networks 2008). It is an area characterised by important interaction between climate variability and key socio-economic activities. These include agriculture, livestock herding, fishing, short and long-distance trading, and a variety of urban occupations (Serigne 2006). In the region, farmers entirely depend on 3–4 months of rainfall, except along the banks of the major rivers, lakes and other seasonal water sources for irrigation. Livestock herding is the main activity and constitutes the major source of income in some areas. More than 80 % of the Sahel population are involved in agriculture and stock-farming. The two sectors contribute almost 35 % of the countries' GDPs (Mohamed 2002; Sahel and West Africa Club 2008).

In the last three decades, the Sahel region climate has experienced various changes, especially in terms of rainfall. The inter-annual variation was very high (Bretaudeau 2009). It is therefore obvious that climate change seriously affects the economies of the region. Furthermore, farmers' incomes depend on agricultural production. Agricultural production in turn depends on good rainfall. Shortage of rainfall due to climate change decreases agricultural production. This invariably increases poverty among farmers in the region. In addition, high population growth

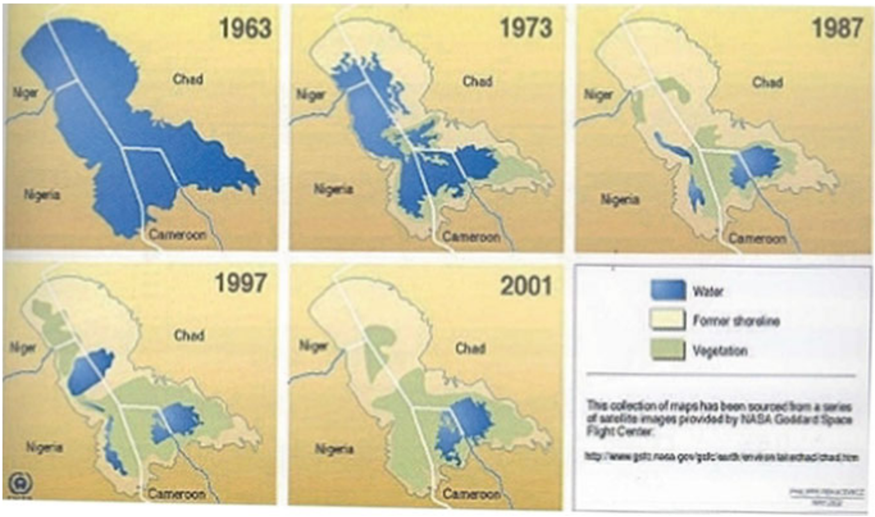

Fig. 14.1 Lake Chad drying up. *Source:* Bretaudeau (2009)

exerts pressure upon ecosystems and poor sanitary facilities. It is safe to conclude that the Sahel region is extremely vulnerable to climate change (Adepetu and Berthe 2007; Gordon, 2008).

Studies have proved that climate change has increased bad weather conditions in the region such as high drought (Figs. 1 and 2) and high floods (Fig. 14.3) (Nick 2004; Kadomura 2005; Economic and Social Council 2007; Bretaudeau 2009). The food security problem has also increased (Fig. 14.4) (Mendelsohn et al. 2000; Butt et al. 2003; Bretaudeau 2009). There has also been an increase in gender inequality issues (Rachel 2002; Rachael 2008; Madeleine 2010). The increase in conflict is also not to be forgotten (Siebert et al. 2005; Lotsch 2006; Marcel 2009; Philipp 2010; Sebastien 2010; Emmanuel 2010; Marie 2010). All these have a negative impact on the implementation on the Millennium Development Goals (MDGs) (Serigne et al. 2006; United Nation poverty-environment Initiative 2003, 2011).

Figures 14.1–14.4 present a diagrammatic illustration of the above state of affairs:

However, nowadays it is clear that there is a correlation between the negative impact of climate change and poverty rate growth (Martin et al. 2009; Kevin et al. 2010). Several policies are being put in place to streamline the negative impact of change on the vulnerable population. This is being done at local, country and regional level (United Nation poverty-environment Initiative 2011).

At regional level, efforts in this direction began in 1973 with the creation of CILSS—the Permanent Inter-State Committee for Drought Control in the Sahel Region—which represented a commitment to address the severe drought conditions that confronted the region from 1970. The objective was to elaborate national strategies for food security as well as national action plans to fight desertification

Fig. 14.2 Mortality of cattle. *Source:* Bretaudeau (2009)

Fig. 14.3 Niger flood. *Source:* Bretaudeau (2009)

and national strategies for domestic energy. The activities of the CILSS are coordinated with other regional institutions such as the Centre for Training, Research and Applications of Agrometeorology and Operational Hydrology (AGRHYMET).

Furthermore, it has also been recognised that there is a need for a combined effort in the region to achieve a system of integrated water resources management. There are several transnational river management framework organisations, such as the Niger Basin Agency (ABN) (Niasse 2005; NIGER—HYCOS 2006; Christophe and Robert 2008), and the Office of Management and Valorisation of the Senegal River (OMVS) (United Nations Development Programme 2004; World Bank 2009).

Fig. 14.4 Cereal deficit in 2005. *Source:* Bretaudeau (2009)

At country level, governments have developed Poverty Reduction Strategies (PRSP) and National Adaptation Programmes of Action (NAPA). These are designed as tools for mitigating the negative impacts of climate change on poverty (United Nations Framework Convention on Climate Change 2006a, 2006b). This is achieved through partnership between governments and NGOs. The NGOs provide financial and technical support to the governments.

At local level, Sahelian local stakeholders have developed strategies to deal with climate change (Serigne et al. 2006; Nyong, Adesina and Osman 2007; Stephen 2009; Sahel and West Africa Club 2008). The local strategies are based on traditional knowledge and practices. This includes Zai techniques, anti-erosive small dykes, half-moon techniques, improved land clearing, and other measures to mitigate soil erosion. This helps to reduce environmental degradation. Farmers have also developed agro-pastoral systems to combat the impacts of climate change, which involve the combination of farming and livestock breeding within the same farm. Local measures also include food market dynamics. During periods of disaster, low-income earners migrate in search of cash and food supply. All these measures have helped to reduce the risk associated the uncertainty of the climate in the region.

This study intends to evaluate the above policies in the Sahel region and their impact on poverty reduction. The aim is to identify the challenges that need to be addressed.

Methodology, Results, Analysis and Discussion

The first part of the research applied a qualitative approach. This was used to make a subjective analysis of climate change mitigating strategies and their effect on poverty reduction at country level. It was based on a scoring system methodology

(Bojo et al. 2004; Kramer 2007). Criteria were applied including the consideration of climate change scenarios and vulnerabilities of the country, the analysis of poverty-climate links, and the analysis of climate change institutional framework in each country. It assumes that PRSPs and NAPAs are the best sources of official information provided by countries in order to make a coherent assessment (Kramer 2007).

The paper considered all the nine Sahel countries. A comparison of the penetration of climate change variables was carried out in the PRSP process and in the assessment of both the PRSP and NAPA for countries that had already developed NAPA before 2010.

The three main criteria were broken into five variables in the assessment of each country and the availability of their respective PRSPs and NAPAs. Descriptions of these variables are provided below.

Consideration of Climate Change Scenarios and Countries' Vulnerabilities

- *Mention of climate change:* Recognition of climate change as a challenge for the development of policies and programmes at national level;
- *National climate change scenarios:* Presence of national climate change scenarios and the use of climate change models for describing national vulnerabilities;
- *Regional climate change scenarios:* Use of regional models or the downscaling of GCM on a regional scale, providing better regional climate change solutions;
- *Identification of sector/community vulnerabilities:* Identification of issues related to communities and sectors that are vulnerable to climate change;
- *Research gaps and needs:* Identification of research priorities in modelling the analysis of vulnerabilities and adaptive capacity.

Analysis of Poverty-Climate Links

- *Statement of poverty-climate link:* Identification of climate change as a threat to poverty eradication and MDG;
- *Identification of a particular poverty-climate problem:* Consideration of other factors which have a negative impact on poverty and development;
- *General analysis of a climate-poverty problem:* Providing explanation of other events which affect vulnerable communities and sectors;
- *Identification of solutions:* Identification of programmes, projects and policies to reduce future and present vulnerability arising from extrame events;
- *Gaps and needs:* Identification of gaps and needs in current policies and programmes related to human and scientific resources, and connections with climate-poverty reductions.

Climate Change Institutional Framework of Countries

- *Statement of climate change institutional framework:* Identification of the components of climate change;
- *NAPA:* Identification of the development of NAPA.
- *National institutional framework:* Issues related to multi-sectoral national climate change institutional mechanisms; in some countries an inter-ministerial commission has been established.
- *Regional/local institutional framework (civil society):* Existence or non-existence of permanent and functional institutional framework—such institutions are examined at regional and local level, allowing for interaction between authorities at national, regional, state and local level, and their relationship with local civil society;
- *Adaptation projects:* Identification of all adaptation projects in line with their priorities and the institutional capacity for their implementation.

Scoring System

This is the assessment of the countries and their PRSPs and NAPAs according to 15 variables. It was based on a qualitative judgment. All variables received a score. The scoring worked as followed:

0 = not mentioned or not elaborated

1 = mentioned; elaboration of the concept.

For each criterion, a country could score within the range of 0–5, depending on the level of attention given to the criterion. In total each country could score a maximum of 15.

Although the assessment does not pretend to be absolutely scientifically precise, it is a good indication of the level of integration of climate change adaptation and risk management into the various national development policies. Scores are interpreted as follows:

0–5 = Little or no progress in the integration of climate change adaptation and risk management;
5–10 = Awareness of needs;
10–15 = Development of institutional responses and solutions to climate change; includes natural disaster management.

It is important to note that different interpretations may be applicable where different items are considered.

The second stanza of the methodology was based on Data Envelopment Analysis (DEA). DEA was developed by Timothy et al. 2005. The framework known as DEA Solver is used to evaluate the efficiency of climate change mitigating policies and its contribution to poverty reduction. It makes use of major

Table 14.2 Adaptation to climate change in PRSP and NAPA

Country	Climate change in PRSP/NAPA (0–5)					Poverty-climate link (0–5)					Climate change institutional framework (0–5)				**Total score (0–15)**	
	Mention of climate change	National climate change scenarios	Regional climate change scenarios	Identification of sector/com-munity Vulnerabilities	Research gaps and needs	Mention of poverty-climate link	Identification of a particular problem	General analysis	Solution identification sector/com-munity	Gaps and needs	Mention of Climate Change Institutional Framework	NAPA	National institutio-nal framework	Regional/local institutional framwork (civil society)	Adaptation projects	
Senegal	×	×				×	×	×	×		×		×		×	9
Mauri-tania	×					×	×	×	×							5
Mali	×	×				×	×	×	×		×		×		×	9
BurkinaFaso	×	×		×		×	×	×	×		×		×	×	×	11
Niger						×	×	×	×							4
Nigeria	×	×		×		×	×	×	×		×		×		×	10
Chad	×				×	×	×	×	×		×				×	8
Sudan																
Eritrea																

Emphasis mine from Sahel countries' PRSP reports from International Monetary Fund (IMF) website http://www.imf.org/external/np/prsp/prsp.aspx

Table 14.2 Adaptation to climate change in PRSP and NAPA

Country	Climate change in PRSP/NAPA (0–5)					Poverty-climate link (0–5)					Climate change institutional framework (0–5)				**Total score (0–15)**	
	Mention of climate change	National climate change scenarios	Regional climate change scenarios	Identification of sector/com-munity Vulnerabilities	Research gaps and needs	Mention of poverty-climate link	Identification of a particular problem	General analysis	Solution identification sector/com-munity	Gaps and needs	Mention of Climate Change Institutional Framework	NAPA	National institutio-nal framework	Regional/local institutional framwork (civil society)	Adaptation projects	
Senegal	×	×		×		×	×	×	×		×	×	×		×	11
Mauri-		tania	×			×	×	×	×	×	×		×	×	×	
×	11															
Mali	×	×		×		×	×	×	×		×	×	×		×	11
Burkina		Faso	×	×		×		×	×	×	×		×	×	×	
×	11															
Niger	×	×		×		×	×	×	×		×	×	×		×	11
Nigeria																
Chad	×	×		×	×	×	×	×	×		×	×			×	11
Sudan	×	×		×	×	×	×	×	×		×	×	×		×	12
Eritrea	×	×		×	×	×	×	×	×		×	×			×	11

Emphasis mine from countries' PRSPs, NAPA papers collected from IMF, and United Nations Framework Convention on Climate Change (UNFCC) website http://unfccc.int/2860.php

Table 14.3 Summary of PRSP/NAPA links

Country	Climate change in PRSP (0–5)	Poverty-climate link (0–5)	Climate change institutional framework (0–5)	Total score (0–5)	Climate change in PRSP/NAPA (0–5)	Poverty-climate link (0–5)	Climate change institutional framework (0–5)	Total score (0–5)
Senegal	2	4	3	9	3	4	4	11
Mauritania	1	4	0	5	3	4	4	11
Mali	2	4	3	9	3	4	4	11
Burkina Faso	3	4	4	11	3	4	4	11
Niger	0	4	0	4	3	4	4	11
Nigeria	3	4	3	10	0	0	0	0
Chad	2	4	2	8	4	4	3	11
Sudan	0	0	0	0	4	4	4	12
Eritrea	0	0	0	0	4	4	3	11

Emphasis mine from countries' PRSPs, NAPA papers collected from IMF and United Nations Framework Convention on Climate Change (UNFCC) website http://unfccc.int/2860.php

climate change mitigating parameters, including input and output. Input data comprises data on fertiliser (metric tonnes), number of people with access to clean water, quantity of $C0_2$ emission (metric tonnes), quantity of NH_4 emission, and forest area. Output data comprises data on the national population living below poverty level. It must be noted that most climate change risk management policies are targeted at GHG (Greenhouse Gas) emission, the fight against deforestation, drought, floods, and the provision of more clean water facilities. The main output is designed to ameliorate poverty and improve household standard of living.

The results from the assessment framework are summarised in Tables 14.1, 14.2 and 14.3.

Table 14.1 shows the result scores for each country's PRSP assessment. It was established that some governments have made limited progress in absorbing climate change into their PRSPs (Burkina-Faso [11/15], Nigeria [10/15], Mali [9/15]). In contrast, Niger, Senegal and Chad have scored poorly.

Nevertheless, most countries showed a better performance with regard to the second criterion: poverty-climate connectivity. This criterion refers to climate variables or extreme events identified as having a negative impact on poverty eradication. It also affects vulnerable communities and other sectors of the economy. All these factors are usually covered by countries in their natural hazard management plans. Such plans have been streamlined into PRSPs in most of the countries investigated. The result shows countries more vulnerable natural hazards have better scores. Graph 1 in Fig. 14.5 illustrates a comparison of poverty level, number of people climate disasters, and number of people affected by disaster.

Moreover, natural hazards in the Sahel region have increased recently with continuous flood and drought (Fig. 14.5).

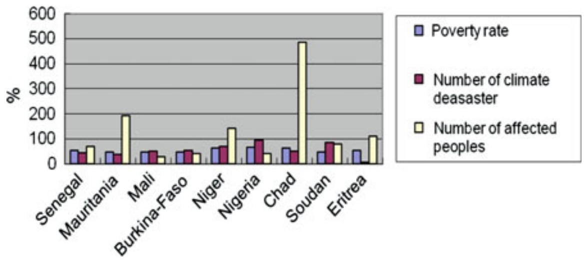

Fig. 14.5 Country comparison in terms of poverty rate level, number of disasters and affected people. (Emphasis given by the author on data from World Disaster Database http://www.emdat.be/)

In considering climate change variables and extreme weather condition, two main points are important. The first is that the integration of climate change into national policies will ultimately enhance resilience to present climate variables and extreme weather conditions. Secondly, the assessment of the relationship between changes in climate and poverty shows that only Senegal, Mali, Burkina Faso and Nigeria included the concept of interconnectivity between climate change and poverty in their PRSP. This is illustrated in Table 14.3.

In most countries there is little or no recognition of climate change. Indeed, only four out of the seven countries investigated mentioned climate change in their PRSP document. Countries such as Niger, Mauritania and Chad did not include climate change in their PRSP at all. This shows the gravity of some countries' neglect of climate change problems in the Sahel region. Burkina Faso was rated on the basis of "Adaptation Projects" in their PRSP. It is the first Sahel country to reduce its PRSP in a written document.

However, Burkina Faso is not the most vulnerable country in terms of poverty rate and susceptibility to natural disaster. The policies were developed as a commitment by the country to reduce the poverty level and achieve MDGs. This is however not the case with respect to other countries in the region. The poorest countries, like Sudan and Eritrea, are more vulnerable to climate change but there is no political will to solve the problems that arise from it.

Burkina Faso has the best practices and implementation framework with respect to PRSP and climate change risk management. This framework includes the strategy framework for fighting poverty (PRSP), the Rural Development Strategy (RDS), the National Plan for Fighting against Desertification (PNLCD), the National Action Plan for the Environment (NAPE), and the National Forest Policy.

The influence of NAPAs in the integration of climate change into the PRSP process is currently under assessment. Results from eight of the nine countries assessed by NAPA were published in 2006: there is no evidence to suggest that NAPAs are helping to mainstream climate change into the PRSPs. The only country that recognises the NAPA process in the PRSP is Burkina Faso. Mauritania, however, was the first country to develop a NAPA, in 2004. Unfortunately it is yet to incorporate either a NAPA or a Climate Change Institutional Framework in its PRSP, which was published in the year 2006. This is due to several obstacles, including financial and technical constraints.

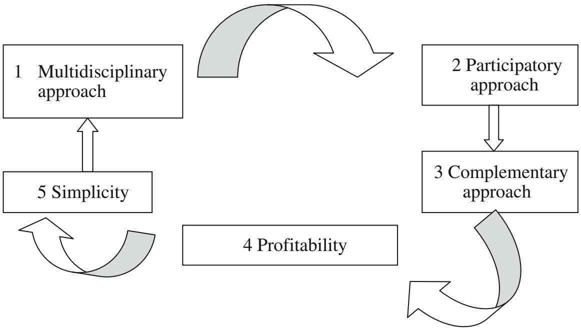

Fig. 14.6 Burkina Faso climate change adaptation approach. (Emphasis mine from Burkina Faso PRSP documents)

Table 14.2 shows that the Sahel countries that developed their NAPAs reaped significant benefits, with the exception of Nigeria. Priority activities were identified that responded to immediate needs with regard to adaptation to climate change.

Table 14.3 below presents countries' scores with regard to their PRSP and PRSP/NAPA strategies. It shows a positive development of PRSP/NAPA in the Sahel region, except in Nigeria. It also describes a better performance in the scoring system of the assessed variables.

These results show that Senegal, Burkina Faso and Niger presented their PRSP progress report and their NAPAs in the same year (2006). There is a considerable difference between the scores of their PRSP and PRSP/NAPA according to the assessment. This indicates that PRSP progress reports and the intended policy/programme reforms have not been integrated into the NAPA process. But this does not apply to Senegal, Burkina Faso and Niger.

It is important to examine those variables that are connected to poor performance. The examination will also include those countries that have developed PRSP and NAPA. The variables for countries whose scores are less than five points are as follows:

- Regional climate change scenarios: most countries used Greenhouse Gas Induced Climate Change SCENario GENerator (SCENGEN MAGICC/SCENGEN), Decision Support System for Agrotechnology Transfer (DSSAT), and GR2M, to model their national climate change scenarios.
- Research gaps and needs with regard to climate change: the majority of countries do not assess their research priorities in terms of modelling, analysis of vulnerabilities and adaptive capacity. Burkina Faso, Senegal and Niger are the exceptions. Climate change research intensity is higher in Burkina Faso compared to other Sahel countries. Burkina Faso received more assistance from the "Centre International de Recherche Agronomique et du Developpement" (CIRAD) Burkina, the Volta-Hylicos project, the African Monsoon Multidisciplinary Analysis (AMMA) project, the International Institute for Water and Environmental Engineering (2IE), and other international communities and NGOs.

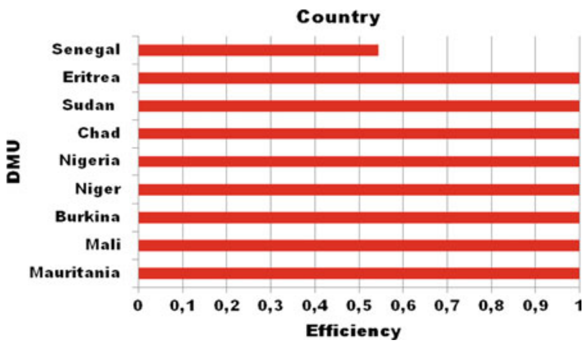

Fig. 14.7 Sahel countries' climate change adaptation efficiency (Emphasis from DEA Solver model)

- Gaps and needs in poverty-climate link: the majority of countries do not assess the gaps and needs (with regard to human and scientific resources) in current or future programmes of action.
- Regional/local institutional framework (civil society): most Sahel countries are part of CILSS, the Permanent Interstate Committee for Drought Control in the Sahel.

Best Practices of Climate Change Risk Management

Burkina Faso is the most successful Sahel country in terms of implementing PRSP and NAPA policies. The country included the impact of climate change in PRSPs. Graph 2 in Fig. 14.6 below provides a summary.

However, the applications of Data Envelopment Analysis (DEA) for evaluating the efficiency of the implementation of climate change risk management policies reveal positive correlation between input and output. It shows that most Sahel countries have an efficient score except Senegal, whose score is 0.5. This is shown in Graph 3 in Fig. 14.7 and Table 14.4a, b.

The majority of the countries received an efficiency score of 1. But the poverty rate nevertheless increased at an alarming rate of 45 % or more. This means that the implementation of climate change adaptation strategies does not involve real vulnerable people. The implementation does not meet the requirements of the MDGs.

These results may also be due to other exogenous parameters, such as corruption, or the inefficiency of stakeholders.

In the case of Senegal, efforts need to be doubled of MDGs are to be achieved. Good targeting and a good monitoring strategy are required in order to ensure that more people in need are involved.

It has been observed that at country level a number of factors limit the implementation of NAPA projects. These factors can be controlled. The degree of stakeholder involvement in the programme implementation was very low. African administrative systems are slow. Administrative and accounting procedures slow down concrete policy action. There is also a lack of efficiency and coordination

Table 14.4 **a** Sahel climate change risk management input–output data for 1960–2003 **b** Statistical results of input/output data and correlation

Country	(I)CO^2 (metric tonnes)	(I) Arable land (ha)	(I) Number of inhabitants with access to drinking water	(I) NH4	(I) Forest area	(I) Fertiliser consumed	(O) Poverty rate
Senegal	2529.844444	3101872.34	3596798.425	76	8965689	22791.26087	2657161
Mauri-tania	1156.375	329541.667	980949.9225	62	331388.9	1609	879387.8
Mali	371.4444444	2568911.11	2308811.98	34	13257056	16181.31707	4041838
Burkina Faso	412.8222222	3059266.67	3482287.424	62	6958790	13440.82222	4182645
Niger	682.8571429	11422357.1	2791403.063	62	1524748	2197.214286	3978016
Nigeria	46626.04545	28527250	37483009.94	62	13961181	155707.1136	32613305
Chad	136.7111111	3206266.67	1440560.525	62	12464187	5833.170732	3618466
Sudan	4166.288889	13376200	14295970.94	62	723640	54010.45652	13769147
Eritrea	693.2888889	531200	1234089.084	77	1577883	3961.911111	1545309

Statistics on input/output data

	CO^2b (metric tonnes)	Arable land (ha)	Number of inhabitants with access to drinking water	NH^4	Forest area	Fertiliser consumed	Poverty rate
Max	46626.045	28527250	37483009.9	77	13961181.2	155707.11	32613304.8
Min	136.71111	329541.667	980949.923	34	331388.896	1609	879387.761
Average	6308.4086	7346985.07	7512653.48	62.111111	6640506.96	30636.918	7734057.27
SD	14306.926	8651552.22	11275033.6	11.570503	5409964.48	46825.111	9759087.9

Correlation

	CO^2 (metric tonnes)	Arable land (ha)	Number of inhabitants with access to drinking water	NH^4	Forest area	Fertiliser consumed	Poverty rate
CO^2 (metric tonnes)	1	0.88668679	0.96170099	0.0195378	0.44738953	0.9655699	0.92615559
Arable land (ha)	0.8866868	1	0.94425354	-0.0309485	0.26195633	0.9156274	0.95247767
Number of inhabitants with access to drinking water	0.961701	0.94425354	1	-0.0028045	0.35745352	0.994228	0.99169688
NH^4	0.0195378	-0.0309485	-0.0028045	1	-0.4058657	-0.0215761	-0.0595573
Forest area	0.4473895	0.26195633	0.35745352	-0.4058657	1	0.4286003	0.34756231
Fertiliser consumed	0.9655699	0.9156274	0.99422804	-0.0215761	0.42860032	1	0.98090705
Poverty rate	0.9261556	0.95247767	0.99169688	-0.0595573	0.34756231	0.980907	1

Emphasis from World Resources Institute [WRI] database, http://www.wri.org/climate among programme managers. Poor mobilisation of financial resources and a lack of a good public budgetary system also have negative effects on the expected result. Funding of programmes is largely dependent on donor agencies, and there is undue delay in the implementation of programmes associated with climate change. Implementation of programmes is also affected by natural disasters. Lack of a biophysical data system is another obstacle.

At local level, the traditional climate change risk management developed by farmers is constrained by limitations in both financial and technical support facilities. This is coupled with the exclusion of farmers from development and monitoring strategies.

Conclusion and Recommendations

It is now common knowledge that there is a correlation between the risks of climate change and the rate of poverty rise in the Sahel region. Therefore, the adaptations in climate change strategies have become a topical issue for government, NGOs and farmers alike. Furthermore, it is recognised by all stakeholders that integrated long-term climate change management strategies are needed.

In a related development, a great effort has been made in different countries to limit climate change risk through NAPA projects PRSP poverty alleviation programmes. However, only one out of seven countries has integrated its NAPAs in its PRSP projects. Local farmer's adaptation strategies are insufficient and require improvement. This is because of a lack of technical support, credit facilities and information flow. The objectives of Government, NAPAs and PRSPs were not achieved due to the realities faced by vulnerable people and inefficiency in domestic accounting systems. Ineffective monitoring systems are another inhibiting factor. Donors' funding constraints and natural disasters such as floods and droughts also play a role, as do insufficient data for biophysical modelling and a lack of skilled labour.

At regional level, it was discovered that only Burkina Faso has integrated a good climate change and poverty reduction strategy. But a good implementation strategy, and the involvement of more vulnerable people, is still required. There is also the need to tackle the problem of corruption.

However, hugely difficult question that has been avoided is "What can be done to reverse the current trend?"

More policies are needed to help stakeholders address challenges in their income generation.

In agricultural sectors, more investment is needed for mechanisation and infrastructure development. This includes roads, dams for water conservation and irrigation, greenhouses and crop conservation systems. This will facilitate household agricultural output and maximise efficiency. It will also increase market access. It was found that none of the countries in the region invest more than 5 % of GDP annually in the agricultural sector.

Investment is needed at regional and local level to develop climate change institutional frameworks. This will strengthen coordination, networking and information flows at different levels of government, as well as the civil organisation of society. The result will be a better response to poverty eradication and climate change.

More research should be conducted on climate change and poverty reduction issues. Small farmer stakeholders and policymakers should work together for greater efficiency. Research should also quantify the contribution of climate change variables to achieved MGDs. According to Washington (2006), no attempt has been made to quantify the actual contribution of climate change variables to achieving MDGs.

Countries should develop regional and local climate change institutional frameworks. This will strengthen coordination, network and information flow.

Climate change risk management projects in each sector of the economy should represent win–win situations, especially with respect to Clean Development Mechanism (CDM) issues. Attention should be given to the development of technology (Rynikiewicz and Chetaille 2006), as the development of win–win projects will face some challenges.

To these ends, government should mobilise more resources. New funds and policies should be developed and mobilised, and countries should not rely on donor funding alone, since the global economic crisis may see such funding significantly reduced.

Sustainable economic growth is required at regional level in order to reduce poverty. It will also improve resilience to climate change in poor countries. Nonetheless, economic growth alone cannot represent a solution to the negative impacts of climate change. Growth may not come quickly enough to help poorer countries, and may even increase vulnerability to climate change hazards. Economic growth is not usually equally distributed, and may not protect the poorest and most vulnerable countries.

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Author Biographies

Labintan Constant was born in 1984 in Cotonou, Benin Republic. In 2006 he received a Bachelor degree in Mathematics/Physical Science from the Ibn Tofail University of Kenitra in Morocco. In 2008, he successfully completed his Master's degree in Natural Resources Management, focusing on integrated water resources management, from 2 IE (International Institute of Engineering in Water and

Environmental Management). Since 2009, he has been a doctoral research scholar (PhD) in Agricultural Economics at Zhongnan University of Economics and Law, Wuhan, China. His research area is "Biofuel and food security issues: A case study of Mali". His research interests are climate change and poverty reduction issues, agricultural growth and efficiency issues, and bio-energy and food security problems.

Mignouna Babatima Djana was born in 1974 in Togo. He holds a Bachelor and a Master's degree in Management at the University of Lome (Togo), and a PhD in Agricultural Economics and Agribusiness. Since June 2011 he has been a lecturer at the Sokoine University of Agriculture (SUA) in Tanzania. His research topic is "Adoption and Impact of Improved Agricultural Technologies in Developing Countries in order to Achieve Food Security and Reduce Poverty".

Ituma Chibueze Calistus was born in 1979 in Izzangbo in the Federal Republic of Nigeria. He is a seasoned legal luminary and a private legal practitioner. He received an upper second class Bachelor of Law Degree (LLB) from Enugu State University of Science and Technology, Nigeria, in 2004. He also holds a Barrister at Law Degree with second class honours from the Kano Campus of the Nigerian Law School. He was admitted as barrister and solicitor to the supreme court of Nigeria on 8 May 2007. He was active in private legal practises from 2007 to October 2010. From 2008 to 2010 he was the legal adviser to the Ohaukowu Local Government Area in Nigeria. Since October 2010 he has been a Master's Degree scholar in International Law and Diplomacy at Zhongnan University of Economics and Law, China. His research topic is "Constitutional Enforcement of Socio-Economic Rights in the Domestic Legal System".

Chapter 15
Impacts of Cyclone Aila on Educational Institutions: A Study of South-Western Bangladesh

Sumana Sharmin and Rumana Naznin

Abstract Bangladesh is considered one of the most disaster-prone countries in South Asia; the country is frequently threatened, mainly by floods and cyclones. Aila, a Category 1 cyclone, hit the south-western coastal region of Bangladesh on 25 May 2009. About 2.3 million people were affected by Aila. This paper is about the damage wreaked by Cyclone Aila on the educational institutions of Bangladesh. The study area is Khulna District's affected Upazilas (Thana), namely Dacope, Koyra and Paikgachha. A rapid assessment was carried out by the education cluster in the three most affected Upazilas and it was estimated that a total of 365 schools out of 480 had been affected. This study selects three criteria to measure the damage to educational institutions. Most of the damage information was collected from secondary sources; impact information was collected by field survey. Simple random sampling is applied here. Generally, children are the most vulnerable group in all types of disaster, but there are no major educational programmes related to Disaster Risk Reduction (DRR) in primary or secondary schools in Bangladesh. Thus, teaching DRR in schools will help raise awareness and give better understanding, not just for children and teachers but in the community at large. At the same time, investing in strengthening school building structures before disasters take place would help reduce long-term costs, protect the community and the

S. Sharmin (✉)
Under the Ministry of Local Government and Rural Development, Town Planner Gazipur Paurashava, Gazipur 1700, Bangladesh
e-mail: sharmin.sumana@gmail.com

S. Sharmin
C/o Golam Moula Chadhury, 146/C/4 (1st floor), West Agargong, Dhaka 1207, Bangladesh

R. Naznin
Jessore Under the Ministry of Local Government and Rural Development, Town Planner Noapara Paurashava, Noapara, Jessore, Bangladesh
e-mail: naznin.nitu@gmail.com

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children, and ensure educational continuity after the event. This study focuses on these points.

Keywords Cyclone preparedness programme · Disaster risk reduction · District disaster management committees · Government primary school · Upazila (area within district) · Building structure

Introduction

Education is very important for an individual's success in life. Education provides pupils with skills that prepare them physically, mentally and socially for the world of work in later life. But when education facilities are under threat, this can cause serious problems for the society. Without education there is no hope. Education is a major aspect of development in any modern society: if there is a deficit of educated people, society will cease to move forward. Without an educated population, no nation is able to develop. Therefore, education in its own right is crucial, not just education about Disaster Risk Reduction. Mainstreaming DRR into school curricula could raise awareness and provide a better understanding of disaster management for children, teachers and communities. Accompanying structural changes to improve the safety of school buildings will not only protect children and their access to education, but will also minimise long-term costs. The capacities of the community and government to understand the causes, prevention and mitigation of risk, plus their knowledge of emergency response procedures, can help reduce vulnerability to hazards by preventing them from becoming disasters.

Bangladesh is one of the largest deltas in the world. It has a unique geographical location in South Asia and is geologically a part of the Bengal Basin—one of the largest geo-synclinals worldwide. It has an area of 147,570 km^2 (Islam, 1999). Sub-nationally, the northern and eastern regions of the country are susceptible to earthquakes, while the south-east is also particularly vulnerable to cyclones, floods, and droughts. Bangladesh is at great risk from the impacts of global climate change because of its very low elevation and exposure to various climate-related hazards.

Cyclone Aila

Cyclone Aila was the second tropical cyclone to form in the northern Indian Ocean during May 2009. The disturbance that was to become Cyclone Aila formed on 21 May 2009, about 950 km (590 miles) to the South of Kolkata, in India. Over the next couple of days the disturbance slowly developed before a Tropical Cyclone Formation Alert was issued by the Joint Typhoon Warning Centre early on 23 May

Table 15.1 Cyclone Aila at a glance

Formed	23 May 2009
Dissipated	26 May 2009
Highest winds	110 kph (70 mph) (3 min sustained) 120 kph (75 mph) (1 min sustained)
Lowest pressure	968 mbar
Fatalities	190 (7,103 injured and 39.28 lakh affected)
Financial losses	USD 40.7 million

Source (SDMC 2009)

2009. It was designated a depression by RSMC New Delhi and hit the south-western coastal region of Bangladesh on 25 May 2009. (SDMC, 2009). Cyclone Aila at a glance is presented in Table 15.1.

This study identifies the damage wreaked by the cyclone on educational institutions in Bangladesh and presents some recommendations for action.

Purpose/Rationale of the Research

The results of this research include the identification of the present situation with regard to the educational system and the impact of the disaster on education in the study area. It is envisaged that the knowledge obtained in the study and the recommendations presented will serve as a good example for drawing lessons on how to mainstream Disaster Risk Reduction into development policy and planning. Moreover, this can also be adapted in other areas.

To meet these research aims, the study of Cyclone Aila's effect on education in affected areas was conducted focusing on the following issues:

- review of current situation
- socio-economic and physical impacts of disasters on education sector
- solution-oriented recommendations.

Selection of the Study Area

The severe cyclonic storm Aila whipped up tidal surges and raged through the southern coastal areas of Bangladesh during the afternoon of 25 May 2009. About 200,000 people, including children, were made homeless. They took shelter in the open on embankments and highlands. Severely affected districts included Sathkhira, Khulna, Bagerhat, Barguna, Pirojpur, Patuakhali, Bhola, Barisal, Noakhali, Laxmipur, and Chittagong. For the purposes of this study, Khulna District is selected as a study area. In Khulna District, eduation was badly affected in three Upazilas: Dacope, Koyra and Paikgachha. For this research these Upazilas are used for surveys and data collection. These areas will be used to represent the whole area affected by Cyclone Aila. Another reason for selecting these study areas is that the Upazilas are near Khulna District, facilitating data collection for the researcher.

Impact Assessment and Information Collection

Desk Review

A review of existing relevant documents and research studies was made in order to get a better understanding of the issues in the paper. A range of Ministries, governmental and non-governmental organisations form one of the main sources of information for this study. Information was collected from the Upazila Education Office, the Union Parishad Office, the Save the Children zonal Office (Nirala), Jagrata Juba Shangha, Rupantor. A review of various books, research works, journals, newspapers, magazines, etc., collected from the respective institutions and organisations, was carried out.

Field Survey

- Reconnaissance survey
- Questionnaire survey.

The data required for the research, after having been collected, was processed by different softwares, including MS Excel, SPSS and GIS (Arc View), and presented in tabular form. Simple random sampling was applied for the questionnaire survey.

Sample Size Determination

A complete list of affected households in the Upazilas was used to determine the sample size. The initial sample size was determined by using the following formula:

$$n = \frac{z^2 \mathrm{pq}}{\mathrm{d}^2}$$

where z is the normal variation, which has 1.94 for 95 % confidence interval. p is the target proportion. In this case we assumed $p = 0.50$ $p + q = 1$, therefore, $q = 0.50$ and d is the desired error, which is 0.1014.

The initial sample size is therefore:

$$n_0 = \frac{1.94^2 \cdot 0.50 \cdot 0.50}{0.140^2} = 480,051$$

.

These sample size is adjusted by using the following formula:

$$n_0 = \frac{\mathrm{n_0}}{1 + \frac{\mathrm{n_0}}{\mathrm{N}}} = 479,581 \cong 50$$

where n is the required sample size and.

N is the total households affected by Aila (48,647) in the area of education, within the three Upazilas Dacope, Koyra and Paikgachha.

Solution-Oriented Recommendations

To double-check the validity of the data, and to enable effective solution-oriented recommendations, qualitative interviews were conducted with relevant stakeholders, namely:

- Ministry of Education, Youth and Sports (MoEYS);
- National Committee for Disaster Management (NCDM);
- Pedagogical Research Department, MoEYS.

Study Area

The study area for this research is Khulna District's Aila-affected Upazilas, Dacope, Koyra and Paikgachha. The study area is one of the remote areas of Khulna District. These Upazilas were adversely affected by Cyclone Aila, and will represent the whole area affected by Cyclone Aila. Map 1 shows the areas where the Danger Signal was shown because of Cyclone Aila; Map 2 shows the study area.

Climate

The study area has a humid, warm and tropical climate, which is fairly uniform throughout the district. There are three main seasons:

- a hot summer season with high humidity from March to June
- a hot and humid monsoon with heavy rainfall from June to October
- a relatively cool and dry winter season from November to March.

During 2008, the maximum temperature was observed on 22 March and the minimum on 14 January. The mean monthly maximum and minimum temperature and average monthly rainfall are given in the following charts. Figure 15.1 shows the average monthly maximum and minimum temperatures in 2008. It shows that from March to June the temperature fluctuates a lot, meaning the difference between maximum and minimum temperature is often large and the maximum temperature can be very high. Most natural disasters, including floods, cyclones, and tidal surges, occur during this time in Bangladesh. Figure 15.2 shows the average monthly rainfall in 2008. This figure indicates that from March to May the quantity of rainfall is small; the period is extremely hot and different natural disasters take place. People living in the country may be aware of this and take necessary preventive measures.

Table 15.2 shows the demographic status of the study area.

Present Situation: Problems and Needs

Cyclone Aila hit Bangladesh's southern coastal areas on May 25. According to the latest statistics from the Disaster Management Ministry, the cyclone left 131 people dead, 1,123 missing and 6,500 injured. In the Upazilas of Khulna District affected by Aila, everything is underwater: houses, trees, paddy fields, and shrimp breeding plants. Homeless people are living in the open or in makeshift tents piched along the main road. The major problems and needs of the people are detailed below from the results of the reconnaissance survey.

Drinking Water and Food Crisis

Scarcity of drinking water and food is the major problem. Villages are inundated. All the food has been destroyed. The ponds are polluted, and many tubewells are underwater and also polluted. Many people are suffering from diarrhoea. A large number of people were seen queuing up to collect water from some unpolluted tubewells one or two hours walk from where they live.

Shelter Sanitation

Houses are flooded all over the villages in the affected area. People have nowhere to live. The affected people have taken shelter on high roads and embankments. They inhabit a very narrow area on the road in very small shelters with their whole families in a single room. They do not have any privacy, and there are no sanitation facilities.

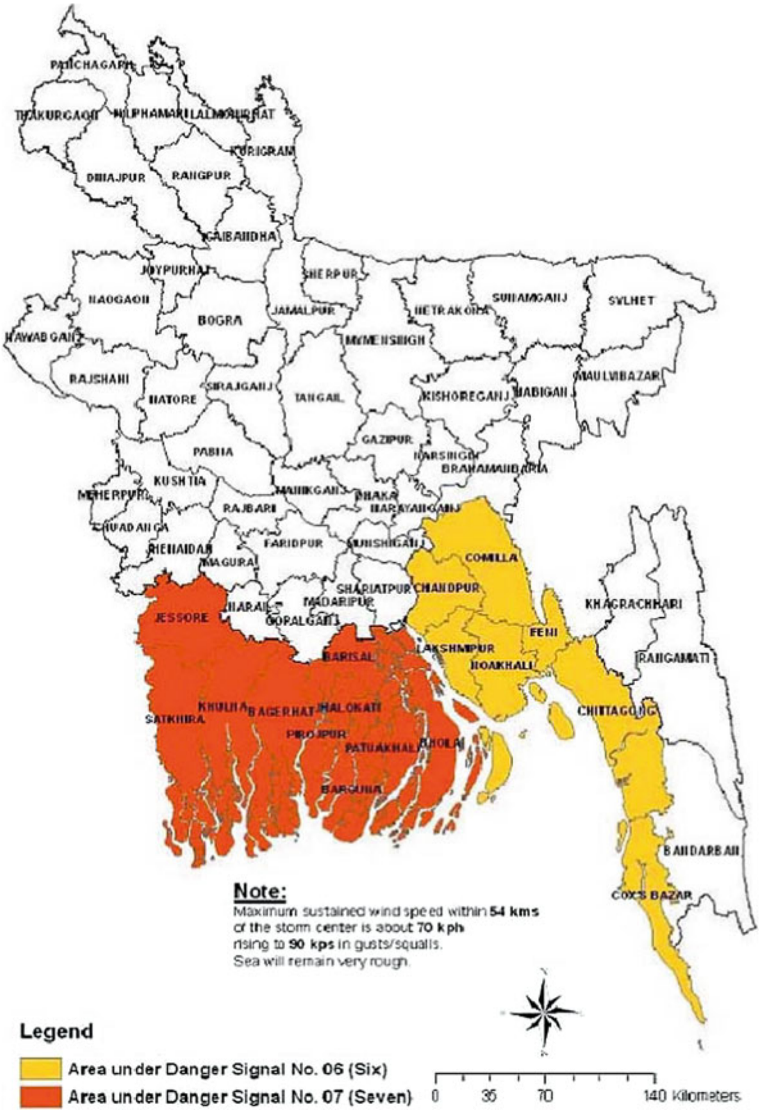

Fig. 15.1 Cyclone Aila (areas where danger signals were shown) (*Source* Disaster Management Information Centre, Web: www.dmb.gov.bd)

Scarcity of Medical Services

After Aila, the scarcity of medicine has also become a big problem. People are suffering from many types of water-born diseases. However, it is difficult for people to go to the Upazila health complex to access medical facilities because of the poor condition of the road.

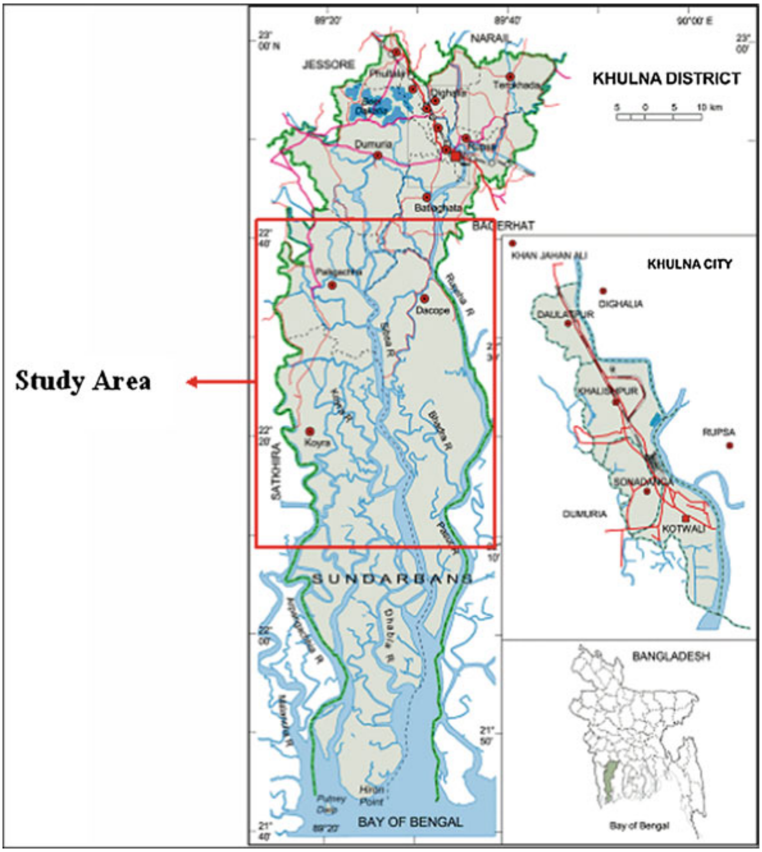

Fig. 15.2 Study area (*Source* Khulna City Corporation Office, 2010)

Table 15.2 Demographic status

Types	Frequency
Total households	105,921
Total number of affected households	68,695
Fully damaged households	36,007
Partially damaged households	32,688
Population density	108.44/sq km
Literacy rate	44.4 %

Source Save the children 2010 and BBS, (2001)

Damaged Embankments and Transportation System

All the dykes and embankments constructed by the Water Development Board were damaged. The embankments had been built to fulfil transportation needs besides providing protection from floods; in fact, the embankments were the only roads connecting some remote areas. During Aila most embankments were damaged and have still not been repaired. People in affected areas have repaired some places by themselves according to their own requirements, but this is not sufficient to get the transport system up and running again. This is a fundamental inconvenience, since people are unable to get to their places of work or study without great difficulty. They are also unable to transport necessary goods to their homes, rendering daily life extremely difficult.

Children: The Most Vulnerable

Children are the most vulnerable after this disaster because it altered their whole living environment and destroyed their comfort zones. They are under threat from different water-borne diseases like diarrhoea and cholera, unable to get regular meals, have stopped going to school, and in most cases end up sleeping out in the open or in make-shift houses which pose a serious threat to their security. Malnutrition and interrupted breastfeeding are other threats.

Education: An Unhealthy Environment

An important problem in these districts is that students cannot get to their places of learning because educational institutions were flooded during the cyclone and are not in good condition. Buildings, chairs, tables, benches, etc., have all been damaged. It is not safe for primary school children during high tide. Many parents are unable to send their children to school because roads are damaged and fields are underwater.

Findings of the Study

The severe cyclone Aila whipped up tidal surges and raged across the southern coast of Bangladesh during the afternoon of 25 May 2009. About 200,000 people, including children, were displaced from their homes and took what shelter they could out in the open. Children were disproportionately affected and their schooling was undermined due to the loss of education materials; Aila also damaged school infrastructure and furniture.

Table 15.3 Education system in study area

Type	Category
Pre-Primary	Government school
	Non-governmental organisation/private school
Primary	Government primary school
	Registered non-governmental primary school
	Community school
	Non-governmental organisation/private school
Secondary	Government school
	Non-governmental organisation/private school

Source Field survey, 2010

Education System in Study Area

Table 15.3 shows the present education system in the study area. There are three types of schools: Pre-Primary, Primary and Secondary. A number of schools are organised by NGOs.

Number of Schools in Study Area

Table 15.4 shows the number and types of schools in the study area. There are, in total, 480 schools in Dacope, Koyra and Paikgachha Upazila.

Damage to Schools in the Study Area

An assessment rapidly carried out by the education cluster in the three most affected areas, and it was estimated that a total of 365 schools had been affected, disrupting access to education for about 60,809 children; the number of affected teachers was 1,574 (Tables 15.5, 15.6, 15.7).

Table 15.5 shows the number of schools that were fully damaged, partially damaged or closed, and the total is 365. “Fully damaged” means: school building/classroom was still standing but class was not carried out by teachers because water was entering the classroom/building structure was broken/connecting roads were fully damaged. “Partially damaged” means: teachers were able to hold a class, but in very poor conditions with regard to window damage, roof damage, floor damage, connecting road damage, etc. There are 480 schools in the study area. From this information it is clear that about 76 % of schools were damaged to some extent by Cyclone Aila.

Table 15.6 shows the situation of school-going children. The education of 60,409 children from 48,647 households was affected by Cyclone Aila.

Table 15.4 Number of schools in study area

Type of school		Dacope	Koyra	Paikgachha	Total
		Number of schools in affected areas			480
Pre-Primary	Govt.	0	0	0	0
	NGO/Private	24	0	0	24
Primary	GPS	56	54	29	139
	RNGPS	53	59	30	142
	Comm.	4	11	0	15
	NGO/Private	0	51	0	51
Secondary	Govt.	46	37	25	108
	NGO/Private	1	0	0	1

Source Survey of local government office (Union Parishad Office), 2010

Table 15.5 Number of schools fully damaged and partially damaged, and number of schools closed

		Dacope	Koyra	Paikgachha	Total
Number of schools fully damaged					
Pre-Primary	Govt.	0	0	0	0
	NGO/Private	5	0	0	5
Primary	GPS	8	0	8	16
	RNGPS	14	0	2	16
	Comm.	1	0	0	1
	NGO/Private	0	26	0	26
Secondary	Govt.	3	0	2	5
	NGO/Private	0	0	0	0
Number of schools partially damaged					
Pre-Primary	Govt.	0	0	0	0
	NGO/Private	12	0	0	12
Primary	GPS	20	48	16	84
	RNGPS	18	53	12	83
	Comm.	0	11	0	11
	NGO/Private	0	18	0	18
Secondary	Govt.	23	30	13	66
	NGO/Private	1	0	0	1
Number of schools closed					
Pre-Primary	Govt.	0	0	0	0
	NGO/Private	0	0	0	0
Primary	GPS	0	0	0	0
	RNGPS	0	0	0	0
	Comm.	0	0	0	0
	NGO/Private	0	20	0	20
Secondary	Govt.	1	0	0	1
	NGO/Private	0	0	0	0
Total affected schools					365

Source Save the children 2010

Table 15.6 Number of children affected

Number of children affected		Dacope	Koyra	Paikgachha	Total
Pre-Primary	Boys	245	2174	0	2419
	Girls	275	1318	0	1593
Primary	Boys	5126	10,964	3350	19,440
	Girls	5271	8994	3094	17,359
Secondary	Boys	4202	4345	2325	10,872
	Girls	3407	3637	2082	9126
Total		18,526	31,432	10,851	60,809
Number of households affected					48,647

Source Save the children, 2010

Table 15.7 Number of teachers affected

Number of teachers affected		Dacope	Koyra	Paikgachha	Total
Pre-Primary	Male	0	0	0	0
	Female	17	0	0	17
Primary	Male	120	269	77	466
	Female	129	199	75	403
Secondary	Male	211	221	137	569
	Female	59	32	28	119
Total		536	721	317	1574

Source Save the children, 2010

Respondents were asked the question: "What problems do you face in getting to school?" They were given the following options:

- School closed
- School damaged
- Reading material damaged (e.g. books)
- Road to school damaged
- No transportation available.

Table 15.7 shows the situation of teachers in the study area. 1,574 teachers were affected by Cyclone Aila. Again, respondents were asked: "What problems do you face in getting to the school?" They were given the following options:

- School closed
- School damaged
- Teaching material damaged (e.g. books, board)
- Road to school damaged
- No transportation available.

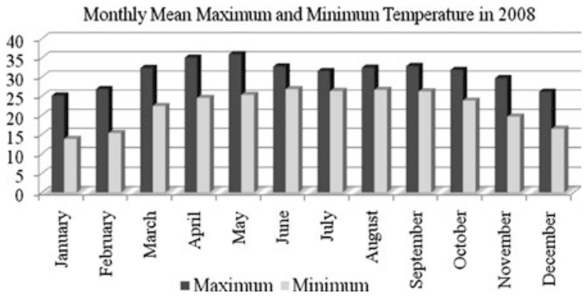

Fig. 15.3 Average monthly maximum and minimum temperatures in 2008 (*Source* Weather Office, Gollamari Observation Centre, 2009)

Types of Damage to Schools

The results obtained from the survey prove that more than 76 % of the interviewed schools have been physically affected by Aila. School damage was assessed at three levels: (i) Severe Damage; (ii) Medium Damage; (iii) Low Damage. "Severe Damage" means: infrastructure and furniture in this category was not in useable condition; "Medium Damage" means: infrastructure and furniture was barely useable; "Low Damage" means: infrastructure and furniture was useable, but not in good condition.

Figure 15.3 shows the percentage of schools suffering different damage types. In the Severe Damage category, about 32 % schools have suffered floor damage. The next most common types of damage were, in order, window, wall, chair/table and roof. In the Medium Damage category, window damage was the most common kind of damage, and was suffered by about 25 % of schools. In order, the next most common types of damage were wall, chair/table, roof and floor. In the Low Damage category, wall damage was the most common, suffered by about 27 % of schools. In order, the next most common were chair/table, roof, window and floor damage (Figs. 15.4, and 15.5).

Figures 15.6, 15.7, 15.8, 15.9, 15.10, 15.11, 15.12 show Cyclone Aila and the damage it wrought.

Disaster Intervention Mechanism of Ministry of Food and Disaster Management and Disaster Management Information Centre (MoFDM & DMIC)

Actions Taken

- A government disaster management system has been activated to coordinate pre-impact preparedness.
- MoFDM, DMB and DRR have opened control rooms (telephone numbers are: 7162116, 7160454, 7164115, 8859634; fax numbers are: 7169623, 7174148).

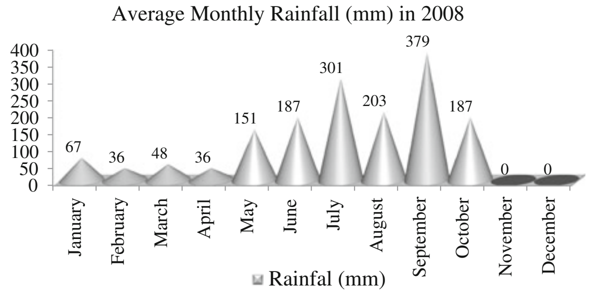

Fig. 15.4 Average monthly rainfall in 2008 (*Source* Weather Office, Gollamari Observation Centre, 2009)

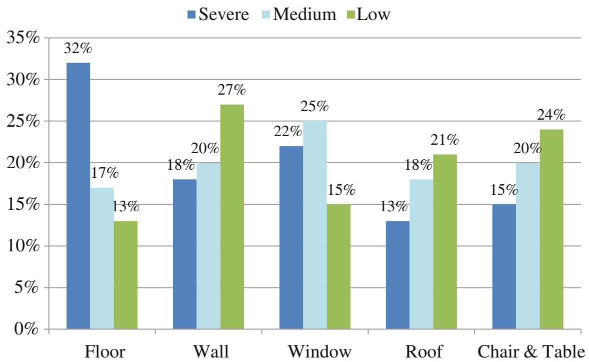

Fig. 15.5 Percentage of schools suffering different damage types (*Source* Field Survey, 2010)

Fig. 15.6 After cyclone Aila (*Source* CBC News, Friday, 29 May 2009)

- MoFDM has ordered Deputy Commissioners and UNOs of coastal districts and Upazila to conduct disaster preparedness meetings on carrying out possible damage assessments after cyclones.
- MoFDM has ordered volunteers from 32 Upazila of 11 coastal districts to be alerted in accordance with established operating procedures.

Fig. 15.7 Damaged road (*Source* The Daily Star Newspaper, Monday, 1 June 2009)

Fig. 15.8 Partially damaged school (*Source* Save the Children, 2010)

Fig. 15.9 Fully damaged school [*Source* Jagrata Juba Shanga (JJS 2009)]

Fig. 15.10 Woman filling water jar for man to transport to their customer's house at Dacope [*Source* Jagrata Juba Shanga (JJS 2009)]

Fig. 15.11 Daily labours include filling water containers from the pond situated at the Upazila Parishad at Dacope [*Source* Jagrata Juba Shanga (JJS 2009)]

Fig. 15.12 Temporary school set up by NGO (the number of these is too small) (*Source* Save the Children, 2010)

- DMIC has been activated and remains open round the clock to monitor and report on changing situations.
- The Disaster Management Bureau (DMB) has instructed the District Disaster Management Committees (DDMC) and Emergency Response Resources of coastal districts to stand by.

(DMIC, 2009).

Recommendations

Ever since Cyclone Aila took place, people in the affected areas are still suffering from insufficient food, water and shelter, and only have access to damaged education and sanitation facilities. It is therefore of the utmost importance to ensure at least subsistence living requirements for the affected people. This study has mainly focused on educational problems in the affected areas in Khulna District. Some recommendations in this context are as follows:

Recommendations for Strategic and Sector Development Plan

- The Disaster Management Bureau (DMB) should be incorporated in the long-term Strategic Plan of the Education Sector to ensure safe school buildings are included in its goals and objectives. The Ministry of Education (MoE) should contribute to the development of additional facilities and capacity building.
- The MoE must seek inter-ministerial and inter-departmental cooperation and collaboration with the Ministry of Housing and Public Works and Ministry of Public Communication (MoHPW, MoC), the Ministry of Post and Telecommunication, and other relevant institutions. This crucial for implementing a holistic approach to Disaster Risk Reduction (DRR). It has been demonstrated that storms not only damage school buildings but also create communication or access problems and sometimes result in the school being used as a shelter.

Recommendations for Structural Measures

- Specific construction guidelines and building codes that integrate DRR must be issued by the Ministry of Local Government, Rural Development and Co-operatives in consultation with the MoHPW and other relevant ministries/institutions. Such integration will reduce economic losses in terms of the re-building and repairing of school buildings after disasters.

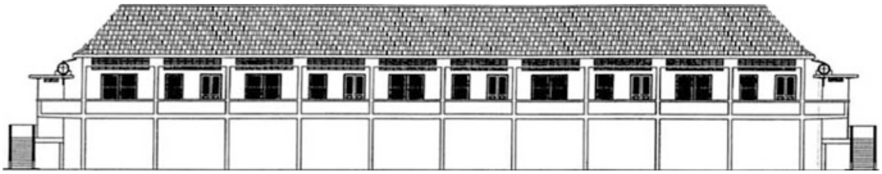

Fig. 15.13 Proposed 11.50 ft elevated school building (*Source* ADPC, 2008)

- Site selection should be an important task before construction of a new school. Land-use planning along with construction guidelines and building codes need to be considered when setting up a school building in a flood-prone area.
- In the construction of new schools in rural and remote areas, attention should be given to the capacities of the local sub-contractors and local community (Fig. 15.13).

Elevated school: This study proposes a school elevated at 11.50 ft. This design is taken from the literature review. ADPC uses this design in a report on the subject (Fig. 15.14).

The reason for including the design in this paper is that it is very suitable for the situation caused by Cyclone Aila. This design of elevated school could be a shelter for people during floods and cyclones. The school also includes a rainwater preserver, which could serve to some extent to augment drinking water supplies. In the study area, no school could be used as a cyclone shelter in the event of a disaster. Figure 15.4 shows proposed 11.50 ft elevated school building. Figure 15.5 shows a cross-section.

Recommendations for Non-Structural Measures

- Integration of DRR in the primary school curriculum. This is the most important stage at which to deliver the message of DRR to the students. Students in the primary classes are the most vulnerable to disasters. It is also significant that in Bangladesh there is a high drop-out rate after primary school, so if DRR is not taught at primary level then a substantial number of potential targets are missed.
- Integration of DRR in the senior secondary and technical school curriculum by the General Secondary Education Department and the Higher Education Department of the MoE.
- Development of curriculum for students and teachers with disabilities, especially for those who are visually and hearing impaired, and students with learning difficulties.
- Development of extracurricular activities for students which complement the DRR curriculum (e.g. games, quizzes).
- Development of training modules which can be used at teacher training institutes to teach the DRR curriculum. This will also involve capacity building of

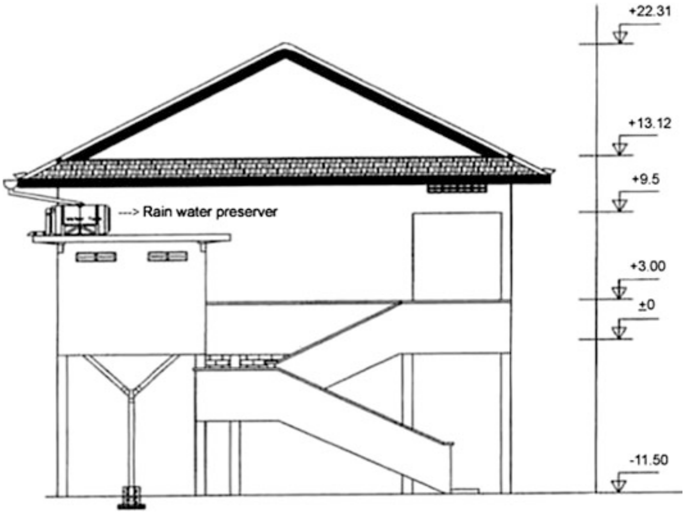

Fig. 15.14 Cross-section of 11.50 ft elevated school building (*Source* ADPC, 2008)

the teacher training institutes and the development of master trainers and resource leaders who can teach other teachers. The modules are needed for newly appointed as well as experienced teachers.

Conclusion

Bangladesh is a high-risk zone in terms of cyclones, tidal surges, embankment erosion, and increased salinity of drinking water sources. These hazards are experienced almost every year. Cyclone Aila caused serious damage to embankments, standing crops, built structures, etc. For this reason, affected areas are still suffering from insufficient food, water and shelter, and only have access to damaged education and sanitation facilities. This research is based on the effects of Aila on education in affected areas in Khulna District. Serious damage was caused by Aila to education in the affected areas rendering students unable to get to their places of learning. Buildings, chairs, tables, benches and so on were damaged in the cyclone. It is not safe for primary school children during high tide, because roads and fields are underwater. For this reason many parents have not been able to send their children to school.

Children are the most vulnerable group in all types of disaster, but there are no major educational programmes related to Disaster Risk Reduction (DRR) in primary or secondary schools in Bangladesh. Thus, teaching DRR in schools will help raise awareness and give better understanding not just among children and teachers, but in the community at large. At the same time, investing in strengthening school buildings will help reduce long-term costs. Appropriately built schools could be used as cyclone shelters, which could protect the community and children in particular, and ensure educational continuity after the event.

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Author Biographies

Sumana Sharmin holds a Bachelor degree in Urban and Rural Planning, which she received in November 2009. Snice then she has completed an internship at Rajdhani Unnyan Kartripakkha (RAJUK) (18 May–8 June, 2008) and attended the course "Professional Training on Disaster Management" (8–12 October 2009). She subsequently received a Postgraduate Diploma in Disaster Management, in March 2011. She has been working as a Planner at Concord Architects and Engineers Ltd., part of the Concord Group, since July 2010. She is the author of a number of research papers, seminar papers, articles, etc., and plans further publications in the future.

Rumana Naznin also holds a Bachelor degree in Urban and Rural Planning, and is currently working towards a Master's qualification in Development Studies at Khulna University, Bangladesh. She has completed an internship on Action Aid (7–29 September 2008), worked as a Field Research Assistant for the UPPRP project, mapping urban poor settlements and vacant lands in 27 UPPR project towns in collaboration with CUS, funded by UNDP (September–November 2010), worked as a Junior Urban Planner at UTIDP, in collaboration with LGED (December 2010–March 2011). She is the author of a number of research papers, seminar papers, articles, etc., and plans further publications in the future.

Chapter 16
The Role of Mangroves in Disaster Mitigation: A Review

Seema Unnikrishnan, Anju Singh and Manoj Kharat

Abstract The aim of this chapter is to study the role played by mangrove ecosystems in minimising the impact of disasters like tsunamis, floods and cyclones. A comparison of the studies concerning effective mitigation of tsunamis and natural disasters by mangrove ecosystems was carried out for various countries, but with a special focus on India. A study of the role of mangroves across various states in India is also presented. The main findings based on the literature review are that mangroves occurring near the coast play an important role in the protection of the coast from the natural disasters like tsunamis, floods, cyclones, and rising sea levels, etc. The conclusion reached is that it is necessary for humans to realise the dangers and consequences of undermining the services provided by the coastal ecosystems in coastal protection and to conserve mangroves in every part of the world. The value of this chapter lies in presenting an exhaustive review of the role played by mangroves in mitigating disasters.

Keywords Mangrove · Tsunami · Cyclones · Floods · Disaster mitigation

S. Unnikrishnan (✉) · A. Singh · M. Kharat
Centre for Environmental Studies, National Institute of Industrial Engineering (NITIE), NITIE P.O., Vihar Lake, Mumbai, 400087 Maharashtra, India
e-mail: seemaunnikrishnan@gmail.com

A. Singh
e-mail: dranjusingh@gmail.com

M. Kharat
e-mail: manojkharat@gmail.com

W. Leal Filho (ed.), *Climate Change and Disaster Risk Management*, Climate Change Management, DOI: 10.1007/978-3-642-31110-9_16,

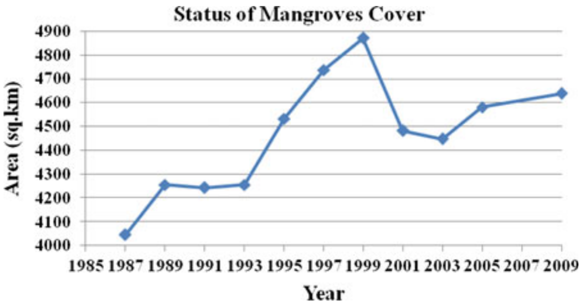

Fig. 16.1 Trend of mangrove cover in India (*Source* FSI 2009)

Current Status and Trend of Mangrove Cover in India and Around the World

The five countries with the largest net loss of mangrove area during the period 2000–2010 were Indonesia, Australia, Burma, Madagascar and Mozambique (FRA 2010). An alarming 17 %, or 3.2 million hectares, of mangroves has been lost since 1980 (18.8 million ha) (FAO 2007). The positive trend during the 2005–2010 period reflects an increased awareness of the value of mangrove ecosystems.

Mangrove forests are scattered along the 12,700-km-long Indian coastline with about 80 % of India's mangroves located along the East coast, which is home to more gentle slopes and rich estuaries favoured by mangroves (FAO 2007). The Sundarbans in West Bengal account for a little less than 50 % of the total area of mangroves in India (FSI 2009). The trend for areas of mangrove vegetation from 1987–2009 is shown in Fig. 16.1.

Role in Carbon Sequestration and Disaster Mitigation

Mangroves are important carbon sinks, and sequester approximately 25.5 million tonnes of carbon every year. They also provide more than 10 % of essential dissolved organic carbon that is supplied to the global ocean from land (Spalding et al. 1997).

Carbon sequestration can be defined as the capture and secure storage of carbon that would otherwise be emitted into or remain in the atmosphere or to prevent, carbon emissions produced by human activities from reaching the atmosphere by capturing and diverting them to secure storage. It is through this process that agriculture and forestry practices remove CO_2 from the atmosphere (Melkania et al. 2007). Carbon sequestration also provides associated ecosystem benefits such as increased soil water holding capacity, better soil structure, improved soil quality and nutrient cycling, and reduced soil erosion (Derner and Schuman 2007).

Role of Mangroves in Protection Against Tsunamis

Tsunamis are described as a chain of fast moving waves that are generated when water in the ocean or even a lake is rapidly displaced due to events such as an earthquake, a volcanic eruption, a landslide or the impact of a meteorite (Tibballs 2005). Large tsunamis have been known to rise over 100 ft, while tsunamis 10–20 ft high can be very destructive and cause many deaths and injuries (NOAA website). Tsunami waves have a small height offshore, and a very long wavelength ranging to hundreds of kilometres, because of which they are not easily detected out at sea (Kowalik 2004; Mojfeld et al. 2000). They can also deflect obstacles and travel in different directions (Yeh et al. 1994).

The majority of the human population in the world is concentrated in coastal areas which are more vulnerable to natural disasters such as floods, wind generated waves, tsunamis and storm surges (Ramesh and Ramachandran 1999). Although mangrove ecosystems provide various advantages, the most important one is the protection against coastal disasters and tsunamis (Osti et al. 2009).

Mangroves prevent coastal erosion, and act as a barrier against typhoons, cyclones, hurricanes, and tsunamis, helping to minimise damage done to property and life (Upadhyay 2002; Dahdouh-Guebas 2006; Pearce 1996; Mazda et al. 1997). Mangrove tree species that inhabit lower tidal zones can block or buffer wave action with their stems, which can measure 30 m high and several meters in circumference (Dahdouh-Guebas 2006). Mangroves defend the land from wind and trap sediment in their roots, maintaining a shallow slope on the seabed that absorbs the energy of tidal surges (Pearce 1999).

Mangroves protect the coast against waves, currents and storms, and from coastal erosion. Mangroves are like live sea walls, and more effective than concrete wall structures (Kathiresan 2000). Some of the mangrove species, such as Rhizophora, act as a physical barrier against tidal and ocean influences and shield the coast by means of their large above-ground aerial root systems and standing crop (Dahdouh-Guebas 2005). It is also found that these mangroves species seem to act as a protective force towards this natural calamity (McCoy et al. 1996).

In India and the Philippines, villagers tell how they have been protected from tsunamis, cyclones and other natural disasters in locations where mangroves are intact, but suffer where mangroves have been converted to shrimp farms or were lost due to human activities (Dahdouh-Guebas et al. 2005; Walters 2004). In Vietnam, mangroves have been observed to limit damage from tsunamis and cyclone waves and have led to large savings on the costs of maintaining sea dykes (Asian Wetland Symposium 2006). In Chidambaram district in Tamil Nadu, India, the shore protection role of mangroves is recognised by local people where a 113 km^2 forest is used as a sacred grove and is traditionally known in Tamil as Alaithi Kadukal, meaning ‘the forest that controls the waves’ (WWF 2005). Remains of rows of mangroves planted by Maoris can still be seen in New Zealand with the aim of stabilising the coast, indicating that mangroves helped in coastal protection (Vannucci 1997).

Wave energy of tsunamis may be reduced by 75 % in the wave's passage through 200 m of mangrove (Massel et al. 1999). It has also been found that 1.5 km belt of mangrove may be able to reduce entirely a wave one meter high (Mazda et al. 1997).

Many observations suggest that mangroves also help to reduce the damage of a tsunami by dissipating the force of the tsunami and preventing the debris washed up by it (IUCN 2005a, b). In India, bathymetry and coastal profile were most important in determining the impact, but less erosion was observed in the Andaman Islands where mangroves were present than where there were no mangroves (Department of Ocean Development 2005).

63 tsunami events between 1750 and 2004 struck the Indian Ocean area and more than three wind generated waves struck per year (Dahdouh-Guebas et al. 2005). A satellite and field data study done by Selvam (2005) showed that mangrove forest plays important role in mitigating the outcomes of the tsunami disaster, especially in 2004. He showed that 30 trees per 100 m^2 might reduce the maximum flow of a tsunami by more than 90 %. Similar results were obtained by Hiraishi (2005) which showed that tsunami flow pressure can be reduced by increasing the density of the planted zone, reproduced by considering drag forces exerted by the individual trunk and leaf parts of trees.

Studies have shown that mangrove forests and certain other types of coastal vegetation can effectively reduce the impact of tsunamis on coastlines (Hiraishi 2003; Dinar et al. 2002; Hiraishi and Koike 2001).

Studies in Vietnam also demonstrate the usefulness of mangrove forests in coastal protection and their role in reducing the impact of coastal disasters like tsunamis (Mazda et al. 1997).

It is reported that the tsunami did less damage to lives and property in Tamil Nadu and in the regions of Pichavaram and Muthupet, which are both shielded with dense mangroves, than in areas where mangroves had been cleared or were absent (MSSRF 2005). Some researchers argue that mangroves do protect shorelines, but the scientific evidence of the study performed is not sufficient to provide certainty about role of mangroves in coastal protection (Cochard et al. 2008; Alongi 2008; Verma and Thampanya 2006; Kerr et al. 2006).

According to Chetenoux and Peduzzi (2007), mangrove forests are mainly located in sheltered areas, estuaries, and in protected bay areas. Therefore the assumption is that they were less impacted by tsunami waves, meaning that less damage is done where mangrove forests are prevalent. According to Bhalla (2007), mangroves do provide protection against tsunamis, but to a lesser extent than other biological features.

Role of Mangrove Forests in Flood Control and Flood Protection

It has been reported in literature that mangroves even protected villages and reduced death toll during floods and cyclones (Das and Vincent 2008).

A public policy instrument has to be adopted which considers options for mitigation of coastal hazards, and adoption of measures for restoration of coastal sand dunes with sufficient forested shelter belts backshore (Antonio and Jayakumar 2008).

The benefits of mangroves for shoreline protection and storm damage control have been estimated to run into tens of thousands of dollars per km^2 in Sri Lanka and Malaysia. Studies carried out in Vietnam show that the value over time of mangroves in protecting against extreme weather events lies around USD 5,000 per km^2 (IUCN 2006).

Role of Mangroves in Reducing the Impact of Cyclones

The Sundarbans mangrove forests to the west of the Ganges delta are the largest in the world extending up to 80 kilometres into the Bay of Bengal. They reduce the impacts of cyclones significantly (Hermann et al. 2007). In the case of tropical cyclones (one of the most devastating natural hazard in India and Bangladesh), the role of mangrove forests could be important in reducing the impact from this type of disaster (Kairo et al. 2001).

It has been reported in the literature that mangroves reduce cyclone impact by dissipating wave energy and decreasing the impact caused due to cyclone (Badola and Hussain 2005; Fosberg 1971). Das and Bellamy (2007) also concluded that mangroves played an effective role in providing protection against cyclones.

In one of the studies done by Narayan et al. (2010), it was concluded that mangroves have a definite positive effect on the port in terms of wave attenuation. From studies conducted worldwide it has been concluded that the cyclone could have been greatly lessened and much loss in life and property damage would have been avoided if healthy mangrove forests had been preserved along the coastlines of the delta (ASEAN 2009).

The role of mangroves in saving coastal lives and property has been well established during the last Orissa super cyclone at Bhitar Kanika and during the tsunami at Nagapattinam and Car Nicober (Ashok et al. 2008).

In Orissa, India, a powerful cyclone in 1999 and associated waves caused extensive economic damage and human mortality, but communities living near the mangrove ecosystems were protected by mangrove belts and were less affected (Mangrove Action Project 2005).

Table 16.1 Studies done by authors of different countries worldwide showing protection by mangroves from various disasters

Country	Author	Work done and analysis used
Thailand	Sathirathai (1998)	Highlighted the role and importance of mangrove forests in protection from coastal disaster and their economic importance to humans
Thailand	Aksornkoae and Hawanon (2005)	Suggested that, in order for the mangroves to effectively provide protection against the actions of waves, the width of the forest should not be less than 100 m from coastal shores
Thailand	Harakunarak and Aksornkoae (2005)	Assessment of mangrove forests value in protection against tsunami and their other benefits to human, as well as conservation of mangrove ecosystems and threats to them
Thailand	Vermaat and Thampanya (2006)	Method used—analysis of variance, showed the protective role of mangroves from coastal hazards
Sri Lanka	Gunawardena and Rowan (2005)	Indicated the protective role of mangroves and the threat to their future existence due to human activities, which could deprive us of their protective role
Sri Lanka	Batagoda (2003)	Benefits from mangrove forests and their role in storm and coastal protection
Sri Lanka	Jayatissa et.al (2005)	Studies showed that mangrove forests can be used as green barriers for protection against tsunami and tidal waves, and play a vital role in reducing the impact of tsunamis
Sri Lanka	Withanage (2005)	Emphasised the role of mangroves in reducing the impact of tsunami waves and providing protection
Sri Lanka	UNEP and Ministry of Environment and Nature Sri Lanka (2005)	Showed the effectiveness of mangroves in providing protection against coastal hazards
USA	McCoy et al. (1996)	Damaged caused to mangroves and their role in reducing the impact of hurricane and cyclones
USA	Dahdouh-Guebas (2006)	Method used—multivariate statistics, clustering
Vietnam	Mazda et al. (1997)	Effectiveness of mangroves in reducing waves—Mangrove age correlated to vegetation density
Japan	Danielsen et al. (2005)	Method used—none
Japan	Osti et al. (2009)	Showed the vital role of mangroves in reducing the impact of tsunami waves and providing coastal protection
India	Kathiresan and Rajendran (2007)	Method Used—linear regression on individual variables
India	Chaddha et al. (2005)	Comparative study of destruction caused by tsunamis in area with mangrove cover in comparison to those without mangroves
Finland	Tynkkyen (2000)	Indicated the loss of green barriers such as mangrove ecosystems and its consequences on coastal protection from coastal hazards
UK	EJF (2004)	Method used—none

(continued)

Table 16.1 (continued)

Country	Author	Work done and analysis used
–		Role played by mangroves in providing protection against tsunami disasters
Indonesia	Parish and Lee (2005)	Assessment of tsunami affected areas and role of mangrove forests in tsunami protection and consequences of loss of mangrove ecosystems on coastal protection
Indonesia	Parish (2005)	Loss of mangroves and consequences of this for coastal protection
Indonesia	Suwarni (2005)	Highlighted that it is necessary to replant mangroves and maintain them for protection from coastal hazards
London, UK	Environmental Justice Foundation (2006)	A report on the impact of mangrove loss and shrimp farm development on coastal land
Malaysia	Abdullah et al. (2005)	Indicated that the loss of mangrove ecosystems can prove dangerous as the protective benefits provided by it can be lost
Malaysia	Blasco et al. (2005)	Studied and recognised the importance of mangroves in reducing the impact of tsunamis
Malaysia	Eong (2005)	Mangroves are necessary for protecting against tsunamis and other coastal hazards

Table 16.2 Studies done by different authors in India showing how mangroves protected and reduced the impact of disasters

Author	Title/work done	Major findings
Upadhyay et al. (2002)	Human-mangrove conflicts: The way out. Current Science, Studies indicated that mangroves minimise damage due to protection Against tsunamis and cyclones	Concluded that the loss of mangrove species will have devastating economic and environmental consequences for coastal communities and may increase the risk, especially in those areas with low mangrove diversity or those subject to loss of mangrove species due to human activities
Satapathy (1999)	The Times of India News Service	Made an observation that areas with high density of mangroves were protected from tsunami and other natural coastal hazards
Chaddha et al. (2005)	The tsunami of the great Sumatra earthquake of M 9.0 on 26 December 2004—Impact on the East Coast of India	Studied the impact of tsunami waves in regions with and without mangroves and found that the damage in those regions with mangroves was less compared to those without mangroves
Padma (2004)	Mangrove forests can reduce impact of tsunamis	Made an observation that mangrove forests can help to reduce the devastating impact of tsunamis and coastal storms by absorbing some of the wave energy
Vidal (2005)	How the mangrove shield was lost?	Impact of tsunami was increased by tourism, shrimp farms, human activities and other industrial developments which have destroyed or degraded mangrove forests and other natural sea defences
MS Swaminathan Research Foundation (MSSRF) (2005)	Showed that how mangroves played an important role in saving lives in Pichavaram and Muthupet region of Tamil nadu from tsunami	The impact of tsunami waves was mitigated and damage to lives and property in the communities inhabiting the region was limited due to the presence of mangroves. It was found that wherever the mangroves had been regenerated, the damage due to the tsunami was minimal
Ganesan (2004)	Showed how mangroves protected people and animals from tsunamis in Nagapattinam district, Tamil Nadu	Found that mangroves saved lives by reducing the impact of waves as well as by preventing people from being carried away by the waves into the sea
WWF report, 2005	Tsunami update reported that mangroves and coastal vegetation helped protect the coast and saved lives in the Andhra Pradesh district of India.	WWF reported that mangroves along with other coastal ecosystems are very important for coastal protection against various natural coastal disasters

(continued)

Table 16.2 (continued)

Author	Title/work done	Major findings
Ravishankar (2005)	Ecological rehabilitation of post tsunami Andaman and Nicobar Islands indicated that mangroves played a vital role in reducing the impact of tsunamis	Found that even the regions near the epicenter having dense mangroves forest were protected from the devastating tsunami waves and the damage was less
Kathiresan and Narayanasamy (2005)	Coastal mangrove forests mitigated tsunami	Suggested that fishermen's hamlets should not be permitted within 1 km of the shoreline and that they should be encouraged to live behind dense mangrove or other coastal vegetation in elevated places
Kathiresan and Rajendran, 2007	Mangrove forests and tsunamis highlighted the importance of mangroves in reducing tsunami impact and saving lives	Found that mangrove ecosystems reduce the energy and velocity of tsunami waves and help in reducing their impact
Vermaat and Thampanya (2006)	Mangroves mitigate tsunami damage: A further response, reported that mangroves reduced tsunami impact and provided protection	Reanalysed the original data of Kathiresan and Rajendran (2006) with an ANOVAmodel with covariates and found that mortality and property loss were less where mangroves are present and also that mortality was strongly and significantly reduced with increasing elevation above mean sea level
Das and Vincent (2008)	Mangroves protected villages and reduced death toll during Indian super cyclone	Used statistical model including wide range of variables and data based on more than 100 villages. They found that villages with wider mangroves between them and the coast experienced significantly fewer deaths than ones with narrower or no mangroves
Roy and Krishnan (2005)	Mangrove stands of Andaman vis-à-vis tsunami	It was observed that most of the plants absorbed the impact of the tsunami but were affected and died due to continuous inundation and submergence

Fig. 16.2 Mangrove distribution in India

Comparative Review of Studies in Various States in India and in Other Countries

A brief comparative study of the role of mangroves in different countries is given in Table 16.1. We will see that the role of mangroves in minimising the impact of cyclones has become important mostly in countries like India, the USA and Sri Lanka which are most prone to cyclonic storms.

Fig. 16.3 Mangrove distribution in the world

Within the states in India shown in Table 16.2, the review shows that most of the studies have been carried out in the southern states like Tamilnadu and Andhra Pradesh, and in the Islands of Andaman and Nicobar. Figures 16.1 and 2 show the distribution of mangroves in India and around the world (Fig. 16.3).

Findings and Conclusions

From the literature review that has been carried out, it has been ascertained that mangroves play an important role in coastal protection against various coastal disasters, therefore coastal ecosystem restoration and protection of mangroves forests worldwide is an important issue. Loss of mangrove habitats would have adverse impacts on water quality, coastal protection from waves and storms, and subsequent effects to fishery production and tourism associated with fishing and healthy estuaries. Population awareness is an important issue in this case. Governments should continue monitoring at local level, and research, conservation and restoration programmes should be undertaken. The conclusion reached is that it is necessary for people to realise the dangers and consequences of undermining the services provided by the coastal ecosystems such as mangroves in coastal protection. The review has discovered that mangroves play a very positive role during disasters such as tsunamis, floods and cyclones. Every effort should be taken by governments and the private sector of countries with large coastal areas to conserve and restore mangrove ecosystems. The review clearly underlines the valuable role played by mangroves in reducing the impact of various disasters.

Participative management of mangrove ecosystems with the active support of local communities can put to the test in various parts of the world.

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Author Biographies

Dr Seema Unnikrishnan has worked in the faculty at NITIE for the past 17 years. Her present title is Associate Professor, Completed Doctoral [fellowship of NITIE] in the area of hazardous waste management. She worked for 3 years before joining NITIE on the Central Pollution Control Board, and has written several research publications in the field of environmental management. She has been involved in teaching subjects such as Disaster Management and Law for the past 17 years. Areas of research: hazardous waste management, cleaner production, disaster prevention and management.

Dr Anju Singh received a PhD from the Centre for Environmental Science and Engineering (CESE), IIT Bombay. He worked at the IIT Bombay as a scientist and consultant and successfully carried out internationally and/or nationally sponsored consultancy projects at the Centre for Environmental Science and Engineering (CESE) and at the Regional Sophisticated Instrumentation Centre (RSIC). He is currently working at the faculty at NITIE and has been involved with teaching, training and research in Environment Management for the past 17 years. She has had more than 60 papers published in journals and for conferences.

Mr Manoj Kharat has a Master's in Organic Chemistry from the University of Mumbai, 2009, and has been working at the Centre of Environmental Studies since May 2010 as a laboratory and technical assistant. He has 2 months of industrial experience as a trainee at the Formulation Department of Associated Capsules Ltd.

Chapter 17
Vulnerability Assessment for Rural Settings: Applicability to Developing Countries

Abel Niyibizi, Aquila Mpeirwe and Susan Ajambo

Abstract It is now widely accepted that climate change will lead to intensification of the global hydrological cycle and will subsequently impact on regional water resources. Variability in climate conditions in Uganda is already having major impact on food security due to prolonged drought, high temperatures, floods and landslides that have lately been prevalent, especially in the northern region. This region has recorded consecutive years of crop failure and low livestock productivity due to erratic weather conditions and inadequate rainfall, which has impacted negatively on food security in the region with records of famine and hunger in some districts during the 2000s. With the smallest number of natural water resources, northern Uganda has been over-dependent on rainfall and ground water sources for its water requirements. Prolonged temperature increase is likely to exacerbate the problems of the already difficult water balance faced in the region and rainfall patterns have already started changing with precipitation being just above the evapotranspiration during the rainy season but the trend quickly reverses at the onset of the dry seasons. This paper aims to illustrate the practical applications of vulnerability assessment frameworks for rural settings in developing countries, based on an ongoing water harvesting project for rural smallholder farming systems in northern Uganda, whose main objective is to improve farm water management systems for enhanced agricultural productivity and poverty alleviation. This paper examines the applicability of vulnerability

A. Niyibizi (✉) · A. Mpeirwe · S. Ajambo
Petro Systems Limited, 8 Pilkington Road, Suite 35 Colline House, P.O. Box 53229
Kampala, Uganda
e-mail: niyibizi.abel@gmail.com

A. Mpeirwe
e-mail: ampeirwe@yahoo.com

S. Ajambo
e-mail: sue_achola@yahoo.com

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assessment frameworks and methodologies to such poverty-ridden rural settings in Uganda, which can be classified as a developing country. Participatory methods were used to collect data using a combination of adaptation and participatory tools from climate vulnerability and capacity analysis (CVCA) and community-based risk screening tools for adaptation and livelihoods (CRiSTAL) as decision support tools to analyse the vulnerability assessment. Results obtained by qualitative analysis show that there is high vulnerability to floods, HIV/AIDS, and anthropogenic activities, notably including civil wars and cattle rustling. The paper concludes that a combination of vulnerability assessment tools can give more rational and realistic results, and that efforts should be made to take stakeholder inputs into consideration while developing and applying the vulnerability assessment tools. It is recommended that vulnerability assessment tools for developing countries be standardised for ease of replication and applicability.

Keywords Adaptation planning · Climate change · Water stress · Smallholder farming systems · Vulnerability frameworks

Introduction

African economies are expected to be most affected by climate change and yet are least prepared to deal with its effects (UNJCCP 2010), and Uganda, which remains one of the poorest countries in the world, is no exception. With 38 % of its population living below the poverty line, poverty remains a common phenomenon (Forum Syd 2007). While rural poverty in the country has generally decreased by 18 % since 1992, the situation has been different in the northern region where poverty increased from 61 to 67 % during the period from 1997 to 2000 (Forum Syd 2007).

Uganda's average gross national income is much lower than that in developing countries and the level of adult literacy is still below 70 %, but this is also coupled with sex disparities in literacy rates with 79.5 % of the males being literate compared to a mere 60.4 % of the female population (Forum Syd 2007). This factor is very significant in adaptation planning and implementation considering the fact that women still provide most of the farm labour in the country, especially the northern region.

Consequently, Uganda has low adaptive capacity, in both financial and human resources, to cope with the effects of climate change, although there is a high level of commitment to actively participate in global climate change processes (Twinomugisha 2005; UNFCCC 2007). The Ugandan economy and its population's welfare are intricately linked to the natural environment by virtue of their high dependence on primary production, and are thus highly vulnerable to climate variability and change (UNJCCP 2010). Empirical evidence of this is based, amongst other things, on an international climate risk report that identified Uganda as one of the most vulnerable countries in the world (CIGI 2007). It is also stipulated that the warming of the global climate system is now unequivocal (IPCC 2007a). The main factors contributing to this kind of situation have been highlighted (Komujuni 2009) as fast growing population coupled with poor social and physical infrastructure, as well as haphazard settlements, with rural communities more prone to the adverse effects of climate change impacts, mainly due to their lower ability to cope and lower adaptive capacities, in addition to less resilience (Komujuni 2009).

Northern Uganda, being one of the most climate-sensitive areas of the country, faces extreme events, notable amongst which are drought and floods. This paper aims to assess the vulnerability to climate change based on a study being carried out in the northern region, which has the goal to develop and implement some appropriate water harvesting and conveyance technologies to enhance agricultural productivity in this region, whose major economic activity is rain-fed agriculture and which suffers water scarcity with exhaustive exploitation of groundwater resources, due to limited surface water resources.

Climate Impacts and Implication for Food Security in Uganda

The existing climate models predict a high temperature increase of up to 4.3 °C by 2080 but this could even be higher if the levels of greenhouse gas (GHG) emissions register a high increase. This is because the previous predictions of future temperature increase were based on the medium high scenario for GHGs.

Impacts of climate variability have already been registered, for example, Twinomugisha (2005) summarises the impact of the El Niño Southern Oscillation (ENSO) of 1997–1998 as having a death toll of 522 people, seeing 11,000 people hospitalised and treated for cholera triggered by El Niño induced floods and landslides, accruing an estimated death toll in flood-related accidents of 1,000 people, and forcing about 150,000 people to be displaced from their homes. The estimated damage to infrastructure totaled around USD 400 million, whilst about 300 ha of wheat were destroyed in Kapchorwa. There was flooding of tea estates, making tea picking difficult, as well as a drop in coffee exports of 60 % due to a disrupted transport system. There was also an infiltration of water resources and flooding of some pumping stations. The Ugandan Government's report to the UNFCCC notes that while there was loss of monetary value in the agricultural sector also due to inaccessible markets, these were not calculated but could add up to hundreds of millions of dollars (UNFCCC 2002).

The cattle corridor that runs from the north-east to the south-west has been identified as the most climate vulnerable area in Uganda due to its fragile ecosystems. It suffers from extreme weather events, notably floods, drought and landslides. This corridor also suffers from the impacts of high population growth and conflict over grazing land with settlers. Lira district is likely to experience challenges mainly due to low adaptive capacity should Uganda start implementing adaptation projects.

Uganda has developed its national adaptation programmes of action (NAPA) with nine prioritised areas for climate change adaptation, and also focuses on indigenous knowledge documentation and awareness creation, farm forestry, water resources, weather and climate information, policy and legislation, land and land use, health and infrastructure (UNJCCP 2010). While NAPA is expected to provide a quick channel for communicating urgent and immediate adaptation needs, little progress has been in implementation to date mainly due to a lack of funds and lack of institutional capacity to prepare detailed proposals and mobilise funding (UNJCCP 2010).

Smallholder farming systems are poised to benefit from appropriate technologies for harnessing water for production in both crop and livestock systems, although implementation has been rather slow, mainly due to a delay in the release of funds.

Climate Change in Uganda: The Imperative to Act

Uganda's average temperatures are expected to increase by between 0.7 and 1.5 °C by the 2020s (Hepworth and Goulden 2008; Government of Uganda 2009a). A review of the IPCC modelling outputs also predicts a significant increase in mean annual rainfall beyond 2060, with a significant shift in the rainfall season to December through February, which are otherwise dry months. For a medium to high emissions scenario and taking the average of different model results, annual rainfall increases have been as up to 7 % by 2080 with the December to February rainfall increase of 13 % by 2080. Worst of all, changes in the severity and frequency of extreme events (drought, floods, landslides, storms and heat waves) are expected although little is known about the nature of these changes, with some models suggesting between 20 and 30 % increase in extreme wet seasons for a medium CO_2 emissions scenario. With this shift in seasonality of rainfall in the future, the current wet season for the country is expected to shift forward in time both for the short and long rainy seasons, with a likely extension of the former and considerable variability in rainfall totals, much of which has been linked to El Niño South Oscillation (ENSO) (Hepworth and Goulden 2008).

However, climate change impact is likely to be most felt through changes in variability rather than the long-term shift in the average conditions, which implies that uncertainty about changes in variability will result in uncertainty regarding the extent of impacts (Hepworth and Goulden 2008).

Existing literature analysis concludes that Uganda's temperatures are likely to increase by up to 1.5 °C in the next twenty years and by up to 4.3 °C by 2080, while changes in rainfall patterns and total annual rainfall, though expected, are less certain than changes in temperature. These changes look set to increase the frequency and severity of natural impacts, notably glacial melting, droughts, floods and landslides and have serious socio-economic implications with regard to food security, health and poverty. Early warning signs have already been manifested by glacial melting at Mount Rwenzori, where recession of icecaps has been estimated at up to 40 %, compared to the 1955 cover (Oxfam 2008). The retreat of the ice caps continues by tens of metres each year mainly due to an increase in temperatures.

Assessing Vulnerability to Climate Change: Concepts, Frameworks and Methodologies

A number of studies (e.g. Nair and Bharat 2011; Santiago Olmos 2001; Nkem et al. 2007; Malone 2009; Adelekan 2009; Warrick 2000; Koverts et al. 2003; Thornton et al. 2006; MacKendrick and Parkins 2004; SSN Tanzania Adaptation Team 2006; Fussel 2007; Chandra 2011; Kasperson and Kasperson 2001; Cutter 1996) have suggested frameworks for assessing vulnerability to climate change.

There is therefore a variety of approaches, frameworks, methods, and tools for assessing climate change impacts and vulnerability, and to prepare adaptation techniques.

Vulnerability assessment frameworks are step-by-step methods that prescribe an entire process for a vulnerability assessment exercise and offer broad strategic approaches (Nair and Bharat 2011). The concepts are closely tied to the frameworks as approaches to the assessments, while the methodologies mainly distinguish the main tools used in data collection and analysis of vulnerability assessment results.

Effective vulnerability assessment frameworks should stress relationships between issues such as sensitivity, exposure, impact, adaptive capacity, vulnerability and adaptation assessment exercises (e.g. Nair and Bharat 2011).

Impact-orientated or first generation frameworks mainly deal with how great the impact of climate change might be, so as to know how much urgency the mitigation agenda or the stabilisation of greenhouse gas (GHG) concentrations in the atmosphere is to be accorded (Nair and Bharat 2011). The models or frameworks are generally based on General Circulation Models (GCMs) or Atmospheric-Oceanic Circulation Models (AOCMs). Second generation impact assessment models deal with the modelling impacts on economic sectors such as agriculture, water, forestry, and health (Nair and Bharat 2011). This is generally followed by a combination of present climate variability and resultant vulnerability along with future climate change and vulnerability (Nair and Bharat 2011). Climate change vulnerability assessment frameworks begin the assessment of current climate variability and adaptation (or maladaptation) followed by projection of future impacts, vulnerability, and adaptation based on the present conditions. New methods, frameworks, and guidelines are currently being developed to facilitate second generation vulnerability assessment approaches. Most of the ongoing work includes a blend of first and second generation approaches. Tools for data collection using these approaches are comprised of sophisticated approaches to socio-economic scenarios, stakeholder participation, adaptation policies, and measures for assessment and strengthening of adaptive capacity.

Vulnerability assessment frameworks can also be partial or have particular research orientation prescribing approaches to assessments of vulnerability (Nair and Bharat 2011). There are also vulnerability assessment tools mainly used for data collection and analysis and these are generally applicable to multiple sectors and address a particular stage of an assessment such as GCM downscaling, socio-economic scenario building or decision-making (see e.g. Kasperson and Kasperson 2001; Cutter 1996). The application of robust decision-making tools based on multi-criteria in combination with a systematic optimisation approach is expounded. This combination approach is meant to provide more robust solutions in vulnerability assessment exercises.

Other approaches to vulnerability assessment are based on subject matter, spatial scale or chronology of the assessment. The frameworks based on these approaches are resilience-driven, scenario-driven or vulnerability-driven respectively (Nair and Bharat 2011). Examples of scenario-driven frameworks include vulnerability and adaptation to climate change in small island developing states (UNFCCC 2007) and comprise mainly vulnerability of place (Wisner 1993; Watts and Bohle 1993; Briguglio 1995; Hewitt 1997). Assessment here is centred on economic, geographic and socio-political factors. Place identity is relevant to the case of developing countries since it is broadly concerned with climate change and global warming, as well as ecological and technological constraints, mainly common to these countries due to their high dependence on natural resources, primary production and low adaptive capacity. Specific vulnerability assessment frameworks with this kind of approach include, for example, place-at-risk, hazard-of-place, or global risk vulnerability to climate change (see e.g. Cutter 1996; Hewitt 1997).

Applies the vulnerability assessment methodology based on a composite vulnerability index (CVI) to provide a broader view of vulnerability by incorporating the geographic environment into the susceptibility to physical and human pressures, and risk and hazards in temporal and spatial contexts. There are also top-down and bottom-up approaches.

Most crucial to vulnerability assessment framework development is the investigation of an operationally feasible and user-friendly methodology for developing countries, which are more economically and environmentally at risk from the impact of climate change. It is argued that this methodology should be replicable in similar geographic environment for evaluation and comparison and that the vulnerability assessment criteria should be simple and easy to apply, have a capacity for international comparison, be relevant, have a capacity to capture the causal structure of vulnerability, and be suitable for systematic assessment. One model of composite vulnerability index (CVI) used by Turvey computes CVI as the simple arithmetic mean of four indices, G_1, G_2, G_3, and G_4, where the indices are the proxy for inundation risk, the peripherality index measuring remoteness and insularity, urbanisation index given by the proportion of the population living in urban areas, and the index of vulnerability to natural disasters defined as the percentage of the population affected by natural disasters during a prescribed period respectively. This model can be adopted to assess vulnerability of small geographic locations in developing countries with rational revision of the parameters and this would provide thresholds of geographic vulnerability for districts and regions in a developing country like Uganda. Preliminary studies are under way to test this approach but owing to the space limitations of this paper, a detailed discussion of the results are not presented here. Also not discussed here are the various vulnerability assessment frameworks and methodologies due to the same limitations. For additional illustration on vulnerability assessment frameworks and methodologies, see, for example, Nair and Bharat (2011), Ziervogel et al. (2006), and Downing et al. (2008).

The concept of vulnerability is seen as central to understanding poverty, and reducing vulnerability to environmental stresses is fundamental to enabling sustainable livelihoods and thereby reducing levels of poverty (OECD 2001; DFID et al. 2002; Ziervogel et al. 2006). It is important that poverty is understood not purely as an economic condition but rather as a multidimensional concept including dimensions of economic, human, political, socio-cultural, and protective capabilities (OECD 2001), and that vulnerability is understood in terms of exposure, sensitivity, and resilience to stresses and shocks so that the important interaction between poverty and vulnerability is clearer (Segnestam 2004).

Conditions of poverty usually result in increased vulnerability, while this same vulnerability reduces people's ability to improve their position and reduce their levels of poverty, often pushing them into positions of chronic poverty (Segnestam 2004; Parker and Kozel 2004). The poor communities in northern Uganda live on marginal land with limited productive capacity and inadequate infrastructure (water distribution systems, roads and electricity) and are therefore more exposed to climate stresses such as droughts and floods. These people also have limited physical and financial assets, limited income and poor access to social amenities such as health care services and good schools. They are therefore likely to be more significantly affected by environmental stresses than the rest of the population in Uganda, who have more access to financial capital, social amenities and better farm management practices. The inadequate capacity to adapt to climate change stimuli in northern Uganda has been exacerbated not only by their low economic endowments, but also by other aspects such as poor nutrition, low access to health facilities, civil wars (viz. LRA war), inadequate access to decision-making and social networks due to prolonged alienation of this region as a result of the civil wars.

Drought has been cited as the most dominant effect of climate change in Uganda (NAPA 2007) and is believed to be increasing both in frequency and severity with severe droughts having been experienced between 1991 and 2000 (Government of Uganda 2007) the most recent drought having been experienced in 2008. These droughts are usually accompanied by consecutive years of crop failure and low livestock productivity due to erratic weather conditions and inadequate rainfall, impacting adversely on food security. Specifically, Uganda experienced serious droughts in 2002, 2004, 2006–2009 (UNJCCP 2010). Other examples of extreme events occurrence include the 2007 floods in Teso (One-World Sustainable Investments 2008) that resulted in the displacement of over 50,000 households with subsequent increase in food insecurity due to loss of both the first and second harvests (NEMA 2008) in addition to severe damage to infrastructure, water and sanitation facilities. Flooding has also recently been experienced in the Butaleja district in 2010, which submerged infrastructure, notably roads and bridges, households and crop fields, in addition to loss of lives (OCHA 2010). The same year witnessed the occurrence of landslides in the Bududa district following heavy rainfall, which buried three villages resulting in numerous deaths and the displacement of hundreds of households, the destruction of two schools and severe damage to the main health centre in the district.

Climate change has general and sector-specific impacts, notably socio-economic impacts on health, water, agriculture and food security, infrastructure and economic development (Government of Uganda 2009a; Hepworth and Goulden 2008; Boko et al. 2007; OCHA 2007; Oxfam 2008; NEMA 2008). These are currently of particular concern for Uganda.

Planned adaptation in northern Uganda has been inhibited by previous constraints in addition to the following:

– inadequate capacity to revert to alternative energy sources
– inadequate institutional and manpower capacity in meteorology and other issues related to climate monitoring
– inadequate meteorological data and equipment for meteorological monitoring
– low awareness of climate change and global issues
– inadequate funding for adaptation projects (Twinomugisha 2005).

Case Study: Vulnerability Assessment for Lira District: Amuca and Akia

The National Agricultural Research Organisation (NARO) is conducting research in the northern region that aims to improve farm water management systems through the development and promotion of water harnessing and conveyance technologies. This is in line with the Ugandan government's plan for the modernisation of agriculture. The project is being implemented by Petro Systems Limited which is a private firm, in line with the existing policy of using public private partnerships to enhance the quality of research outputs and promote accelerated scaling up of the outputs through the most relevant uptake pathways. The project has been pilot-tested in Lira district through two case studies in Amuca and Akia, whose vulnerability to water stress had been identified as "demanding" by the national agricultural advisory services (NAADS) at the district level.

The initial focus of this project was to provide improved water harvesting and conveyance facilities for enhancing agricultural productivity among smallholder farmers in Lira, Apac, Pader, Kitgum and Gulu districts where drought was affecting farming systems and livestock productivity. The project carried out participatory vulnerability assessment in close collaboration with district disaster management coordinators (DDMCs), district water officers, and local leadership and planning committees to identify sites for water and sanitation infrastructure and target interventions appropriately. A combination of adaptation and participatory tools from climate vulnerability and capacity analysis (CVCA) was used to enable prompt collection of data and obtain information on regional, ecological and country-wide climate context for the project area. Essentially, the tools used were community-based tools risk screening tools for adaptation and livelihoods (CRiSTAL) as decision support tools to analyse the vulnerability assessment data collected using CVCA. The approach enabled the project to integrate climate change adaptation at community level and identified adaptation actions for improving resilience to climate-related hazards, notably drought (FAO, 2010, Climate change adaptation measures for Uganda: a concept note focusing on eastern and northern Uganda. Draft FAO funded NARO report, "Unpublished"). Supplementary tools for data collection and analysis used by the Office of the Prime Minister (Komujuni 2009) were also used. Multi-stressor vulnerability assessment in Lira was performed using a holistic approach to assess vulnerability due to political instability, notably the LRA war that lasted for about 20 years in this region and resulted in the internal displacement of more than 1.5 million people. It cannot be over-emphasised that the civil population was forced to abandon their homes and this created issue of food insecurity, unhygienic conditions in over-populated Internally Displaced Persons (IDP) camps, and aggravated poverty levels. Secondary impacts included hunger, malnutrition and poverty. The water harnessing and conveyance project was targeted for Amuca and Akia sub-counties where drought is known to have the greatest impact across multiple sectors of livelihood resources, mainly water resources, health, and food production facilities.

Drought was found to have the greatest impact on natural resources, notably water and land, with significant impacts discovered on farmer groups and liquid assets. Wind appeared to have had less influence on the community and livelihood resources but greater impact on natural resources, notably land, water and forestry resources in addition to agricultural skills and food production facilities. Land and good health were identified as the most significant resources that were likely to impact on the success of the existing and proposed coping strategies. Natural resources were generally found to be a continuing theme in the identified importance of livelihood resources on the success of coping strategies.

Existing coping strategies practiced in the region together with suggestions for sustainable adaptation are summarised in Table 17.1 alongside respective hazards and impacts. The study envisages that domestic water constraints will be overcome by increased funding to construct better protected wells, while adaptation to drought needs sustainable interventions, notably irrigation and valley (earth) dams. Improved building designs will enable adaptation of homesteads to floods, while improved public infrastructure such as improved drainage on roads would also enhance adaptation to floods. Hazard assessment (Table 17.2) shows the main causes of conflict were greed and nepotism while floods were caused by heavy rainfall. The severity of the disaster in previous years is summarised in Table 17.3

Table 17.1 Summary of climate hazards, their impacts and coping strategies for Akia and Amuca sub-counties in Lira district

Hazard	Impact	Current coping strategy	Alternative coping strategy
Drought	Famine	Food rationing	Diversification of income generating activities
	Water shortage	Alternative water sources	Drilling bore holes
	Low crop yield	Cultivating wetlands	Irrigation
	Loss of livestock to heat stress	Migration (Nomadic pastoralism)	Construction of valley dams
Floods	Water-borne diseases	Use of a combination of vaccination, traditional and modern medicine	Use of traditional medicine
	Destruction of physical infrastructure	Relocating settlements to higher ground	Improved building designs using fencing as barrages against floods
			Improved road drainage systems
	Destruction of crops leading to famine	Planting fast yielding (early maturing) crops	Improved food storage
Strong Winds	Destruction of houses	Reconstruction of houses	Planting windbreaks
	Destruction of crops	Buying food	Promotion of agro forestry
	Air-borne diseases	Going to hospital	Traditional medicine

Source Survey data

while seasonality calendars are shown in Table 17.4. The seasonality calendars were found to be unreliable, and therefore traditional knowledge systems applications in farming practices had been demystified by climate change. Extreme events had negative impacts on all categories of resources but notably for individual, natural, constructed, social and economic resources (see Tables 17.5–17.9). The study performed impact and cross-impact analyses and the results are presented in Tables 17.10–17.12.

Discussion, Conclusion and Recommendations

Discussion

Lira district, like other districts in northern Uganda suffered intensely from the impacts of human-induced or anthropogenic events, notable among which are civil strifes from the erstwhile Lord's Resistance Army (LRA), which resulted in the internal displacement of the rural population. This has greatly affected agriculture and livestock farming practices of the population of Lira which is mainly involved in subsistence or smallholder farming. Other anthropogenic factors were the cattle rustling of the Karimojong people who reside in the north-eastern part of the country but frequently attack neighbouring districts in the Lango region (where

Table 17.2 Hazard assessment

Hazard type	History	Force	Warning signals	Fore warning	Speed of onset	Frequency	When	Location	Duration	Severity
Floods	Heavy rainfall between August to October of every year.	Heavy rainfall	2 weeks of frequent heavy rainfall, over flowing streams and water logging	Heavy rainfall	When water logging is experienced and rivers begin bursting banks	Less frequent	Between August and October	Along river Moroto flood plains, Moroto County and Otuke County	4 months	Rivers bursting banks, Bridges submerged, homes and farm land destroyed
Cattle rustling	Throughout the year but most critical during drought	Karamojong rustlers	Border raids by the rustlers	Drought spell	Unpredictable	Less frequent	November to march, during dry spell	Otuke county especially Olilim, Orum sub counties which border Karamoja	3 months	Lives lost and Many cattle rustled
HIV/AIDS	It began 1982 and has affected largely all sections of the population	HIV/AIDS	Public campaigns	Window Periods	After two years, depending on ones' body immunity	frequent	Throughout the year	Entire District	Depending on one's body Immunity	Loss of life
WAR	Began in 1986 with UPA, Lakwena and LRA	Conflicts	News, Conscriptions, Suspicion	Intelligence reports, rumours	When war takes place and people killed	Less Frequent	unpredictable	Entire District	22 years	Loss of lives and property

Source Survey data

Table 17.3 Timeline/historical profile tool what severity has disaster had in the past 10 years?

Year	Disaster	High	Low
1997	War	*	+
	HIV/AIDS		*
	Rustling		
1998	War	*	+
	HIV/AIDS		*
	Rustling		
1999	War	*	*
	HIV/AIDS	*	
	Rustling		
2000	War	*	*
	HIV/AIDS		
	Rustling		
2001	War	*	*
	HIV/AIDS		+
	Rustling		
2002	War	*	*
	HIV/AIDS	*	
	Rustling		
2003	War	*	*
	HIV/AIDS	*	
	Rustling		
2004	War	*	*
	HIV/AIDS	*	
	Rustling		
2005	War	*	*
	HIV/AIDS		*
	Rustling		
2006	HIV/AIDS	*	*
	Rustling		*
	Malaria		
2007	HIV/AIDS	*	*
	Rustling	*	
	Floods	*	
	Malaria		

Source Survey data. Pluses denote anthropogenic (human-induced) events while asterisks denote events due to natural causes

Lira is situated) and Teso region, resulting into loss of their livestock. The population was also found to be poor in general, but the extent of poverty and impact on adaptive capacity has not been quantitatively assessed. Vulnerability to health impacts including water-borne diseases, HIV/AIDS and livestock diseases was also assessed and this area, just like other districts of Uganda, has a high prevalence rate for HIV/AIDS and susceptibility to water-borne diseases, as well as livestock diseases. Cross-impact assessment of vulnerability indicates that floods are the worst extreme events in Lira district followed by rustling, epidemics and HIV/AIDS respectively. This is evident from successive results from analyses of extreme events, their impact, severity and cross-impacts (Tables 17.10–17.12).

Table 17.4 Seasonality calendar

Months	Hazard	Activity (ies)
Jan	Dry spell, Bush Burning and strong wind	Opening up land, harvesting
Feb	Bush burning, Food shortage	Opening of land, small scale trade
Mar	Heavy rain	Planting
Apr	Heavy rain	Planting
May	–	Planting and weeding
June	–	Planting and weeding
Jul	–	Harvesting
Aug	Heavy rain	Harvesting, Second planting Season
Sept	Floods, Water Logging	Harvesting and second season Planting
Oct	Floods, water logging	Weeding
Nov	Dry spell	Weeding
Dec	Dry spell and strong wind	Harvesting

Source Survey results

Table 17.5 Impact of extreme events on economic assets

Elements at risk	Vulnerable conditions	Pressures	Underlying causes
FLOODS • Crops • Domestic • Animals Trade	Farming on flood plains Poor farming methods Lack of technology Settlement	Heavy rains Environmental degradation, farming in wetlands.	Population growth climatic change poor wetlands management poor innovation adaptation (technology) Corruption, poor drainage (dams) poverty, poor polices.
WAR • Trade • Agriculture	Fear for life Displacement	Conflict Politics	Bad policies Poor governance
CATTLE RUSTLING • Livestock • Farming/ crops	Bordering cattle rustling districts Escalating poverty	Greed Culture	Cultural differences Poor distribution of resources
HIV /AIDS • production	Displacement Abduction Polygamy	Nature Inadequate Information Immorality/ prostitution	Poverty War Poor treatment or lack of drugs stigmatization

Source Survey results

There were also some cultural beliefs about the hazards and risks, especially when they were likely to occur and possible causes. These ranged from human-induced due to greed, beliefs, nepotism, and natural causes. Tribal conflicts were common in the study areas in form of intrusion of the Karimojong who both come by force to graze on the land and are also known for their notoriety practices of cattle rustling. These are likely to exacerbate the already low adaptive capacity.

Table 17.6 Impact of extreme events on natural assets

Elements at risk	Vulnerable conditions	Pressures	Underlying causes
FLOOD • Farm lands because soil was washed away.	Farming on flood plains	Population growth Environmental degradation, heavy rains	Shortage of land, change in weather pattern
WAR • Environmental degradation	Deforestation Displacement	Fire Human beings	Politics Nepotism
CATTLE RUSTLING • Grazing land	Over growth of bushes in previously grazing land	Cattle rustlers(k'jongs)	Culture Greed
HIV/AIDS • Vegetation	Looking for herbs/ medicines for HIV/ AIDS	The need to find a cure for HIV/ AIDS	Failure by government ton find a solution Desperation by researchers to find a cure.

Source Survey results

Table 17.7 Impact of extreme events on constructed assets

Elements at risk	Vulnerable conditions	Pressures	Underlying causes
FLOODS • Homesteads • Roads • Bridges • Schools • Health centers • Water points	Buildings on low plains Poor technology Location of water points	Heavy rainfall Unplanned development	Rain storms, unplanned development, Poor technology, failure to follow construction guidelines
WAR • Infrastructure • Property	Conflicts	Conflict	Politics Marginalization Greed
CATTLE RUSTLING • Destruction of property	Bordering with rustlers Inadequate Protection	Insecurity	Greed Possession of fire arms Illiteracy (ignorance) Culture
HIV/AIDS • Lack of development	Death Poverty	Prostitution Moral decadence	Affluent society

Source Survey results

Conclusion

The existing vulnerability assessment frameworks use different criteria and approaches based on the different requirements of users but no particular framework is deemed superior to the other. However, it is necessary to select frameworks that consider stakeholders at each level to avoid conflict. Multi-sectoral

Table 17.8 Impact of extreme events on individual assets

Elements at risk	Vulnerable conditions	Pressures	Underlying causes
FLOODS • Tools • Property	Settlement in low plain area, around river banks.	Heavy rain fall	Deforestation Lack of technology
WAR • Brain drain • Human life • Education • Production	Poverty Weak state authority	Conflict	Nepotism Greed, marginalization
CATTLE RUSTLING • Human life •Livestock • Property	Weak state authority Presence of grazing land & water points	Poor governance Favourable climatic conditions.	Geographical location Drought Culture
HIV/AIDS • Human life • Human resource • Orphans	Exposure to risk of infection	Marriage Excessive sexual desire	Lack of awareness Distance and cost of HIV testing

Source Survey results

Table 17.9 Impact of extreme events on social assets

Elements at risk	Vulnerable conditions	Pressures	Underlying causes
FLOOD Displacement Accidents Death Cultures challenged Education Politics	Settlement along flood plains Poor sanitation Ignorance-rights, situations technology	Settlement on low plain areas population	Population growth Land disputes, deforestation for settlement and farming.
WAR • Displacement • Death • Culture • Property	Poverty State neglect Conflict	Conflict Integration	Nepotism Insecurity Greed, marginalization
CATTLE RUSTLING • Livestock • Displacement	Weak state authority Presence of grazing land & water points	Poor governance Favourable climatic conditions	Geographical location Drought Culture
HIV/AIDS • Human resource •Orphans • Production	Exposure to risk of infection	Marriage Excessive sexual desire	Lack of awareness Distance and cost of HIV testing

Table 17.10 Risk assessment matrix

Hazard	Vulnerability (unsafe conditions)	Capacities/ Resources	People's perception of the risk
Floods	Destruction of crops, buildings	A forestation, Avoid swampy areas/ low lands,	Natural
War	Destruction of Property, Loss of life Displacements	Peace talks, good Governance	Marginalization, Nepotism
Cattle rustling	Loss of livestock, Destruction of live	Deployed of ASTUs, Disarmament of the K'jongs	Traditional, greed
HIV/AIDS	Death, Orphans, Loss of human resource	Awareness of the dangers of HIV/ AIDs i.e How its spread	Spread by the rich

Table 17.11 Hazard ranking

Type of hazard	Severity	Frequency
Floods	Moderate	Often
HIV/AIDs	High	Rampant
War	High	Unpredictable
Cattle Rustling	Low	Irregular

Table 17.12 Pair-wise ranking matrix

Type of hazard	Floods	HIV	War	Rustling
Floods		HIV	War	Rustling
HIV			HIV	HIV
War				War
Rustling				

Summary

Hazard	Number of times preferred	Rank
Floods	00	4
HIV	03	1
War	02	2
Rusting	01	3

frameworks should be preferred to sector-specific frameworks to enhance a holistic or integrated approach while assessing vulnerability to climate change since the different sectoral constraints are interdependent. A combination of top-down and bottom-up approaches should also be adopted.

It is crucial to develop a summary of climate-related hazards, their impact on the community and existing coping strategies for these hazards for development of effective community adaptation strategies. The efficacy and sustainability of each coping strategy need to be determined in order to identify priorities for sustainable adaptation. Key livelihood resources are important for evaluating existing and potential adaptive capacity of the community (Ziervogel et al. 2006).

A participatory approach to community vulnerability assessment enables revised activities to be derived from the vulnerability assessment processes and the approach identifies ways of improving existing coping strategies or interventions. For example, agro-forestry is likely to be effective in crop protection, and crops near water points can be surrounded by a fence. Capacity building, for example training farmers, will fast-track implementation of effective crop calendars. Tree planting is essential for protection of homes and crops against heavy winds. Improving future housing designs will improve the catchment area for rainwater harvesting for home use and production of crops and livestock.

Recommendations

Vulnerability assessment and adaptation planning will be more effective if stakeholders and partners are actively engaged in all lifecycle activities right from the development of work plans. This will improve ownership and involvement or buy-in. Adaptation planning should emphasise efforts that make natural systems and society more resilient to climate change, notably crop diversification efforts, increased awareness, information and communications improvement for effective dissemination, improved water and agricultural management practices and general poverty alleviation efforts. Efforts must also be made to increase investments with a long life time, notably land use planning, agro-forestry options, plantation farming (reinvigorating coffee growing), and strengthening work on watershed management. Local government budgets should be refocused to incorporate climate adaptation, but the starting point for this should be at national level to ensure policy support of this.

Capacity building needs to be jump-started in order to benefit from existing funding opportunities such as the Global Environment Facility or carbon trade. There is thus the need to expand regional and national capacity in climate change with focus on climate modelling, especially within the meteorological department, as well as vulnerability assessment and adaptation planning in addition to advocacy of policy leadership engagement. This would subsequently call for mainstreaming climate change and adaptation into all national and regional projects, as well as all development plans of government ministries, government agencies, local governments, NGOs and development partner agencies

Multi-disciplinary and integrated approaches to vulnerability assessment and adaptation planning are needed to facilitate the effectiveness of project implementation. Emphasis needs to be placed on disaster risk reduction expertise.

Climate-proofed projects need to first be piloted by use of demonstrations prior to full scale activity implementation to minimise project failure. Full scale activities should incorporate feedback on lessons learned from such pilot activities that need to be modified or revised from the original project design.

There is a need to strengthen integrated watershed management through proven approaches such as reforestation, rehabilitation of wetlands and riverbanks, and the protection of water sources to improve the quality and quantity of water for multiple uses. Capacity building in water harvesting and distribution systems should focus on both macro and micro water harvesting and conservation for domestic and farm uses with particular emphasis on reinvigoration of soil and water management practices like mulching and terracing, the latter being applicable in highland areas like north-eastern Uganda.

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Author Biographies

Abel Niyibizi, MBA, BEng, MATPS, MICOH, is a researcher and consultant and works with Petro Systems Limited, a private firm dealing in research and consultancy in organisational development, integrated water resources management, sustainable and renewable energies, and climate systems analysis. He also collaborates with other researchers on several projects such as the Lake Victoria Research Initiative (VicRes) of the Inter-University Council for East Africa, and the National Agricultural research organisation. He is a member of a number of professional institutions including the African Technology Policy Studies Network (ATPS) and the International Commission on Occupational Health (ICOH). He has worked as project manager on several national and multinational programmes in Uganda, Rwanda and the Democratic Republic of Congo (DRC).

Aquila Mpeirwe, BSc, Dip. Agr., is an extension worker at the National Agricultural Advisory Services (NAADS) in Uganda. His areas of specialisation are farm equipment and animal bleeding. He has also worked as a production manager with British American Tobacco in the Farmer Programmes in Uganda.

Susan Ajambo, MA, BA, is an administrator with the Faculty of Information Technology and Computing at Makerere University in Uganda. She is a specialist in International Policy, Advocacy and Gender. Susan has worked as a social scientist on several projects.

Part II
Category 2

Chapter 18
A Sensitivity Study of Storm Surges Under the Conditions of Climate Change in the Elbe Estuary

Annette Schulte-Rentrop and Elisabeth Rudolph

Abstract For adequate adaptation strategies in the metropolitan region of Hamburg, a detailed understanding of the future hydrodynamic situation along the German Elbe is required. To achieve this aim, we will investigate the impact of a possible change in climate on storm surge water levels along the Tidal Elbe. The outcomes will help to identify vulnerabilities and aid the development of adaptation measures as part of the project KLIMZUG-Nord. A sensitivity study is carried out for probable future storm surge scenarios: based on historical events, the scenarios are derived by systematic variation of the key parameters influencing storm surge conditions in the estuary. A hydrodynamic numerical model is used to calculate water levels, currents and characteristic numbers in the Elbe whilst a meteorological model provides the local wind field. An increase of mean sea level, wind speed and river discharge influences the storm surge characteristics along the Tidal Elbe. A rise in mean sea level and wind speed leads to an increase in high water levels. Upstream of Hamburg, high water levels are mainly affected by river discharge. However, the sensitivity of water levels to the key parameters varies along the estuary. This behaviour is observed for two investigated storm surge types. The results enable us to identify vulnerabilities along the Tidal Elbe for a range of possible future storm surge conditions. It can be determined whether existing protection strategies will be effective or must simply be replaced by new concepts. In the future the present results can be assigned to climate change projections and estimations of occurrence.

A. Schulte-Rentrop (✉) · E. Rudolph
Bundesanstalt für Wasserbau, German Federal Waterways Engineering and Research Institute, Wedeler Landstrasse 157, 22559, Hamburg, Germany
e-mail: annette.schulte-rentrop@baw.de

E. Rudolph
e-mail: elisabeth.rudolph@baw.de

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Keywords Tidal Elbe · Storm surges · Climate change · Adaptation measures · HN modelling

Introduction and Objectives

Due to changing climatic conditions, several parameters influencing water levels during storm surges in the Elbe estuary are expected to change. In order to find a strategy for adaptation to climate change it is important to understand today's situation and analyse the possible future situations arising as a result of climate change. Several storm surge scenarios based on the historic storm surges of 3 January 1976 (SF76) and 28 January 1994 (SF94) are investigated. These scenarios are, as explained by Kosow and Gassner (2008), for example, not intended to represent a full description of the future, but rather highlight central elements of a possible future. Central elements influencing the height of a storm surge in the Elbe estuary include the water level of the German Bight at the mouth of the Elbe estuary, the wind over the Elbe estuary and the river run-off into the Elbe estuary.

Based on a sensitivity study, the influence of a sea level rise (SLR) in the North Sea/German Bight, a decrease in river run-off (Q) into the estuary, and an increase in local wind over the estuary on the highest water level (HW) along the Elbe estuary during storm surges can be analysed. The parameters mentioned are varied according to today's knowledge about expected changes to the future climate.

The aim of this investigation is to get a better understanding of the probable changes of water levels during storm surges along the Elbe estuary depending on parameters that might change in a future climate. The results will help to identify vulnerabilities in, e.g., shore protection along the Elbe estuary, especially in the metropolitan region of Hamburg, and give us a chance to work on adaptation concepts and mitigation of problems caused by possible climate change. We are also able to consider whether existing protection strategies will still be effective or, as formulated by Kwadijk et al. (2010), whether they must be replaced by new adaptation concepts when certain adaptation tipping points are reached. The results of this study will contribute to finding a possible future adaptation route (see Thames Estuary 2100 case study in Lowe et al. 2009) for the Elbe estuary even in the case of extreme changes.

Study Region

The River Elbe is the fourth largest river in central and western Europe with a catchment area of approximately 150,000 km^2. The river flows from its source in the Czech Republic over a total length of 1100 km into the North Sea near the city of Cuxhaven (Elbe km 725) (among others, IKSE 2005). The study region (defined

Table 18.1 Characteristic discharges at the gauging station Neu Darchau, Elbe km 536 (Deutsches Gewässerkundliches Jahrbuch 2010)

NQ	(low water discharge):	145 m^3/s
MQ	(mean discharge):	710 m^3/s
MHQ	(high water discharge):	1940 m^3/s
HQ	(highest discharge observed):	3620 m^3/s

(*Source* Deutsches Gewässerkundliches Jahrbuch 2010)

here as "Tidal Elbe") is located in the lowest part between Bleckede (Elbe km 550) and the German Bight (Elbe km 750). Along this stretch, the river exhibits tidal influence until the weir at Geesthacht (Elbe km 586) which represents an (artificial) tidal barrier. During periods of high discharge (>1100 m^3/s), and in the case of storm surges, the Geesthacht weir is opened so that the tidal signal can travel further upstream until Bleckede. Topography (width and depth) varies along the study region and significantly influences the hydrodynamic conditions. Near the mouth at Cuxhaven, the estuary has a width of 15 km. Further upstream, the width reduces to 3 km until Brunsbüttel (Elbe km 695), and finally down to 300 m at the Geesthacht weir. At the mouth, the water depths reach 20 m in the navigation channel, but decrease significantly on the tidal flats. Further upstream, between the cities of Cuxhaven and Hamburg, the river Elbe is maintained as fairway to the port of Hamburg. Here, water depths have been adapted for shipping purposes. Finally, upstream of Hamburg, water depths decrease to –5 m m.s.l. at the Geesthacht weir.

The discharge regime of the Elbe River is characterised by high fresh water discharges during winter and spring due to snow melting in the catchment area and low discharges in summer and autumn. Extreme summertime precipitation in the catchment area, however, can cause high discharge events as well. Table 18.1 shows mean characteristic discharges at the gauging station Neu Darchau (Elbe km 536) for the period 1926–2006 (Deutsches Gewässerkundliches Jahrbuch 2010).

Method

Historic and Possible Future Storm Surge Conditions in the Elbe Estuary

Due to its location at the German Bight the Elbe estuary is regularly subjected to storm surges. The region exhibits high vulnerability due to valuable agriculture and congested urban areas along the river and tributaries such as the port and city of Hamburg.

Along the Tidal Elbe the height of storm surges is influenced by different parameters: for example, tidal dynamics, mean sea level and wind over the German Bight, local winds over the estuary, the fresh water discharge into the estuary,

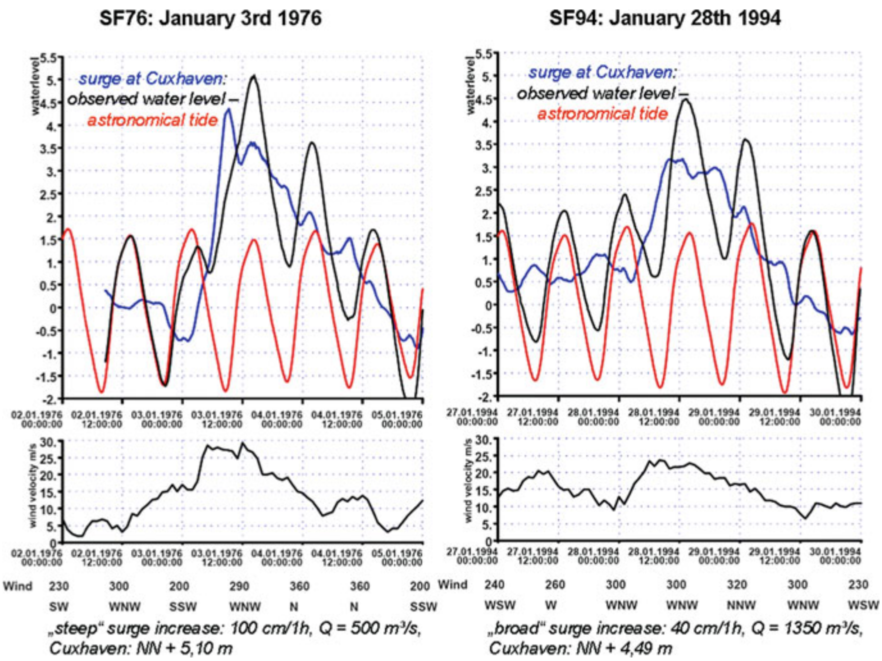

Fig. 18.1 Characteristics of the historic storm surges SF76 (*left image*) and SF94 (*right image*) with water levels at Cuxhaven and the wind situation at Scharhörn (measurement HPA)

as well as the river topography. Since the knowledge about the local future climate is still limited (among others, von Storch and Claussen 2011), we assume in a first step that the basic storm characteristics above the German Bight will not change in future. That means that storm surges that occurred in the past would also be likely to occur in future, but with higher wind speeds, for example. We therefore chose two historic storm surge events with different characteristics as reference scenarios; see Fig. 18.1:

1. 3.1.1976: This event caused the highest water levels ever observed in Hamburg, Hamburg St. Pauli: m.s.l. +6.45 m (No. 1 in Hamburg).
2. 28.1.1994: This event caused very high water levels: Hamburg St. Pauli m.s.l. +6.02 m (No. 2 in Hamburg). Westerly wind velocities were less severe than 1976 but freshwater discharge was high (1350 m^3/s).

Using the historic storm surge types of 1976 (“SF76”) and 1994 (“SF94”) as a reference, scenarios of probable future storm surges are derived: the independent key parameters influencing local storm surge conditions in the Elbe estuary are systematically varied according to the current state of knowledge about expected changes in a future climate. The independent variables are: (a) freshwater discharge into the estuary, (b) mean sea level in the German Bight, and (c) local wind over the

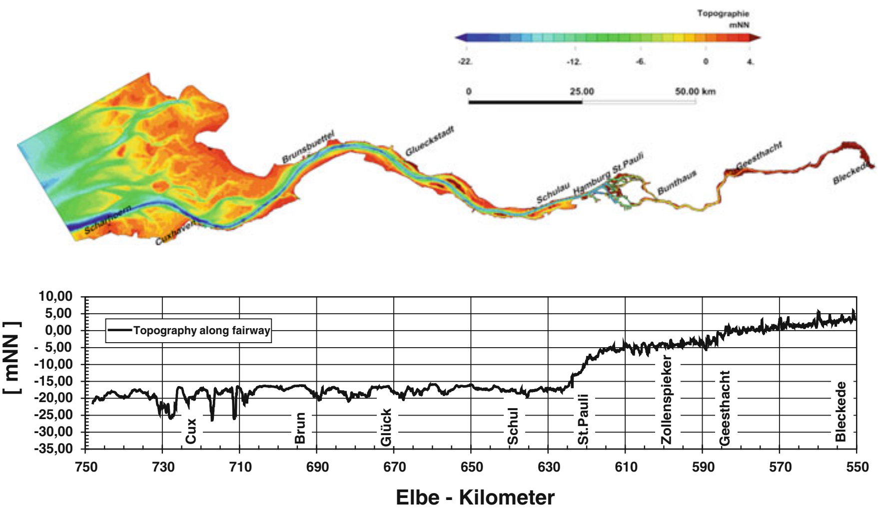

Fig. 18.2 Model area and topography of the Tidal Elbe

estuary. For the simulations of these scenarios, the hydrodynamic numerical (HN-) model UnTRIM (Casulli and Walters 2000) is used. The lateral boundaries of the model are formed by the dike line. The model topography represents the state of 2003 (see Fig. 18.2). The wind fields have been provided by DWD using the wind model MKW (Schmidt and Pätsch 1992). The input data for the seaward boundary has been generated by the North Sea model of BAW.

Investigated Variations of Freshwater Discharge ("Q")

The meteorological situation causing storm surges in the German Bight and snow melting or extreme precipitation in the catchment area are independent from each other and can occur in succession (Gönnert et al. 2005). It is therefore possible to vary the freshwater discharge during a storm surge.

In the present study, it is assumed that the present regime of freshwater discharges would not change in future. Given that highest discharges can be expected in the Elbe river during the storm surge season from September to April, the following rather high values of freshwater discharges are investigated for each storm surge type in addition to the measured values (SF76: 500 m^3/s, SF94: 1350 m^3/s):

2000 m^3/s
3000 m^3/s
4000 m^3/s.

Investigated Variations of Sea Level Rise in the German Bight

The global mean sea level is influenced by various processes, such as thermal expansion, melting of glaciers, gravity effects and re-distribution of water masses. Up to now, the value and future development of local sea level rise in the German Bight has always been uncertain. As a first approximation, we chose a range of SLR data from the literature. Moreover, we assumed that the basic characteristics of tidal dynamics within the German Bight will not be affected by SLR as suggested by Lowe et al. (2001). Thus, the rate of SLR is added as offset to the water level time series at the model boundary to the North Sea (see also Sterl et al. 2009). The following range of future SLR scenarios was investigated:

- 25 cm (observed sea level rise over 100 years in German Bight, NLWKN 2007)
- 80 cm (central values for German Bight, according to Gönnert et al. 2009; see also Solomon et al. 2007)
- 140 cm (Rahmstorf 2009)
- 200 cm (extreme value, own choice).

Investigated Variations of Local Wind Velocities Over the Elbe Estuary

Up to now, it is unclear whether the wind climate over the German Bight will change before 2100. According to the literature, an increase of wind velocities up to 10 % can be expected (Daschkeit 2011; Norddeutscher Klimaatlas 2010; von Storch et al. 2006). In order to cover these possible future conditions, the wind velocity fields of both storm surge types are increased by 5 and 10 % for this study. As mentioned above, wind direction is not modified.

Results

Influence of Freshwater Discharge on Water Levels

Figure 18.3 shows the simulated time series of water level for the reference scenario SF76 and variations of freshwater discharge ("Q") at two locations. Cuxhaven (Elbe km 725) located at the mouth of the estuary, represents the hydrodynamic conditions close to the German Bight whereas Schulau (Elbe km 640) represents conditions close to the city of Hamburg. Comparing the time series of Cuxhaven and Schulau shows that high water levels ("HW") increase in an upstream direction (e.g. BAW 2000). Regarding the influence of Q on water levels,

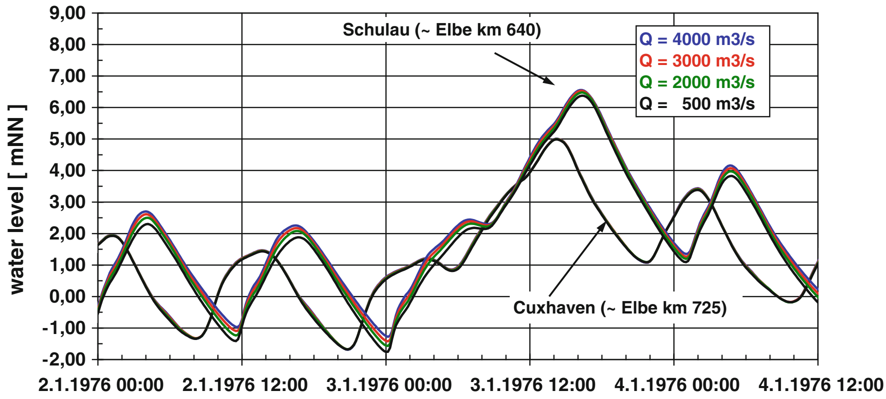

Fig. 18.3 Influence of freshwater discharge on water levels for locations Schulau and Cuxhaven for storm surge type SF76

the two locations exhibit different sensitivities: at Cuxhaven near the Elbe mouth, the influence of Q on water levels and high water time is low. At Schulau the water levels increase with increasing Q. Moreover, HW is reached earlier with increasing Q at this location, due to an increase in wave speed. The same behaviour is also observed for the SF94 storm surge type (not shown).

The larger influence of Q on water levels at Schulau compared to Cuxhaven is in accordance with BAW (2000) and Rudolph (2005). BAW (2000) investigated the hydrodynamic processes of the storm surges of 1976 and 1994 in detail with a hydronumerical model. They found that the mean flood or ebb flow at Elbe km 725 is more than ten times higher than the river run-off. The influence of Q on water levels near the mouth becomes negligible. At Schulau, 85 km upstream of Cuxhaven, the flood and ebb volume is increased by up to 35 % due to the discharge scenarios. Here, the river bed narrows and the cross sectional flow area decreases in comparison to the mouth. The influence of Q on the water levels can clearly be detected.

Along the fairway profile from the mouth (Elbe km 750) towards Bleckede (Elbe km 550) the water levels are analysed in order to find the highest water levels during storm surge HW. Figure 18.4 depicts HW for the SF76 and SF94 reference scenarios and Q variations along this profile. The HW of SF76 reference is higher than HW of the SF94 reference event (black lines in Fig. 4) in most parts of the estuary. As already indicated, HW increases along the estuary from the mouth upstream.

The spatially variable impact of Q on HW can be clearly observed. Three zones of different HW sensitivity to Q can be found:

1. Hamburg—Bleckede: HW is mainly influenced by Q and less by storm surge conditions in the German Bight. An increase in Q can cause an increase of several decimetres in HW. Upstream of Elbe km 570 for example, HW of the

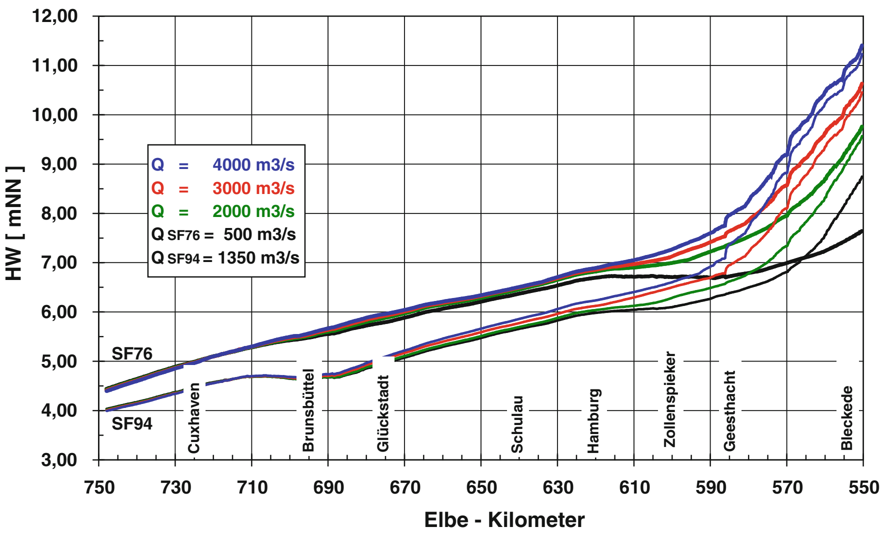

Fig. 18.4 Influence of freshwater discharge on high water for the storm surge types SF76 and SF94 along the Elbe estuary

SF94 reference event (black lines in Fig. 4) exceed those of the SF76 reference event due to higher Q during the SF94 storm surge;

2. Brunsbüttel—Hamburg: HW is less influenced by Q but an increase of several centimetres of HW due to an increase in Q can still be observed;
3. Elbe mouth—Brunsbüttel: HW is not influenced by Q; changes in HW due to Q variations cannot be observed.

Influence of Sea Level Rise on Water Levels

Figure 5 displays the simulated water level time series for the locations Schulau (thick lines) and Cuxhaven (thin lines) with variations of sea level rises (“SLR”) as described above for the SF76 type. The sea level rise at the boundary to the North Sea results in increasing water levels at both locations. High water occurs earlier in the SLR scenarios at these locations compared to the reference events. For example, regarding the scenario SLR + 25 cm, HW reaches Schulau approximately four minutes earlier than at the SF76 reference event. At SLR + 80 cm, HW is reached at Schulau approximately ten minutes earlier, while at SLR + 200 cm HW is reached at Schulau approximately 20 min earlier.

The influence of SLR on HW is shown in more detail in Fig. 18.6 and 18.7. Figure 18.6 presents HW in the study region for the SF76 reference event (Fig. 18.6, upper panel) and for the SLR scenario +80 cm (Fig. 18.6 lower panel).

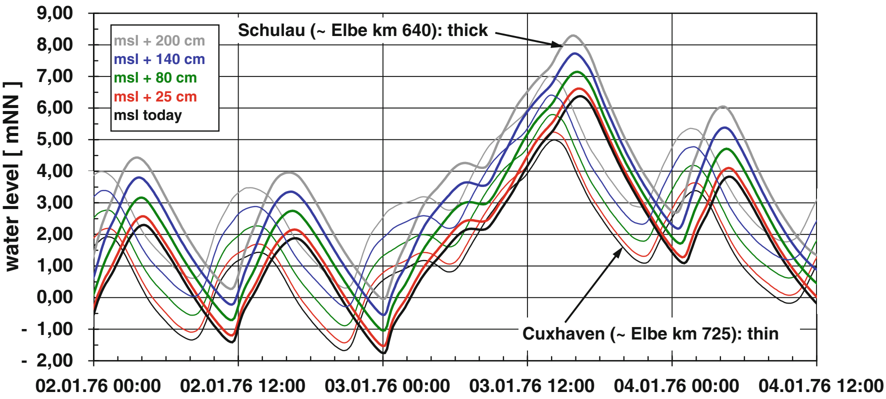

Fig. 18.5 Influence of sea level rise on water levels for locations Schulau and Cuxhaven for the storm surge type SF76

Figure 18.7 presents HW along the fairway profile for the investigated SLRs and both storm surge types. A rise in mean sea level at the seaward model boundary leads to rising HW along the estuary. Comparing the HW of the reference events (Fig. 18.6 upper panel; black lines in Fig. 18.7) with the HW of the SLR scenarios (Fig. 18.6 lower panel; coloured lines in Fig. 18.7), a parallel shift approximately by the amount of SLR can be observed: the signal of the North Sea mean sea level is more or less completely transferred until Geesthacht. Further upstream, the influence of the North Sea conditions decreases while the influence of Q increases. The analysis of the data reveals further that in the case of sea level rise, the storm surge signal moves beyond the model domain near Bleckede. Model extension in upstream direction will be necessary in order to detect the upper boundary of the storm surge influence in the river Elbe under a possible future rise in sea level.

Influence of Increased Wind Velocities on Water Levels

In this section, the influence of possible future wind velocities on the storm surge water levels in the Elbe estuary is investigated. Figure 18.8 depicts the simulated water level time series at the locations Cuxhaven and Schulau for the reference event SF76 (black lines, Fig. 18.8) as well as for two scenarios with increased wind velocities over the estuary by 5 or 10 %. Water levels are affected by increasing wind velocities: an increase in the original wind velocities of 5 and 10 % increases the water levels in the estuary during storm surges by several centimetres. The tides in times of low wind speeds before and after the storm surge (see Fig. 18.2) are not influenced by an increase in wind speed of 5 or 10 %.

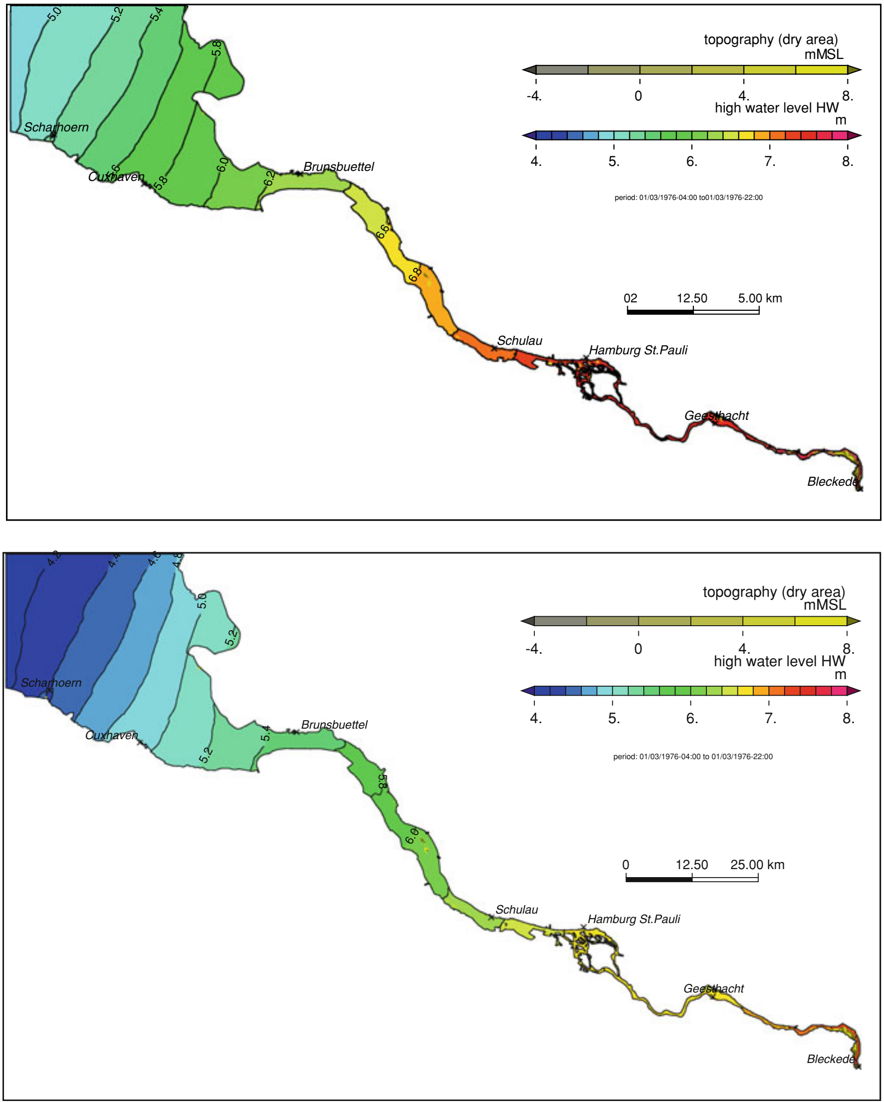

Fig. 18.6 High water in the study area for the reference scenario SF76 (*upper panel*) and the sea level rise scenario +80 cm of SF76 (*lower panel*)

Combined Variations of Sea Level Rise and Freshwater Discharge and Their Influence on Water Levels

This section investigates how high water levels ("HW") might be affected if the sea level rises ("SLR") in the German Bight and the range of high freshwater discharges ("Q") occur at the same time. As mentioned above, the processes

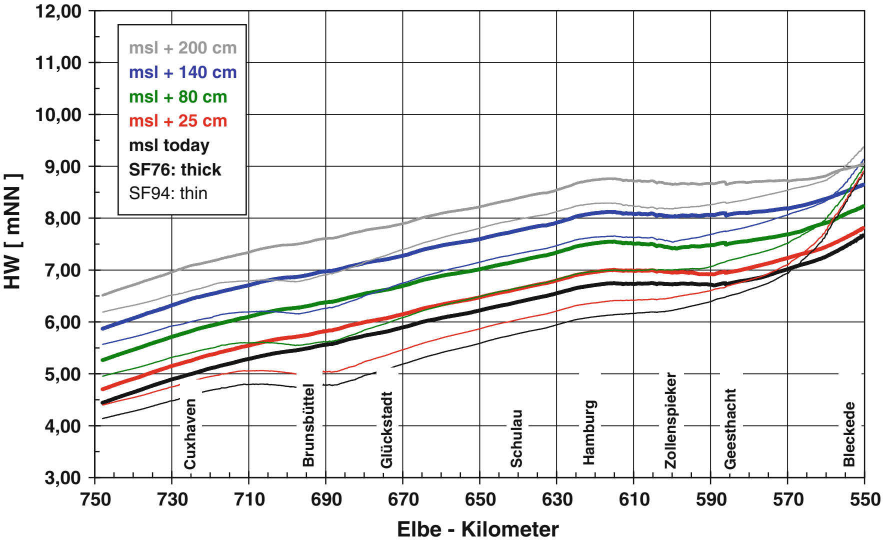

Fig. 18.7 Influence of sea level rise in the German Bight on high water for the storm surge types SF76 and SF94 along the Elbe estuary

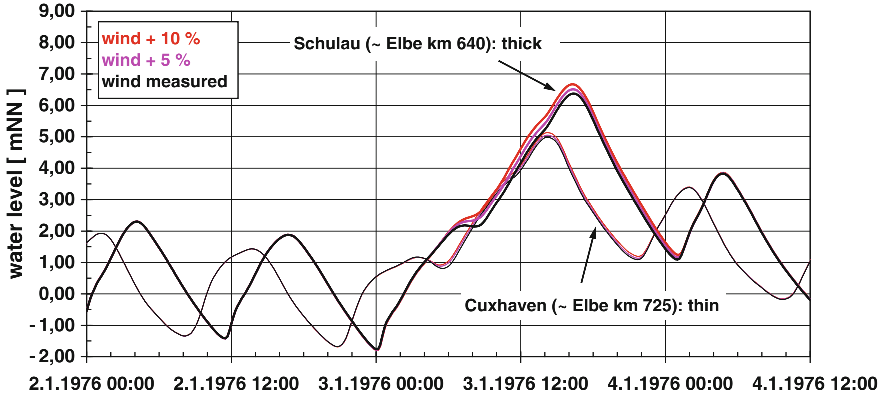

Fig. 18.8 Influence of wind speed increase on water levels for locations Schulau and Cuxhaven for storm surge type SF76

influencing the discharge regime in the River Elbe can be regarded as independent from those processes which govern the conditions of storm surges. This is also the case for the mean sea level in the North Sea: its occurrence is independent from actual meteorological conditions over both the North Sea and the Elbe catchment area. Therefore, it is feasible to combine the variations of Q and SLR which have been already investigated separately in the previous sections.

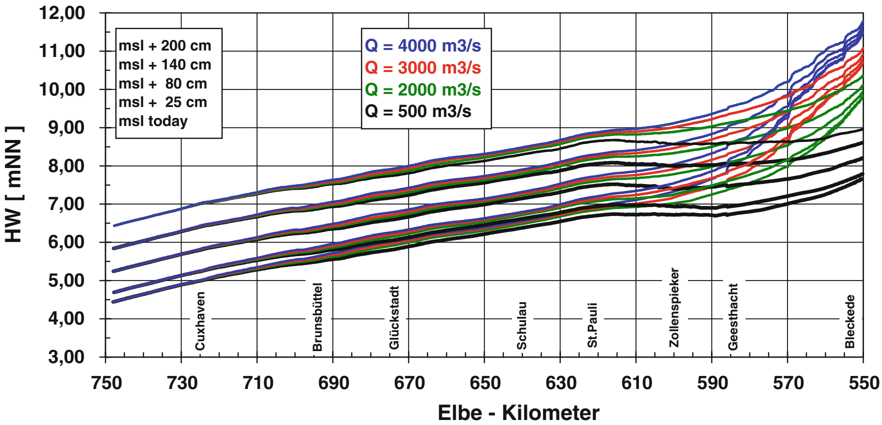

Fig. 18.9 Influence of sea level rise and freshwater discharge on high water for storm surge type SF76 along the Elbe estuary

Figure 18.9 depicts HW along the Elbe fairway profile for four different SLR and four different Q scenarios. It can be observed that HW increases throughout the estuary under these conditions. Apparently, the separate effects of Q and SLR on HW superimpose when occurring simultaneously: HW is shifted approximately by the amount of SLR along the estuary from the mouth until Hamburg. In the upstream direction, HW further increases due to the influence of Q. The same behaviour is observed for the storm surge type SF94 (not shown). Thus, three zones of different HW sensitivity to Q and SLR can be determined:

1. Hamburg—Bleckede: HW is mainly influenced by the variation of Q and to a smaller degree by SLR;
2. Brunsbüttel—Hamburg: HW is less influenced by the variation of Q than upstream, but mainly influenced by SLR (parallel shift);
3. Elbe mouth—Brunsbüttel: HW is mainly influenced by SLR (parallel shift), influencing of HW by Q cannot be observed.

Combined Variations of Sea Level Rise and Wind Velocities and Their Influence on Water Levels

Finally, the combined influence of sea level rise (“SLR”) in the German Bight and wind velocities over the estuary during storm surge was investigated.

Figure 18.10 depicts the water level time series for Cuxhaven (thin lines) and Schulau (thick lines) for the reference event SF76 and one SLR scenario (+80 cm, wind measured) in black lines. The combined scenarios with SLR and wind

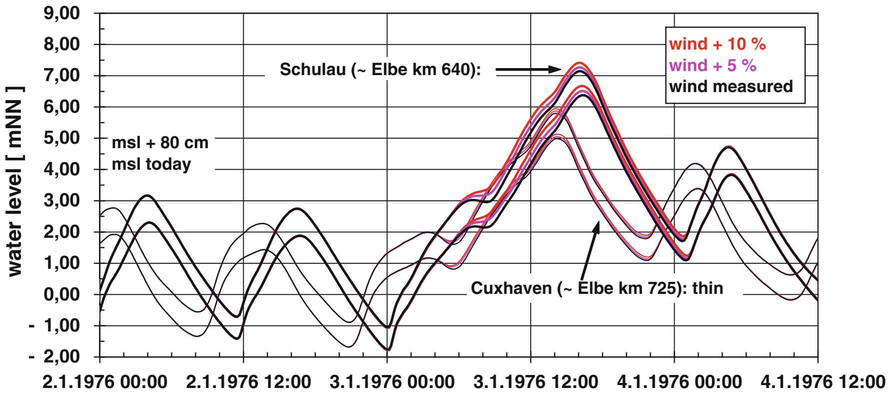

Fig. 18.10 Influence of sea level rise and wind speed increase on water levels for the locations Schulau and Cuxhaven for storm surge type SF76

velocity variations are shown in coloured lines. Apparently, the separate effects of SLR and wind on water levels superimpose when occurring simultaneously. It can be observed that the higher wind velocity (here: +5 or +10 %) cause higher water levels. Figure 18.10 highlights that SLR significantly influences water levels. It leads to a parallel shifting of the water levels by the approximate amount of SLR. This behaviour can be observed for all investigated wind scenarios, at both locations and for both storm surge types (not shown).

Conclusions and Perspectives

The investigated storm surge scenarios provide a first idea about the behaviour of the Elbe estuary under possible changed climate conditions. They show that variations of freshwater discharge, sea level rise and wind velocities have a significant impact on storm surge water levels along the Elbe estuary for the two investigated storm surge types. The magnitude of high water changes is dependent on the magnitude of parameter variations, but the sensitivity of the water levels to sea level rise and fresh water discharge is variable along the estuary. The mouth of the Elbe is mainly influenced by changes in the North Sea such as sea level rise. The area upstream of Hamburg is influenced by the changes originating in the catchment area such as river run-off. In the part of the Elbe between Brunsbüttel and Hamburg, the water levels during storm surges are influenced by changes in the North Sea and the catchment area. This will provoke various vulnerabilities along the Tidal Elbe. Embedded in the project KLIMZUG-Nord, the study will help to determine whether existing protection strategies will still be effective in future or whether they must be replaced by new adaptation concepts when certain adaptation tipping points are reached (amongst others, Kwadijk et al. 2010).

Furthermore, a possible future adaptation route for the Elbe estuary as developed for the Thames estuary (see Lowe et al. 2009), can be derived even in the case of extreme changes. In the future, the present results can be assigned to climate projections and probabilities of occurrence.

Since modelling of extreme events including the morphodynamic response in estuaries is still in the focus of research, the present study is carried out with static topography as a first approximation. Thus, it is assumed that topography has not changed under the current climate. However, alluvial estuaries continuously adapt their morphology based on changing hydrodynamic conditions, which affects storm surge heights in return. In order to investigate this influence the sensitivity study will be conducted for possible future morphologic states of tidal flats and oxbows, for example. In this manner, the impact of adaptation measures such as dike relocations will also be tested and optimised. Moreover, other storm surge types besides SF76 and SF94 can be considered in the sensitivity study, given that changes in storm surge characteristics over the North Sea will be expected.

For reasons of clarity, the present paper focuses on the impact of a possible future climate on storm surge water levels; however, the wave climate regarding sea level rise and rising wind velocities along the estuary was also investigated. Interested readers are invited to contact the authors for more information.

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Author Biographies

Annette Schulte-Rentrop received her PhD in Civil Engineering and a diploma in Geoecology. She is working in the Estuary System Group at the department of Hydraulic Engineering in Coastal Areas at the BAW-DH in Hamburg (www.baw.de). Her position involves working with the KLIMZUG-Nord project and investigating the impact of a possible changing climate on the hydrodynamics and sediment transport in the Tidal Elbe by use of numerical modelling. Adaptation strategies will also be developed and tested.

Elisabeth Rudolph holds a PhD and a diploma in Meteorology. She is also working in the Estuary System Group at the department of Hydraulic Engineering in Coastal Areas at the BAW-DH in Hamburg. Her main interests are storm surges and the numerical modelling of storm surges in the estuaries along the German coast of the Elbe, Jade-Weser and Ems.

Chapter 19
An Analysis of the Impacts of Climate Change for Management and Governance of the Antarctic Region

Danilo Comba

Abstract In recent years, great advances have been made in our understanding of Antarctic climate and environmental change. For lawyers, knowledge is relevant primarily because it reinforces decision-making. In some cases, a more in-depth knowledge and awareness leads to the fundamental rethinking of an approach to a situation or the respective legal construction. For a long time analysed as a "pole apart", Antarctica is not treated in this article simply as proof of climate change and interconnectivity: the Intergovernmental Panel on Climate Change (IPCC) will use these data to integrate the results of the International Polar Year (IPY) in its Fifth Report (2014). Rather, in this article we analyse the region's relationship with climate risk management, as Antarctic actors try to transform the IPY legacy into a more effective Antarctic regime. The extensive cooperation in Antarctica, centred on the Antarctic Treaty System (ATS), is certainly a good foundation for achieving concrete results. From 2006, climate risk management has been given some attention by the Antarctic Treaty Consultative Meeting (ATCM XXIX). Following the SCAR Report (2009), the Parties of the Antarctic Treaty System (ATS) met in 2010 in Norway. The meeting served to redefine the Antarctic Region as an element in and for climate-smart disaster risk management. It was recognised that the Antarctic Region offers a unique environment for the study of climate change, and the matter became a specific item within the ATS. The parties agreed to adopt a climate change response work programme. Improving protection for the Antarctic Region means acting on climate capacity building regarding in situ growth activities. A more regional approach to the application of environmental management tools is to be taken into particular consideration. However, according to an integrated interpretation of the Antarctic environment (holistic approach), is the federal cooperation strong enough to face up to concrete future challenges?

D. Comba (✉)
Via Rocca de Baldi n. 14, 12100, Cuneo, Italy
e-mail: combadanilo@fastwebmail.it

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Impacts of Climate Change on Management and Governance of the Antarctic Region

The SCAR "Antarctic Climate Change and Environment" Report (ACCE, 2009) underlines Antarctic regions as a Tipping Element in climate risk management and provides key findings for decision-making (1). Some of the Consultative Parties of the ATS, the main legal mechanism for Antarctic governance, met in 2010 in Norway (Meeting of Experts on Climate Change, ATME).

Many working and information papers were submitted to the ATME. The meeting adopted 30 recommendations on the impacts of climate change for management and governance of the Antarctic Region. The recommendations highlight legal challenges, providing a scoping programme (2).

Our focus is on those recommendations that try to address Antarctic capacity building regarding in situ activities. Uncontrolled, they could negatively influence Antarctic roles for and in climate risk management. The focus is on protected marine areas, monitoring, EIA, and invasive species.

The Parties give an answer to a specific issue—the underlying originality of ATS—in accordance with international environmental law (3).

The subject calls for some consideration on Antarctic governance: environmental protection of the region is functional for scientific surveillance, without any other specific qualification addressing the comprehensive protection of the environment (4).

Antarctic as Climate Tipping Element: Clarifying Scientific Scenarios

The Scientific Committee on Antarctic Research (SCAR), a committee of the ICSU (International Council for Science), coordinates the research in the Antarctic Area and provides high-quality, objective and independent scientific advice to the ATS (for the definition of the Antarctic Treaty System, see *Article 1, Protocol on Environmental Protection to the Antarctic Treaty*, signed in Madrid in 1991).

One of the three "official" observers of the Antarctic Treaty [with the CCAMLR and the COMNAP; see ATCM XXI, Decision 1 (1997), Revised Rules of Procedure], its role includes scientific and technical advice, reviews of the state of knowledge, and information on emerging policy-relevant issues (the Standing Committee on the Antarctic Treaty System [SC-ATS] provides SCAR representation at the meetings of the ATCM and of its CEP). Therefore SCAR contributes to the development of the ATS.

The ACCE Report is the SCAR input to the IPY.

Presented in 2009 to the XXXII ATCM, it provides key findings with the intention of clarifying controversial issues (the role of Antarctic in the Earth System, the comprehension of changes occurring in Antarctic region, the consequences of Antarctic changes on global and regional scales, etc.). The Report follows five SCAR documents presented to the ACTM (2006–2010). It underlines that Antarctic areas (continent and surrounding waters) are coupled to the other parts of the global environment

"through both ocean and atmosphere circulation and CO_2 exchange".

It gives essential information on *why* the Antarctic is a Tipping Element, and on *how* and *to what extent* environmental changes are occurring. For example (Key Finding 4b):

"The loss of ice shelves along the Antarctic Peninsula, such as the Larsen B Ice Shelf, is primarily a result of regional warming caused by intensification of the westerlies as a result of the ozone hole".

The Report underlines that higher resolution global models, regional climate models, and ecosystem and ice sheet models, are required (Point 10).

Although it is a step towards compiling a comprehensive assessment, the ACCE already informs politics and lawyers.

Providing key information to define the challenge, mainly on how the climate is predicted to change, its predictions translate incertitude (disaster) in risk. Policy-makers can therefore work towards its management.

The objective is to ensure Antarctic environmental protection (*Article 2, Protocol on Environmental Protection to the Antarctic Treaty*) that is consistent with human needs. Therefore, preserving this natural laboratory means guaranteeing accessible data, preventing sea level rise, protecting southern waters as a sink of atmospheric CO_2, etc.

In 2010, at the XXXIII ATCM, the Parties recognised that the Antarctic Region offers a unique environment for the study of climate change. With Resolution 4 (2010), they confirmed their intention to work together to better understand changes to the Earth's climate and to:

"actively seek ways to address the effects of climate and environmental change on the Antarctic environment and dependent and associated ecosystems".

Acknowledging the SCAR report, the ACTM follows the first of the recommendations arising from the 2010 Climate Change ATME.

The ATME's Recommendations on Impacts of Climate Change: Ways for Addressing Challenges for Management and Governance of the Antarctic Region

Organised in accordance with Decision 1 (2009) of ATCM XXXII, the Meeting of Experts on Climate Change took place in Svolvær, Norway, on 7–9 April 2010. The ATME was attended by representatives of 15 Antarctic Treaty (Consultative)

Parties (see Article IX of the Antarctic Treaty and Recommendations 4–24), experts from four organisations (SCAR, CAAMLR, ASOC, and IAATO) and one representative from the Antarctic Treaty Secretariat.

According to Decision 1 (2009), five topics were in the ATME Agenda: key scientific aspects and consequences of climate change in the Antarctic environment, implications for the management of Antarctic activities, the need for monitoring, scenario planning and risk assessment, the outcomes of UNFCCC negotiations relevant for the Antarctic, plus further considerations and ways in which goals could be achieved.

Three working and thirteen information papers were submitted and presented (documents are available at the website of the Antarctic Treaty Secretariat). ATME made considerable progress on the topics. Remarking that the ACCE findings informed its deliberation, the Meeting adopted 30 recommendations regarding the impacts of climate change on management and governance of the Antarctic Region (Co-Chairs' Report from Antarctic Treaty Meeting of Experts on Implications of Climate Change for Antarctic Management and Governance). These recommendations were aimed at the ATCM, at the Parties, and at CCAMLR.

The recommendations are not binding (see Decision 1, 1995), but they highlight challenges from a management perspective. The Co-Chairs' Report produces a scoping paper describing objectives and tools.

Providing advice for action, they draw up a process (who, how) for international and Antarctic communities that defines exactly what an Antarctic climate management programme could realistically contain.

Some issues will certainly merit further consideration (iron fertilisation, long-range transport of pollutants, ocean acidification). The ATCM XXXIV began to tackle the difficult task of assessing the risks posed by tsunamis—a pressing problem due to the number of research stations located in coastal areas.

The Parties noted that ATME has been able to address only a few selected topics.

The first part of the report acknowledged interdependency, seeing the Antarctic as an input on and of climate issues. A component of the Earth System, the region's preservation means acting for climate governance. Changes in the Antarctic call for action at regional and global level. Recommendations 9–16 encouraged close cooperation among institutions and projects, and in the collection of scientific data. According to Articles III and VII of the Antarctic Treaty, the Parties are obliged to share scientific data and operational information. ATCM and the Environment Protocol of 1991 added important information exchange obligations on environmental matters (see EIES, the Electronic Information Exchange System developed by the Antarctic Treaty Secretariat, and SC-ADM, the Antarctic Data Directory System managed by the SCAR).

The ATME recommends national agencies to maintain the 2007–2009 momentum and their contributions to the IPY legacy. In 2009, during ATCM XXXII, the ATS and Council Arctic Parties met for the first time, and adopted a joint resolution in which they supported the objective of delivering a "lasting legacy" for the IPY (Antarctic Treaty-Arctic Council Joint Meeting, Washington

Ministerial Declaration on the International Polar Year and Polar Science; also XXXII ATCM, Resolution 6 (2009), "Ensuring the Legacy of the IPY").

Scientific findings should be further investigated in order to predict future change with increasing accuracy on various temporal and geographical scales (Recommendation 10). Moreover, these findings should be used to inform other bodies. Confirming and extending Decision 8 (2009), the Consultative Parties have adopted Decision 5 (2010, ATCM XXIII), by which they undertake to transmit the ACCE Report to the Secretariats of the United Nations Framework Convention on Climate Change (UNFCCC), the IPCC, the World Meteorological Organisation (WMO), and the International Maritime Organisation (IMO), and Resolution 4, by which they recommend that their governments:

"(…) forward copies of the (…) report to (…) respective departments and agencies engaged in climate change negotiations".

To preserve the value of the Antarctic, the Meeting recommended that Antarctic Parties (Consultative and Non-Consultative) reduce the carbon footprint of activities in Antarctica (stations, vessels, and aircraft). These actions could have symbolic value in a global context. Recommendations encouraged efforts in energy efficiency and alternative practices (e.g., evaluating the potential for wind power).

In particular, the ATME recommended that each Party define risk assessment processes for (national) activities and develop EIAs (Environmental Impact Assessment) for new facilities (Recommendations 7 and 8). At ATCM XXXIII, Australia presented Information Paper 105 ("Management Implications of Climate Change in the Antarctic Region—an Initial Australian Assessment"), a modified version of the Paper submitted to the ATME. The paper presents the risk evaluation framework used by the Australian Antarctic Division (AAD).

Moreover, for the Experts, the importance of the topics (changes to the terrestrial and marine environment, implications for the management of Antarctic activities, necessity for monitoring, scenario planning and risk assessments) justifies a separate item on the Committee for Environmental Protection (CEP) and ATCM agendas. Both have accepted and included the item in the Preliminary Agendas for the Meeting of 2011 (XXXIII Final Report, Preparation of the Agenda for ATCM XXXIV: ATCM, § 541; CEP, § 241).

The second part of the report brings in regional adaptation requests for different aspects of climate change. ATME encourages ATCM to consider which of the ATME recommendations deserve priority treatment in future discussions.

Providing a Climate Orientation for In Situ Activities: Confronting Issues with ATS-ATCM Capacity Building

The federal cooperation that forms the basis for governance of the Antarctic, particularly within the ATS (Madrid Protocol, its six Annexes, and the CCAMLR Convention signed in Canberra in 1980), is a strong foundation for achieving results in environmental matters.

According to Article 3, activities in the Antarctic Treaty area shall be planned and conducted so as to limit adverse impacts on the Antarctic environment and dependent and associated ecosystems. Article 8.2 of the Protocol provides that activities undertaken (at least for the most part) in the Antarctic Treaty Area (according to Article VI of the Antarctic Treaty, the area south of 60° S) are subjected to the assessment procedures of Annex I.

However, some activities, if they are not climate oriented and appropriately controlled (or not covered by the agreements), could jeopardise the protection of this fragile environment and therefore also the effectiveness of the administration of the area (difficulties linked to (territorial) sovereignty issues, jurisdiction, effective control of activities conducted in the area, and coordination between ATS compounds and with other specialised mechanisms) and the Antarctic role for and in climate risk management.

Consequently, climate implications for the management of Antarctic activities necessitate an effort within the ATS (ATCM-CEP-Parties-CAAMLR) to use the variety of specialised treaties applying to the Antarctic region (UNCLOS, IMO Conventions, ACAP, IHO).

The ATME recognised that this is a broad topic. According to Decision 1 (2009), Recommendations 18–30 "try to address ATCM capacity building regarding in situ activities". Considering the scientific and legal specificity of the Antarctic Area, ATME gives orientation on adapting management.

Two main recommendations, closely related, are given by the ATME.

First, according to Recommendation 18, the ATCM and CEP will take (give consideration to) a more regional approach in applying environmental management tools.

The idea is to observe a stringent systematic approach, particularly towards terrestrial and marine biodiversity and the development of long-term monitoring programmes to reduce risks and protect species and habitats (i.e., climate refuge areas), in addition to the traditional continent-wide perspective (60° S). Consistent with the precautionary principle, the ATME recommends the CEP to advise ATCM on potentially automatic interim measures; these measures could in the future be specifically applied for marine areas exposed through ice-shelf collapse. CEP discussed the issue and agreed to work along these lines.

Second, according to Recommendation 19, CEP will consider developing a climate change response work programme, incorporating or reviewing some special Antarctic environmental topics. Improving climate information management, advising the ATCM under Article 12 of the Protocol, CEP supports and can develop its environmental responsibilities.

CEP XIII Added Recommendation 19 to Its Five-Year Work Plan (Final Report, ATCM XXXIII−CEP XIII, pp 182–189, § 374)

However, ATME has already placed the focus on

- invasive species
- classification of existing protected areas according to climate change vulnerability (WP 43 submitted at XXXIV ATCM proposes a methodology for re-classifying existing protected areas)

- ecosystem monitoring
- EIA
- collaboration between CEP and SC-CCAMLR (Recommendations 26–28).

Given that the Committee is already addressing a number of the issues highlighted by ATME, many recommendations could indeed be readily incorporated into the CEP's programme of work.

Actually, CCAMLR and CEP are working towards increased cooperation, particularly on subjects of marine protected areas and ecosystem monitoring (see Protocol, Annex V, and CCAMLR Convention). CCAMLR had developed the Southern Ocean Bioregionalisation Programme for creating a network of marine protected areas by 2012.

Furthermore, the Scientific Committee of CCAMLR is reviewing its Ecosystem Monitoring Programme (CEMP) to ensure its ability to manage the Southern Waters fishery (according to Article 1, up to the Antarctic Convergence) and to attempt to distinguish the effects of fishing activities (for which the Protocol and CEP have no competences) from the effects of climate change. As underlined during CEP XIII, an opportunity for joint working on broader monitoring issues exists. It centred on a biodiversity perspective, permitting CEP to monitor on the basis of Article 3 and Annex II of the Protocol (see also Measure 16 [2009], Amendment of Annex II).

In 2010, however, only a small number of the recommendations were fully considered. Parties (Consultative and Non-Consultative), the CEP, and Observers submitted a large number of working and information papers at the XXXIV (2011).

The consensus seems to be for an extension of work on marine protected areas, incorporating Comprehensive Environmental Evaluation (CEE) for the exploration and research of subglacial aquatic environments (Lake Ellsworth) and affording a high priority to the management of non-native species.

On this subject, Parties discuss ensuring a precautionary approach (on the Antarctic Peninsula, some activities have inadvertently introduced alien organisms). Recognising this as a major concern, the CEP has presented a manual of control techniques (guiding principles on prevention, monitoring, and response; working and information papers submitted at ATCM XXXIV).

One working paper in particular, submitted by the UK and Norway (WP 44), "Progress Report on ATME on Climate Change", would facilitate the ATCM's ongoing consideration of the recommendations arising from the ATME, providing a summary table on actions taken against each recommendation. The proposal is that the ATCM requests the Antarctic Treaty Secretariat to maintain and update the table. The will is to ensure a deeper discussion and an appropriate implementation of ATME recommendations.

Concluding Remarks

From a global perspective, acting for the protection of the Antarctic region means reducing disaster risk, limiting dangerous anthropogenic interference with the climate system and protecting this unique environment for science.

The status of Antarctica as a natural reserve—"devoted to peace and science" —is functional to scientific surveillance (natural laboratory), in particular research essential to understanding the global environment (Article 3.3).

The IPY provides an assessment of the importance of Polar regions for the reinforcement of global observing systems. Climate change studies underline that this natural laboratory is both an archive (barometer) and an engine of the Earth System.

From a regional perspective, Parties are considering a more regional approach in applying management tools and acting on capacity building regarding in situ growth activities. The SCAR ACCE Report underlines the importance of strengthening climate resilience and the role of ATS as an example of climate-smart capacity building.

However, according to an interconnected interpretation of the Antarctic environment (continent, sea, atmosphere), the federal cooperation is not enough for confronting future challenges. The issue calls for building a broader adaptive capacity on both a global and regional scale, requiring efforts from within and outside the ATS.

Taking into account the views of CCAMLR, Consultative Parties are considering recommending further steps to be taken within the IMO to extend northward the Antarctic Special Area (MARPOL Convention) to the Antarctic Convergence (ATCM XXXII—CEP XII, Resolution 1,2009).

One issue seems to emerge above all: does ensuring the preservation of the Antarctic in the medium to long-term mean a paradigm change from a (scientific) functional perspective to a specifically *environmental* orientation? According to SCAR (Standing Scientific Group on GeoSciences, SSG-GS), the challenge of the next phase of Antarctic science will be to integrate all branches of science into a holistic understanding of the trajectory of change.

The IPY legacy suggests addressing the "refrigerator role" of the Antarctic in Earth's ecosystem. The task is assessing all the implications on both a regional and a global scale. The ACCE Report is the first step towards better connecting the Antarctic to the international environmental architecture.

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Author Biography

Danilo Comba (Italy) is a PhD student enrolled in the joint doctorate programme of the University of Nice Sophia-Antipolis (France) and the University of Milano-Bicocca (Italy), researching in the areas of polar systems, international law, environmental law, and maritime law.

Chapter 20
An Analysis of the Impacts of Rainfall Variability and Crop Zones Classification for the Federal Capital Territory, Nigeria

Hassan Shuaib Musa

Abstract This study aims at analysing agro-climatological parameters and establishing a link between certain selected agro-climatological indices and the sustainability of agricultural production in the Federal Capital Territory (FCT). Two sets of data, climatic and crop yield data were collected and subjected to various agro-climatological analyses. Agro-climatological analyses include the derivation of onset, cessation and Length of rainy season (LRS), seasonality index, drought index and precipitation periodicity index. The statistical analyses include monthly and annual means, and deviation from the mean trend line. The result of moisture index in line with crops optimum moisture requirement was used to classify the territory into agro-climatic zones for crop production. The result of the climatic indices revealed that although rainfall has declined throughout the study period, the results from other derived rainfall parameters showed that the region has done well in terms of crop yield. Temperature and humidity levels have increased during the study period owing not just to global warming alone but also to some anthropogenic activities, particularly deforestation through the activities of using wood as a fuel and the charcoal business within the territory. The uniqueness of the rainfall pattern was very clear (increasing from south to north). Another important feature is the division of the region into two climatic zones by the PP Index. The result in the characterisation of the territory into crop-ecological zones revealed three ecological zones whose rainfall is zonal in orientation: (1) the southern humid zone, (2) the mid-central sub humid zone, and (3) the north-eastern humid zone. It is therefore recommended that further studies be carried out on trends of agro-climatic conditions in the study area.

H. S. Musa (✉)
S.C. Kato Department of Geography and Environmental Management,
University of Abuja, Abuja, Nigeria
e-mail: hassanalabo@yahoo.com

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Introduction

Limits to the productive capacity of land resources are set by climate, soil and landform conditions, as well as by the use and management applied to the land. Sustainable management of land resources requires sound policies and planning based on knowledge of these resources, the demands of the use to which the resources are put, and the interactions between land and land use. Above all, knowledge of the influence of rainfall and other relevant climatic characteristics on the above mentioned resources is vital if the ever teeming population is to be fed. The discussion therefore focused on the observed and futuristic implication of insufficient input from relevant climatic conditions and the consequences of its variation on food production and food security, in order to cater for the teaming population.

Although there are 3.3 billion hectares of potentially arable land available on Earth, the economic and ecological costs of bringing it all into production are prohibitive. An effort to bring three billion hectares under cultivation implies an enormous loss of habitat for many species as well as for the critically important varieties of animals eaten by humans (Barney 1980). As a consequence, we must also give attention to efforts made both to preserve arable land and to increase yields. Berry has argued that:

> If present beliefs and policies continue, the world in the 21st century will be more crowded, more polluted, less stable economically and ecologically, and more vulnerable to violent disruption than the world we live in the 20th century…. Overall, Earth's people will be poorer in many ways than they are today

Coupled with the loss of agricultural lands due to urbanisation and land degradation, this leads to food shortages.

According to the World Bank (2008), agriculture has received considerable attention recently with regard to climate change because of the high dependence of agriculture on the climate. Dependence on agriculture, especially in developing countries, also means that agriculture has an important role to play in debates about adaptation to climate change. Most studies and models on the impacts of climate change on agricultural production indicate that there will be negative effects on crop yields over the next century. Some models predict that there will be an estimated 600 million additional people at risk of hunger if temperatures increase by 3 °C, particularly in developing countries where people are already at risk.

The world's population is projected to continue increasing well into the present century. The primary question is whether and how global food production may be increased to provide for the population expansion. It will be necessary to increase the current level of food production to a level more than proportional to population growth so as to meet the human demand in food production (adequate diet). There are also a number of actions that may be taken to help these food expansions; however, there are also a number of constraints that make expansion of food output difficult. These include:

- Impacts of climate variability and change in the agricultural sector are projected to steadily manifest directly from changes in land and water regimes, the likely primary conduits of change. Changes in the frequency and intensity of droughts, flooding, and storm damage are all expected to increase. Climate change is expected to result in long-term water resource shortages, worsening soil conditions, drought and desertification, disease and pest outbreaks on crops and livestock, and sea-level rise, etc. Vulnerable areas are expected to experience a reduction in agricultural productivity, primarily due to reductions in crop yields (Rosenzweig et al. 2002; Pradeep and Shane 2003).
  Increasing use of marginal land for agriculture (especially among smallholder farms) is anticipated as the availability and productivity potential of land begin to decline.
- Rainfall variability, diminishing arable lands, and a decrease in agricultural output resulting into food crisis. The economic consequences of reduce rainfall in form of drought are of great concern, especially in area of food supply, because the effect of drought last longer than the effect of excessive rainfall.

IFPRI (2009) asserted that biophysical effects of climate change on agricultural production will be positive in some agricultural systems and regions, and negative in others, and these effects will vary through time. In developing countries, the study area in particular, yields declines for most crops without CO_2 fertiliser while on average, yields in developed countries are less affected. In the developed countries the yields of some crops are influenced positively. Socio-economic factors influence responses to changes in crop productivity, with price changes and shifts in comparative advantage (Parry et al. 2004).

Sustainability is an aspect of economic and social development that meets the needs of the present without compromising the ability of future generations. Therefore, understanding the concept of climate variability in crop yield sustainability is essential in order to sustain the dietary requirements of the ever increasing population.

The aim is to carry out an agro-climatological analysis of Abuja FCT with a view to establish the links between certain selected agro-climatological indices and agricultural production in the territory.

The specific objectives of the study are:

- To analyse the essential and critical features of rainfall and temperature patterns relevant to crop production in the area.

- To evaluate the indices of precipitation effectiveness.
- To characterise trends in crop production in the area
- To delineate proper agro-climatic zones to allow effective utilisation of the limited agricultural lands in the area.

Two types of farmlands have been identified in the study area (Hassan 2008):

The Upland (Gona)

Gona is a Hausa word meaning farm fields located on the uplands.

The fields are rain fed and hence are cultivated only during the rainy season. Upland fields are only devoted to the cultivation of root and grain crops such as yam, cassava, maize, guinea corn, millet, beniseed, and legumes like cowpeas, groundnut, melon etc.

The Floodplain (Fadama)

Fadama is a Hausa word for seasonal flooded area or plains mostly along river valleys. This floodplain can be found in the FCT along the valleys of the rivers Gurara and Usuman and their tributaries. They are fairly rich in nutrients and can produce a regular harvest even without manure or fertiliser due to annual replenishment of the topsoil with alluvial materials from the uplands. They have good water supply throughout the year and so can produce two or more crop yields in a year.

In Nigeria, the variation in rainfall pattern from the coast to the north is a reflection of the seasonal variations of the surface location of the ITD. This variation, which follows the apparent movement of the sun, controls the rain belt. Rainfall thus decreases both in duration, intensity and amount from the coast to the interior, except where the altitudinal effect creates an island of high rainfall as experienced in the Jos plateau. It is therefore important to understand the mean rainfall pattern and its derivatives in order to unmask major trends that could be used to reveal the cause and effect of recent rainfall ineffectiveness to agricultural activities, especially in crop production. Several research works have established that the great potential of agricultural development in sub-Saharan Africa lies in meeting the requirements of major agricultural lands especially the Fadama (seasonally flooded floodplains) lands. The great potential of the Fadama agriculture has been recognised in Abuja FCT, they are, however, used only for vegetables and garden crops during the dry season using hand pumps supplied by Abuja Agricultural Development Project (AADP).

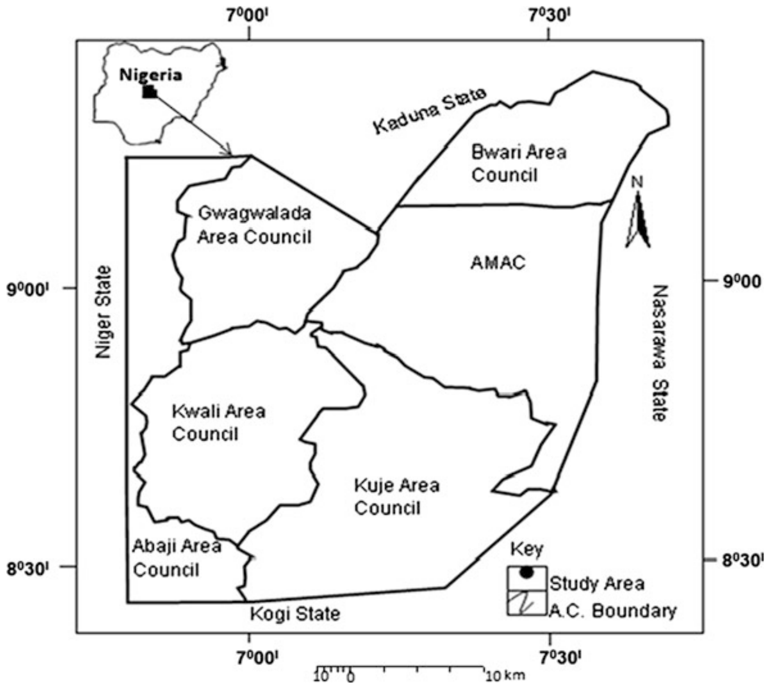

Fig. 20.1 Map of Nigeria showing the study area

The Federal capital territory is located between latitudes 8° 25′ and 9° 25′N of the equator and longitudes 6° 45′ and 7° 45′E of Greenwich Meridian (Fig. 20.1). The territory covers an area of 8,000 km^2 and occupies about 0.87 % of Nigeria. The territory is situated wholly within the region generally referred to as the "Middle Belt" (Mabogunje 1977), and is bordered on all sides by four states namely Niger, Nassarawa, Kogi and Kaduna (Fig. 20.1).

FCT, the political and administrative nerve centre of Nigeria, is undergoing population upsurges on a daily basis. The daily increase in the number of people moving into FCT has to be fed. Of course food can be imported from other parts of the country into FCT, but the economic implication of such action necessitates the scientific development of its own agricultural sector given its abundant arable land estimated at about 800,000 hectares. Compared to other parts of the country, FCT has good ecological conditions that favour the production of both plants and animals including fish farms.

Materials and Methods

Agro-Meteorological Analysis

The daily rainfall records were used to obtain the mean monthly, seasonal and annual rainfall records from which other relevant precipitation indices were derived.

Precipitation Periodicity Index

The index was obtained from the lowest monthly, the highest monthly and the total annual rainfall data in percentage. This index is computed using:

$$PP = (A/Y - B/Y)100\,\% \tag{20.1}$$

where;

PP = precipitation periodicity
A = the highest monthly rainfall
B = the lowest monthly rainfall, and
Y = the total annual rainfall.

This index is used to determine the magnitude of zonal rainfall variability (Hassan 1996; Hassan and Adefolalu 2003) and it has the following threshold values:

- $PP \leq 20\,\%$ = uniform distribution of rainfall
- $PP \geq 20\,\% \leq 30\,\%$ = slight periodicity
- $PP \geq 30\,\%$ = excessive periodicity

The quality or state of being periodic is the recurrence at regular intervals of variation in precipitation. The measure of periodicity is the frequency at which a drought period can occur.

The Onset, Cessation and Length of Rainy Season

Walter (1967), Ilesami (1972) and Olaniran (1988) took several methods to calculate these indices. However, it has been observed that the Ogive method using daily data is the most appropriate (Adefolalu 1993; Adebayo 1997). The Ogive method involves plotting the cumulative frequency graph (Ogive) of each pentad rainfall to obtain the onset date at the first point of inflexion and cessation date at the last point of inflexion. The LRS is then obtained by subtracting the onset date from the cessation date.

$$\text{LRS} = \text{C} - \text{O} \tag{20.2}$$

Rainfall Seasonality Index

According to Walsh and Lawler (1981), the seasonality index is the sum of absolute deviations of mean monthly from the overall monthly mean divided by the mean annual rainfall. This index is given as:

$$\text{SI} = 1/\text{R} \sum /\text{Xn} - \text{R}/12 \tag{20.3}$$

where;

SI = seasonality index
Xn = mean rainfall of month n
R = mean annual rainfall

Drought Index

A drought index value is defined as a single number, useful for decision making in agricultural policies.Drought index

$$\text{R} = \frac{R - \bar{R}}{\bar{R}} \tag{20.4}$$

R = Annual rainfall
$\bar{R}$ = Mean annual rainfall
In the drought index optimum years, drought index ranges from 2.8 to −2.8.

Results and Discussions

Firstly we shall present the monthly rainfall graph of the FCT (Fig. 20.2) from which other derivatives were also obtained.

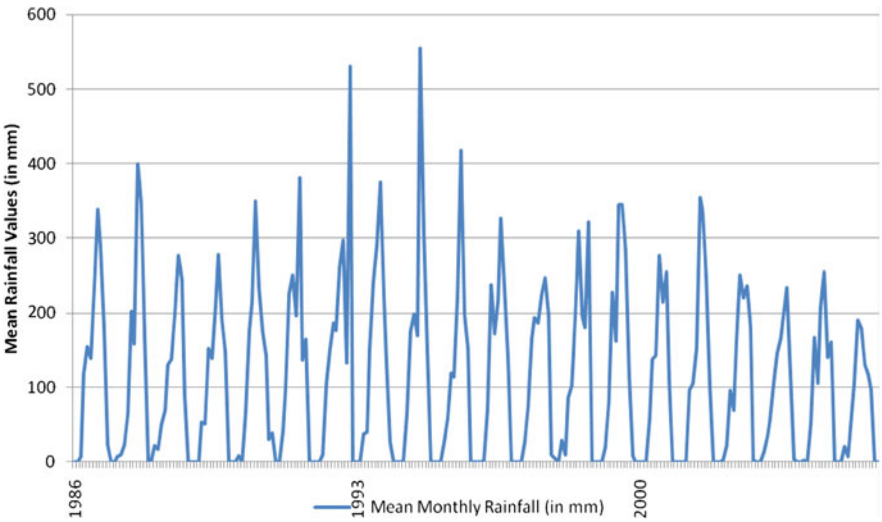

Fig. 20.2 Mean monthly rainfall of FCT from 1986 to 2005 (in mm)

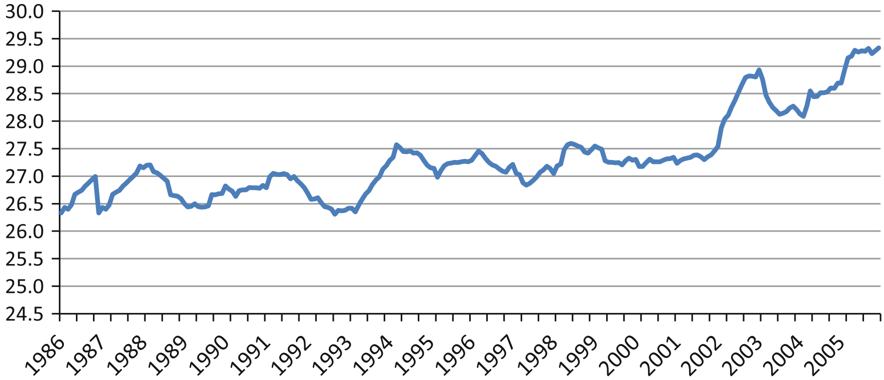

Fig. 20.3 Mean monthly temperature trend of FCT within the study period

The result of this study based on a study period of 20 years, showed the total average rainfall to be 1,358.7 mm which is within the total annual rainfall figures of 1,120 and 1,630 mm quoted for the territory in earlier studies. Mabogunje and Adakayi pointed out that the mean monthly distribution of rainfall has a tendency to show extreme concentration in 2 or 3 months as about 60 % of the annual rainfall falls during the months of July, August and September which is more pronounced in the northern rather than the southern part of FCT.

The surface temperature of the FCT between 1986 and 2005 has actually increased by 3 °C as shown in Fig. 20.3. This cannot be too far from the impact of

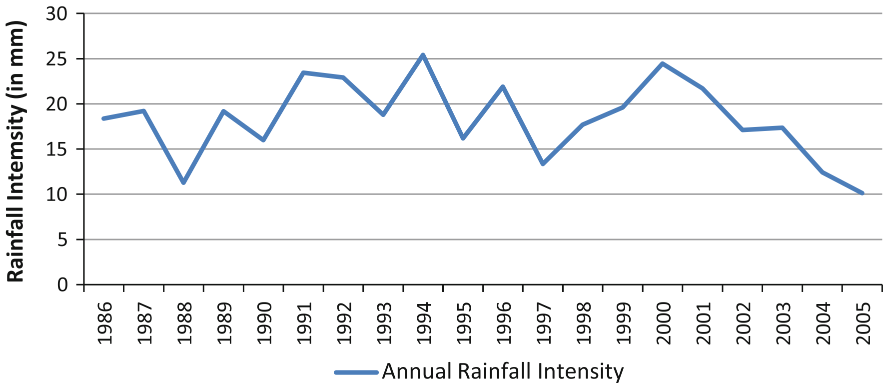

Fig. 20.4 Mean annual rainfall intensity of FCT (in mm)

global warming or the anthropogenic activities or both. The noticeable increase in the surface temperature of the region is an indication of climate change.

Figure 20.4 illustrates the rainfall intensity of the FCT, highlighting the critical years of rainfall ineffectiveness.

Using 20 mm of rainfall as the lower threshold the Fig. 20.4 reveals that only 6 years of the study period have had adequate moisture for sustainable agriculture (i.e. 1991, 1992, 1994, 1996, 2000, and 2001). The rest of the period under study have below adequate moisture for agricultural practice.

The zonal monthly rainfall portrays the actual rainfall characteristic in these zones which is shown in Fig. 20.5.

Figure 20.5 shows Abaji to have the onset (⊖) date of the rain in March and cessation (C) date in October. Therefore its Length of Rainy Season (LRS) is 8 months. The peak of rains is in September. Bwari on the other hand has its ⊖ date to be January and the C date to be November with an LRS of 11 months. Its peak month of rainfall is in August.

Gwagwalada has its ⊖ in February and C in November and an LRS of 10 months, but this varies from year to year and it is not a permanent feature like that of Bwari. It has a double peak with an apparent little dry season in August, termed August break in many parts of the country.

Kwali's ⊖, unlike Gwagwalada, begins in March and the C is in November with an LRS of 9 months. Its double peak is not well defined but there is a slight little dry season in July. The Municipal also has its ⊖ in March and C in October with an LRS of 8 months. Its peak varies between July and August, while Rubochi has its ⊖ around March and C in November with an LRS of 9 months. The peak of the rainy season is in August. In the case of Yaba it has its ⊖ around February and C in November with an LRS of 10 months. Its peak rainy season is in August.

A notable revelation is the LRS for which Bwari records 11 months, the highest, while Municipal is has the lowest at 8 months. The second highest LRS of 10 months occurs in Yaba which is located in the south-western part of the FCT. The two areas are within the ecological zone of less variable rainfall.

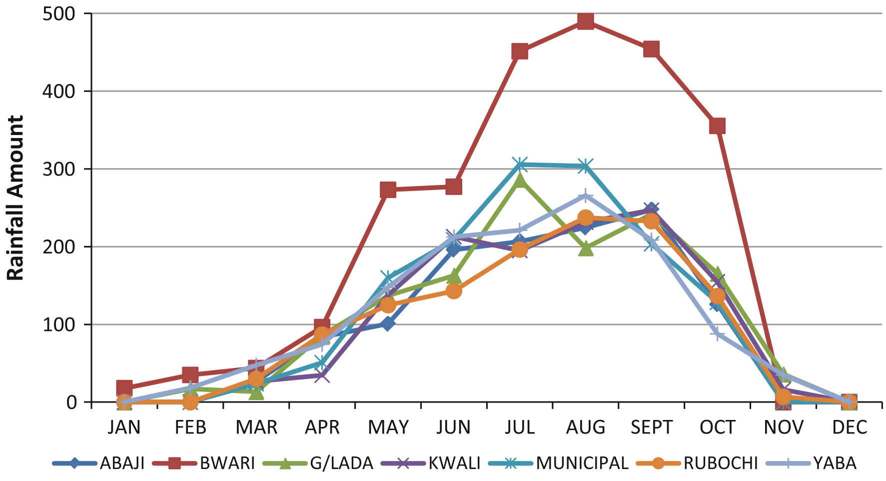

Fig. 20.5 Zonal monthly mean rainfall of FCT (in mm)

Bwari has its peak in August followed by the Municipal, having its peak in July and August, while the area with the lowest amount of rainfall is Rubochi in the south east of the territory and Abaji in the south. To get a clearer picture of the nature of rainfall within the territory, a graph of mean annual rainfall was plotted (Fig. 20.5) and arranged from the north to the south to reveal the latitudinal trend of this parameter.

Figure 20.6 therefore confirms the earlier statement that rainfall increases from the south to the north in the FCT which is otherwise in other parts of the country. The reason for this as hinted earlier is the influence of the Jos plateau on the north-eastern border of the territory. This is why Bwari which is at the extreme end of that border appears to enjoy this influence more than the other areas, coupled the contribution from numerous large bodies of water (hydro-schemes in this part of the FCT (Hassan 2008). The zonal monthly rainfall portrays the actual rainfall characteristic in these zones (Fig. 20.5).

Figure 20.7 illustrates the years with adequate and those with deficit moisture for crop cultivation.

It is clear from Fig. 20.7 that the value for the year 2000 is above the average in the previous Fig. 20.2 but below the average in the drought index chart in Fig. 20.7. This is a clear indication that some periods may have above average rainfall but yet still not enough to meet the adequate moisture requirement for plant development and crop yield. Between 2000 and 2005 the drought index shows the FCT to be negative with only 2001 showing a positive value which is less than one millimetre.

Further analysis revealed the salient feature of rainfall characteristics within the FCT, that are actually in conjunction with other physical factors such as topography, are responsible for ecological characterisation. This analysis results in the determination of the moisture index forms the backbone of the discussion of the

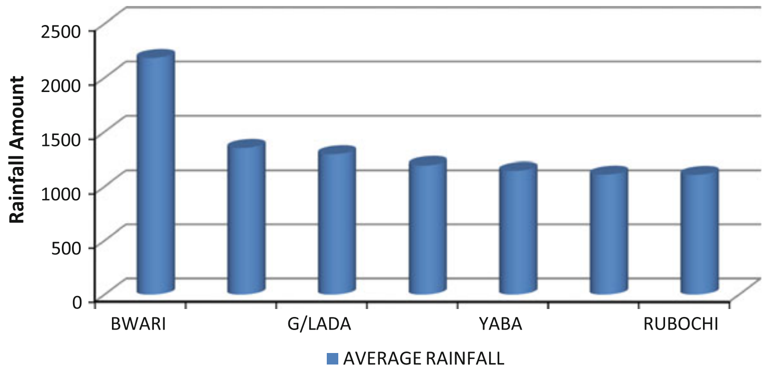

Fig. 20.6 Latitudinal rainfall distribution in the FCT

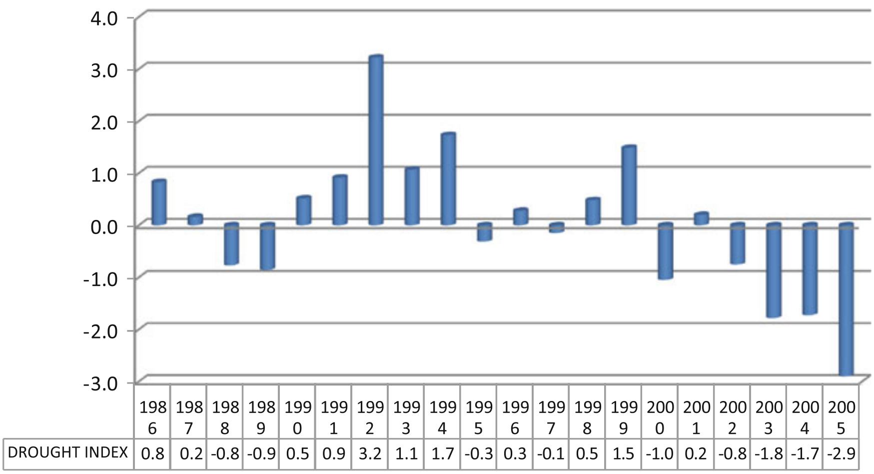

Fig. 20.7 The drought index chart of FCT

agro-ecological characterisation. The spatial distribution of the moisture index in the FCT is illustrated in Fig. 20.8.

The measure of periodicity is frequency. That is, the frequency at which a period of drought can occur. This periodicity was used to unmask the salient feature of rainfall over FCT (Fig. 20.8). The moisture index model was first applied to Kaduna State (Hassan and Adefolalu 2003) whose less than 20 % periodicity in south-eastern Kaduna bordered the FCT where it is also observed to have similar characteristic of rainfall (Fig. 20.8).

The characteristic pattern of rainfall has divided the study area into two climatic zones; the zones of less variable precipitation (precipitation periodicity less than 20 %), are the south, south west and the north east of FCT; and the zone of highly variable precipitation periodicity greater than 30 % consists of the east through to the central zone, terminating at the north. The zone of less variable rainfall

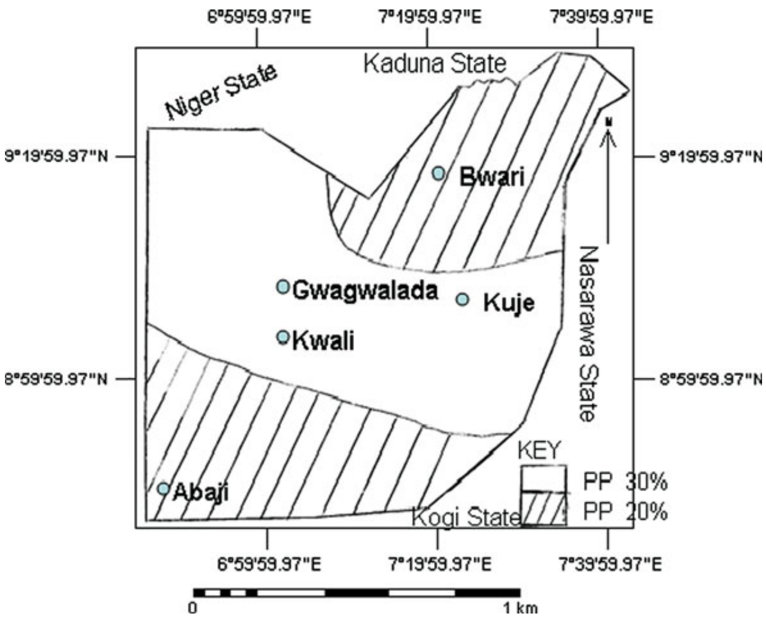

Fig. 20.8 Moisture index derived from PPI

received almost uniform rainfall during the rainy period while the zone of highly variable precipitation has drier spell periods during the active raining months.

Climate is probably the most important factor that determines what crops can be grown in any given geographic region. The most dominant climatic characteristic in this regard is precipitation and according to Raoul, agro-ecosystems are often named after their predominant crop. Owing to the pressure on the arable land of the FCT we cannot afford the luxury of defined crop belts if we are also concerned about sustaining the farm lands. Bearing this in mind the researchers have been able to derive crop zones for the FCT as illustrated in Fig. 20.9.

The crop zones classification was done based on moisture availability in each zone and optimum requirement (moisture index derived from PPI in Fig. 20.8), holding other edaphic factors at a constant.

Conclusion

Based on the two sets of data analysed (climatic and crop yield), the climatic indices revealed that although rainfall has declined throughout the study period, the results from other derived rainfall parameters showed that the region has done well in terms of crop yield. Temperature has increased during the study period as a result of global warming. The uniqueness of the rainfall pattern was very clear (increasing from south to north).

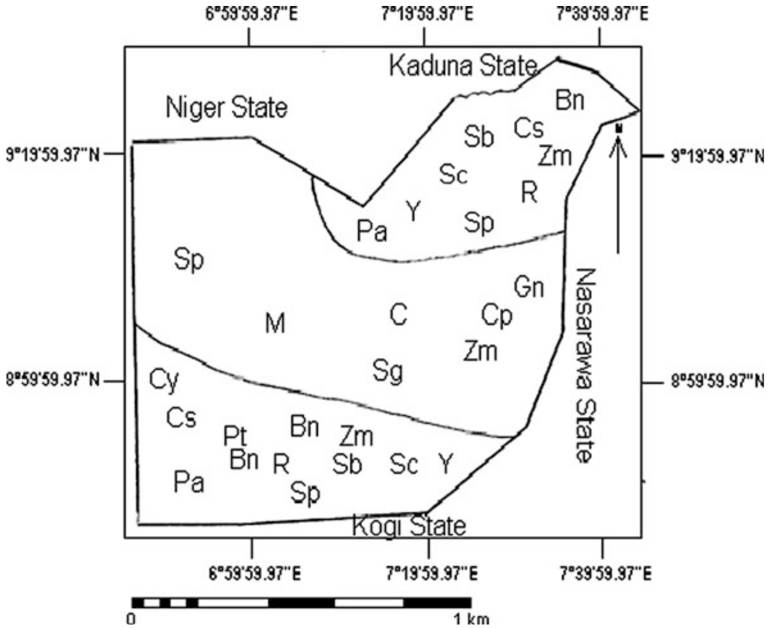

Fig. 20.9 Crop zones characterisation of FCT based on Fig. 20.7. Key: *Sp* sweet potatoes, *Gn* groundnut, *Sg* sorghum, *M* millet, *Zm* maize, *Cp* cowpea, *C* cotton, *Sb* soybean, *Y* yam, *Pa* pineapple, *Pt* plantain, *Sc* sugar cane, *Cs* cassava, *Cy* cocoyam, *Bn* banana, *R* rice

The result has the signature of change as depicted in the trends of rainfall and temperature within the study period. For example, the division of the region into two climatic zones by the PP Index, and the result in the classification of the territory into crop-ecological zones, revealed three ecological zones whose rainfall is zonal in orientation; (1) the southern humid zone, (2) the mid-central sub humid zone, and (3) the north-east humid zone. This provided the basis on which the crops were classified using the optimum moisture requirement by crops.

It is therefore recommended that further studies be carried out on trends of agro-climatic conditions in the study area.

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Author Biography

Dr Hassan Shuaib Musa holds a PhD in environmental resources planning. He is a senior lecturer and departmental postgraduate programme coordinator of geography and environmental management department, at the University of Abuja. Nigeria. He is an applied hydro/agro meteorologist and applied climatologist with over 15 years teaching experience. His areas of research interest include applied climatology/meteorology, climate change, environmental resource issues and GIS.

Chapter 21
Building Climate Resilience in Coastal Ecosystems in India: Cases and Trends in Adaptation Practices

Prakash Rao

Abstract Changes in precipitation, temperature, drought, and sea level rise a rise in sea level are increasingly being seen as affecting the world's ecosystems and natural resource base. Recent reports from the Intergovernmental Panel on Climate Change have provided ample evidence of the importance of climate variability in the changing nature of natural resource ecology, as well as the vulnerability of communities and their livelihoods. Climate variability and the rise in the incidents of extreme events and disasters like cyclones are major threats to the coastal and marine ecosystems in the Indian subcontinent, e.g. low-lying islands and coastal regions, some of which are already facing partial submergence, resulting in shoreline changes. Most of the coastal ecosystems in the South Asian region have a very high population density and are dependent on an agro-economy, whilst increasing changes to the weather have often led to adverse impacts on the local eco-diversity. Ecosystem-dependent communities are particularly vulnerable where single-crop agriculture, fishing and harvesting of other local resources are practised. These in turn could be adversely affected by changes such as sea level rise, increase in salinity, changing patterns of rainfall, and an increase in moisture content in the atmosphere leading to increasing incidences of vector-borne diseases. Addressing traditional knowledge systems with new research ideas and the development of innovative technologies is the need of the hour in order to provide a suitable adaptation response in the face of adverse climate impacts and natural disasters. The paper discusses approaches and trends for enhancing the coping capacity of coastal communities through two cases in India from the Sundarbans in West Bengal and Tamil Nadu. The paper also throws light on integrating national/state policies and

P. Rao (✉)
Energy and Environment, Symbiosis Institute of International Business, G No. 174/1
Hinjewadi, Pune 411057, India
e-mail: prakash.rao@siib.ac.in

W. Leal Filho (ed.), *Climate Change and Disaster Risk Management*,
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programmes for mainstreaming climate adaptation practices in development planning.

Keywords Climate change · Adaptation · Coasts · Communities · Planning

Introduction

Since the last industrial revolution, emissions resulting from anthropogenic activities have led to a substantial increase in the atmospheric concentration of greenhouse gases. The resultant warming of the Earth's atmosphere, has consequently led to a rise of about 0.8 °C in the average global surface temperature.

As a result of these changes, widespread ecological and socio-economic impacts of climate change could threaten the future growth and economic activities of several countries in the Asia Pacific region. Some indicators and triggers of global warming include increased extreme weather events (i.e. more flooding, drought, frequent heatwaves, cyclones, and depressions), increased agricultural losses, melting of sea ice, retreating glaciers, sea level rise, coral bleaching, and a decline in biodiversity. Communities in both developed and developing countries are already suffering from these impacts, and countries with a tropical climate are likely to be more vulnerable than developed countries.

Scenarios compiled by the Inter-governmental Panel on Climate Change (Parry et al. 2007) suggest than unless humans dramatically reduce greenhouse gas emissions, we will see a doubling of pre-industrial carbon dioxide concentrations resulting in an increase of the earth's temperature from between 1.1 to 6.4 °C (depending on estimates for low and high scenarios), with recent modelling suggesting upwards of 11 °C by the end of the century (Stainforth et al. 2005).

The last decade has been observed as the warmest with India and South East Asia experiencing frequent extreme climatic events. While recent climate models predict an increase in rainfall patterns, regional change may be different (Rupa Kumar et al. 2006). India is an agriculture-based developing economy, surrounded by a long coast line and a mountainous Himalayan range in the North. Given this, the country is vulnerable to any major changes in the overall climate. There is an urgent need for developing strategic interventions to address the adaptation needs of local communities and ecosystems based on impact studies. The regional climate variability and the various uncertainties involved in projecting future climate scenarios make local adaptation attributes a very complex issue and often region specific.

Interventions which have strong links to field projects currently focus on understanding climate impacts in vulnerable and eco-sensitive regions like the Himalayas, Sundarbans and the coastal regions. The process is guided by in-depth research and analysis of the regional and site-specific needs, and leveraging institutional capacities and organisational strength in the identified regions.

Himalayas

The vast number and range of glaciers and perennial river systems originating from the Himalaya mountain range in the north are the major source of freshwater supplies to the subcontinent. Due to rising temperatures and changing precipitation patterns, the glaciers are expected to show higher rates of retreat, (Xu et al. 2009) and with possible implications regarding the availability of fresh water and agricultural productivity in the South Asian region (WWF 2005). The direct evidence of real climate change impacts in the Himalayas requires immediate attention from the international community, as well as from regional and national policymakers for consideration in any future development planning.

Coastal Ecosystems

The coastal region of India is perhaps one of the most productive and ecologically diverse landscapes covering over 7,500 km of coastline. The importance of promoting regional fisheries in enhancing local livelihoods through sustainable measures is an important aspect of maintaining a local ecological balance (MoES 2010). The vast majority of coastal communities are currently facing stress from various pressures such as large-scale development along costal sites which threaten to affect their survival. Climate impacts are likely to further add to the growing changes and decline in the productivity of marine ecosystems in India's coastal sites. Several institutions have been involved in research and advocacy by studying some of the impacts caused by climate change in selected fishing communities in southern India including finding the ways and means of building resilience amongst local communities against the adverse impacts of climate change.

Sundarbans

Sundarbans is the world's largest mangrove ecosystem, a UN heritage site, a WWF designated Global 200 eco-region, and it is now under severe stress due to sea level rise and associated problems. The approximately four million-strong human population residing in the Indian Sundarbans is severely stressed due to sustained variability in local weather coupled with the occurrence of frequent cyclonic storms and depressions impacting their overall livelihood. The threat of decline of endangered species like tigers, turtles and some of the rare mangroves is also a major issue in this unique ecosystem (Loucks et al. 2010). This is also likely to adversely affect the overall ecological balance and increase the vulnerability of the region. Immediate attention is required from the global community as well as from stakeholders at the local level, in order to develop an effective coping mechanism to reduce the vulnerability of the region.

Climate Change and Coastal Ecosystems

The oceans and seas are an integral part of the earth's climate system and are responsible for maintaining the natural cyclical patterns. According to the Intergovernmental Panel on Climate Change (IPCC) climate change impacts on the ocean and marine ecosystems are likely to play a significant role in shaping the changes of the sea surface temperature, sea level, sea ice cover, salinity, ocean circulation and climate-related oscillations. Some of the main features of observed and projected changes in the characteristics of ocean systems include:

- An increase in the global ocean heat content since the 1950s.
- Global average sea level rise of between 0.1 and 0.2 m due to thermal expansion of water and the loss of mass from glaciers and ice caps. This is expected to increase to 0.6 m or more by 2100 (Parry et al. 2007).
- A decrease in the extent of sea ice in the northern hemisphere of more than 10 %, including a decrease of 40 % in recent decades of sea-ice thickness.
- An increase in the frequency, persistence, and intensity of extreme weather events based on the El Nino southern-oscillation (ENSO) cycle since the mid-1970s.

In the past few years, changes in rainfall, currents, and sea level associated with global warming, are already affecting the world's coastal ecosystems and fisheries. The recent IPCC report has also provided ample evidence of the implication of climate change on our biodiversity, as well as on the increasing vulnerability of some of our critical ecosystems and consequences for people's livelihoods (TERI 1996). Erratic weather and monsoon patterns along the Indian coastline, along with frequent extreme climatic events like cyclones, are major threats to the ecosystem including in some cases low-lying islands some of which are already facing partial submergence resulting in shoreline changes (Patwardhan et al. 2003).

Coastal ecosystems are particularly sensitive to physical and biochemical changes with reference to:

- Increased levels of flooding, loss of wetlands and mangroves, and saline water intrusion into freshwater habitats;
- Severity and increase of cyclonic events leading to coastal erosion and a loss of ecological diversity along shorelines.

Marine ecosystems are also likely to be affected by changes in sea water temperature, oceanic circulation patterns which may lead to changes in composition of marine biota, changes in migratory patterns, and changes in ecosystem functions. The increased amounts of CO_2 absorbed by oceans are also likely to have significant impacts on the acidity of ocean waters which in turn can have serious consequences for certain marine animals like molluscs, corals, etc.

The Fourth Assessment Report of the IPCC (Parry et al. 2007) has suggested that climate change is likely to have significant impacts on the coastal regions of India. Some of these include:

- Increased frequency of hotter days and multiple-day heat waves in the past century, with an increase in deaths due to heat stress in recent years.
- Sea level rise has led to an intrusion of saline water into the groundwater in coastal aquifers thus adversely affecting local freshwater resources, e.g. for two small and flat coral islands at the coast of India, the thickness of the freshwater lens was computed to decrease from 25 to 10 m, and from 36 to 28 m respectively, for a sea-level rise of only 0.1 m.
- Warmer climate, precipitation decline and droughts in most delta regions of India have resulted in the drying-up of wetlands and severe degradation of ecosystems.
- Ganges–Brahmaputra delta: More than one million people are likely to be directly affected by 2050 from risks of coastal erosion and land loss, primarily as a result of the decreased sediment delivery by the rivers, but also through the accelerated rate of sea level rise.

In coastal regions like the Sundarbans delta in West Bengal, the recent drastic changes in weather conditions and monsoon patterns, along with frequent extreme climatic events like cyclones are major threats to the ecosystem of the region. Climate change induced by anthropogenic activities is thought to be behind the observed rise in sea level, lengthier summers, and a dramatic increase in rainfall over the past 15–20 years. The already marginal economy of human populations dependent on single-crop agriculture, fishing, and harvesting of forest resources is also adversely affected by changes such as sea level rise, increase in salinity, changing patterns of rainfall, and an increase in moisture content in the atmosphere, leading to increasing incidences of vector-borne diseases (WWF 2010). This has increased their vulnerability and possibly their dependence on the forest resources.

Similarly, fluctuations in the sea surface temperature along the coasts of the Bay of Bengal and Arabian Seas have also resulted in changes and a decline in the availability of fish species, some of which are of good commercial value. The impact of climate change on regional fisheries can be ranked in terms of likelihood (for either warming or cooling) of impacts. Most of this knowledge comes from empirical studies over the last 50 years, when weather and environmental records became fundamental to explaining individual species' behaviour and the population responds to changes in local conditions (Patterson and Samuel 2004).

Climate events such as ENSO warm and cold events promote different levels of productivity. According to K. Krishna Kumar of the Indian Institute of Tropical Meteorology (IITM) in Pune in a paper published in Science (1999), the weakening link between ENSO and the Indian monsoon could be a result of global warming.

It is also a well-known fact that many large civilisations grew along the banks of rivers and coasts. More than half of the world's population presently resides in the coastal zone of Asia. Demographic changes, urbanisation, industrial development, trade and transport demands, and lifestyle changes have largely been responsible for the increasing pressure on coastal regions. Tropical Asia would probably experience the highest impact of present day climate variability and is therefore more prone to global climate change (Nicholls and Leatherman 1995).

In the Asia Pacific region many low-lying coastal cities are at risk and at the forefront of impacts. These include developing cities like Shanghai, Tianjin, Guangzhou, Jakarta, Tokyo, Manila, Bangkok, Karachi, Mumbai, and Dhaka, all of which have witnessed significant environmental stresses in recent years. A recent study (McGranahan et al. 2007) indicates that one tenth of the global population live in coastal areas that lie just 10 m above sea level. The study also brings home the fact that nearly two-thirds of urban settlements with more than five million inhabitants are at least partially in the 0–10 m zone, while on an average 14 % of people in the least developed countries live within the zone (compared to 10 %in OECD countries).

Cases and Trends from Two Indian Coastal Sites

Recognising the value of information available from the broader community, as well as the changing framework of traditional knowledge and local perceptions of coastal communities, recent cases and initiatives aimed at enhancing the coping capacity of these communities, and vulnerability reduction in selected locations of India's eastern coasts are discussed in this section.

Sundarbans

The study in the Sundarbans primarily focused on documenting local community knowledge and perception about the adverse impacts of climate change through the "Climate Witness" Initiative (WWF International 2005). The idea of studying people's perception and knowledge of extreme weather events originated from the strong indicators of climate change that were available in the region through the various scientific studies that were being carried out by different academic institutions and universities. Climate change was seen as one of the factors responsible for sea level rise, flooding, salt water intrusion, and an increased frequency of extreme weather events, apart from loss of land and property of local communities.

The "Climate Witness" approach is a methodology, which aims at documenting the perception of the community at various stakeholders' level on the adverse impacts of the climate change. This was expected to stimulate an integration of climate change concerns in overall development planning through a

Fig. 21.1 Mangrove ecosystem in the Sundarbans (*Source* Prakash Rao)

bottom-up approach in the decision making process. The following approach was adopted to study and understand community knowledge about the adverse impacts of climate change:

- Use of traditional community responses as well as scientific assessment of the local impacts;
- Involvement of different levels of stakeholders in developing model intervention;
- Identification of a homogeneous geographical area for validation of the model;
- Including local concerns about climate change in overall development planning.

The Sundarbans is part of the world's largest delta (80,000 km^2) formed from sediments deposited by three great rivers, the Ganges, Brahmaputra and Meghna, which converge on the Bengal Basin. It consists of 102 low-lying islands in the Bay of Bengal and forms one of the world's richest mangrove ecosystems with 34 true mangrove species (MoEF 1989). The faunal diversity of this area is also significant with a significant tiger population in the region (Loucks et al. 2010). The combination of terrestrial, freshwater and marine flora and fauna make this one of the most diverse and productive ecosystems in the country (Fig. 21.1).

The islands selected for the Climate Witness Initiative studies are mostly located in the south-western corner of Sundarbans except for Chhoto Mollakhali and the Bali islands situated at the north-eastern part of the delta. There are more than 100 islands spread over the entire Sundarban region of which the sea-facing ones are influenced by both the tidal action and delta-forming process. This coastline is remarkable for its highly productive mangrove forest and nutrient rich backwaters nourishing the aquatic diversity of the Indian east coast.

Several physical climatic factors provided indication of climate-induced changes in natural systems and help to understand the trends and potential hazards in future, e.g. temperature and rainfall. For the local community in these sites, the rise temperature was not a matter of concern. Rather the erratic weather patterns, such as the gradual delay in the onset of monsoons during the last few years was of great importance as this had implications for local agricultural productivity. Average maximum temperature in Sundarban delta ranged from between 35 to 39 °C while the minimum level was between 12 and 15 °C. Delayed monsoons and untimely rain often hampered the agricultural productivity leading to crop loss. An extended period of heat was observed during last few years. The majority of the farmers reported pest attacks on account of an irregular climate pattern.

A rise in sea surface temperature in the monsoon season had a correlation with the frequency and intensity of tropical cyclones. Tidal amplitude ranged from between 4.5 to 5.5 m from April to September, which had resulted in inundation. Local residents reported a very high frequency of thunder and lightning during storms in the last 10–15 years. In their opinion depression and cyclonic storms now occurred more frequently than earlier. The extreme dependence on monsoon-fed agriculture systems in these islands influenced the productivity and economy to a great extent.

Gulf of Mannar, India and the False Trevally (Lactarius Lactarius)

Most of our knowledge on regional fisheries and related climate impacts originates from scientific studies from the last 50 years, when weather, local climate and environmental changes became fundamental to explaining individual species distribution and behaviour patterns (Patterson and Samuel 2004).

The fisheries seen as highly sensitive to climate change are also often the most affected by other human disturbances such as infrastructure, local migration along rivers, encroachment of wetlands, habitat loss, and other issues related to human population growth.

A study coordinated by the author, along with Dr J.K. Patterson in 2004 in the Gulf of Mannar region, analysed the effect of climate change on the fishery of false trevally (*Lactarius lactarius*) and the reduction in the income of the dependent small-scale fisher-folk community. The study helped in understanding the present status of this fishery as well as understanding the identify shift in breeding grounds or migratory patterns of the fish species.

False trevally is an economically and culturally important fish in India and found near the Rameshwaram coast of south-east India. The species is generally seen at depths ranging from 15 to 90 m. Over the past few years there has been a steady decline in the catch of this fish both as a consequence of human disturbance and changes in the ocean temperatures. Human activities involving the use of destructive fishing practices and regular violation of coastal laws have also been responsible for the decline of the species (Fig. 21.2). This has resulted in the movement of the species to other regions along the coast including the east coast of Sri Lanka (Patterson and Samuel 2004).

Fig. 21.2 The net used by local fishermen for catching false trevally (*Source* J K Patterson Edward)

Community Interactions and Adaptation Policy Responses

Past studies in the Sundarbans deltaic region and in other regions have focused on developing coping capacities for the communities, particularly those in the islands and low-lying regions, which experienced a loss of landmass over the past few decades. Interactions with local communities have helped in categorising community knowledge based on environmental impacts like soil erosion, loss of landmass, damage of coastal embankments, siltation, unsustainable livelihood practices, population pressure, storms and cyclones, and the effects of tidal waves, etc.

The study revealed that ecosystem-dependent communities like farmers and fishermen formed a major part of the work force of these islands. In the absence of industries and other developmental activities, livelihood options were limited here. The general livelihood pattern indicated that the majority of the inhabitants were vulnerable to climate related adversities.

The interventions response of the community in developing adaptation responses has been primarily a localised effort with village communities implementing short-term actions as a reactive response to the threat of climate change impacts. Some of these responses included:

- Shifting of farming time in anticipation of the shifting monsoon season;
- Diversification into different weather resistant crops;
- Construction and renovation of ponds and canals for rainwater harvesting and use in winter cultivation;
- Constructing of mud barrages around the islands to protect from incursion of saline water;
- Reforestation activity (mangroves) on the mud barrage.

The coastal ecosystems are known to be one of the most productive ecosystems across the world, harbouring a diverse range of floral and faunal elements. The range of ecological services generated by marine ecosystems has had tremendous implications for the wellbeing of coastal communities in sustaining local livelihood. The increasing pressures being brought upon the coastal regions as a consequence of unplanned development along the fragile coastal belt have already resulted in severe pressures for both local ecology and dependent communities. Future efforts in building the resilience of the local community and the ecosystems should take into account a visionary and integrated approach (MSSRF 2009).

Multi Stakeholder Based Approach

The role of climate adaptation efforts in the context of natural ecosystems has gained considerable momentum in the past few years through national and international efforts under the UNFCCC as well as through the intervention of civil society institutions. Several studies have focused on understanding the vulnerability and adaptive capacities of communities, livelihood and ecosystems across different regions of the world using complex field methodologies. However, it must be mentioned here that adaptation responses to climate change should be considered through a detailed and integrated approach focused on the involvement of all stakeholders who may be directly impacted by climate change, as well as those who may play an indirect role in the adaptation process (UNDP 2010).

In the present case two important studies have been dealt with, particularly with reference to Sundarbans, the Gulf of Mannar, and the false trevally. Building the resilience and adaptive capacity of the region of these critical and fragile ecosystems should be considered, not only from an ecosystem perspective, but also from the view point of understanding the requirements of people and their livelihood. In both cases, local communities have a strong livelihood dependency factor on ecosystem thereby increasing their vulnerability to climate-related stress.

The involvement and role of multiple levels of stakeholders is therefore a challenge in developing suitable adaptation frameworks in the affected regions. The Sundarbans case study is an interesting example to explore some of the challenges of developing multi stakeholder based approaches.

While there are clear signals of district and grass-roots level initiatives to implement climate adaptation initiatives through a bottom-up approach, clearly the involvement of academics, research scientists, and policymakers at the governmental level needs to be strengthened and brought together in implementing an integrated Sundarbans development plan. Although the Sundarbans Development Board has been in existence for some years and performing tasks according to a mandated policy, it might be necessary to build in an interdisciplinary team to develop an effective plan in the region involving multiple stakeholders like various line ministries, academics, civil-society representatives, local community personnel, development sector specialists, policymakers, and communication and media specialists, etc.

It may be of relevance to note here some of the important challenges faced in building a sound adaptation initiative through a multi stakeholder based approach. These include:

- Effective inter-governmental coordination between various line ministries particularly those which have a direct relevance to issues related to the affected ecosystem. Using the case of Sundarbans, this could involve Ministries of forests, irrigation, agriculture, fisheries, revenue, inland waterways, and rural development, etc.
- The role played by academics and research scientists is very vital in building a common understanding of the scientific validation of the problem. In the case of the Gulf of Mannar and the false trevally case, it is important to bring together marine scientists, social and developmental scientists, oceanographers, marine biologists as well as climatologists for understanding the factors leading to a decline in the density of false trevally as an economically viable fish for the communities living in the Gulf of Mannar region.
- Communications and media workers often effectively play a major role in the dissemination and documentation of local and traditional knowledge systems and key issues of the region to local communities, policymakers at a state and, national and international level. One of the challenges in this area is the lack of such information being made available across all sections of society particularly at the level of policymakers for effective implementation of policies.

The PPP Model

The role of local institutions and networks often shape the effects of climate change adaptation-related initiatives and livelihoods in a region. These could be developed through a process of partnerships amongst public, private and civil society institutions. The Public–Private Partnership Model (PPP) which is being already seen as a major governance paradigm across many countries, and implemented with moderate success across other developmental sectors, could be an answer to such collaborative arrangements.

PPP is seen as a third alternative to governance for bringing about efficient delivery of services, stakeholder involvement, and benefits for public goods and services, in a wide range of sectors ranging from utility services in water supply and distribution services, power generation and distribution, irrigation management, sustainable transport, and urban waste management, etc. (World Bank 2006). Climate adaptation efforts could follow a similar model of building suitable PPP-based approaches through integrating the private sector (in this case civil society institutions, NGOs, etc.) into the larger decision-making process. Local institutions could structure environmental risks and variability, create suitable market mechanisms and influence the capacity of community's adaptation choices. Such institutional structures would help build information about the dissemination processes, resource mobilisation and allocation, skills development, and leadership, etc. The model also shows clearly the link between local and national institutions as a way forward to building up an effective multi stakeholder relationship.

Using a PPP-based approach with a clear community focus may also be a viable option to policymakers in addressing these issues. Some of the key functional attributes of PPPs include, short to long-term time frames of implementation, fair and transparent processes, stakeholder consultative processes, proper legal and institutional frameworks, as well as financial and economic considerations.

At the level of the Indian government, there has been some progress in addressing these challenges through a comprehensive focus related to adaptation through the National Action Plan on Climate Change. The National Action Plan on Climate Change (NAPCC) formulated by the Government of India in 2008 (NAPCC 2008) as a key follow up to the Bali Action Plan, has placed emphasis on the adaptation and vulnerability of local communities against the adverse impacts of climate change as a major focus area. According to the NAPCC, existing government expenditure on adaptation related activities in India constitutes about 2.6 % of GDP which includes several natural resource areas including coastal zone environments and extreme weather events. However, this approach could be debated considering several on-going activities that are being implemented in a "business-as-usual" scenario, have for a long time been classified as adaptation to climate change and therefore, cannot be termed a classical adaptation related intervention since they fail to integrate climate change into development planning efforts. Adaptation to climate change and reducing vulnerability in coastal regions may be dependent on several factors including gender, access to information, technology, and infrastructure, etc. A case in point is gender-based vulnerability where women in coastal regions often tend to face a higher mortality rate during natural disasters like cyclones, and extreme weather events. For example, in the 1991 cyclone in Bangladesh, women constituted nearly 90 % of the total deaths out of about 140,000 people.

While the NAPCC is a document which strategizes the future response to tackle climate change, it is suggested that community-based frameworks and action plans should be given more importance (Thakkar 2009). The NAPCC does not lay specific emphasis on coastal zone adaptation in India and reducing the vulnerability of local communities, as well as improving livelihood resilience. In a country with a critically vulnerable coastal ecosystem ranging over 7,500 km, and with a significant population of ecosystem dependent communities, it is imperative to have a targeted action plan.

Conclusion

Coastal regions around the world are one of the most fragile ecosystems which require immediate attention for their conservation. The existing pressures from rapid and unplanned industrial development, population growth, and pollution, have also been putting stress on these systems. In a climate-constrained world, additional stress and increased vulnerability from climate change will only make these ecosystems difficult to manage (Shukla et al. 2003).

A number of interventions through adaptation are possible to build up the resilience level across coastal regions. These could take different approaches where people, livelihood and ecosystems are considered as an integral part of the biosphere. Adaptation responses in coastal systems could therefore be divided on the basis of technology and innovation, biological, regulatory, institutional and developmental approaches to reduce vulnerability from climate-related hazards.

In summarising the study it is suggested that such integrated actions will benefit the coastal zone communities through the inclusion of sound policies and climate adaptation practices in state, regional and national level plans using the following visionary approach;

> Ecosystems-dependent communities and local economies need to be adapted for climate change impacts and supporting mitigation advocacy.

As part of this process multiple stakeholders at various different levels need to come together to address the issue of climate change and environmental security.

- Local: Community-level site-specific measures could be developed;
- National: Common consensus for national adaptation strategies;
- International: Supporting inter-governmental processes.

In the context of building coastal ecosystem resilience, some of the stakeholder groups could include:

- Poor and vulnerable;
- Ecosystem-dependent communities (Agriculture, fisher-folk communities, etc.);
- Decision-making bodies at local, state, and national levels;
- Urban consumers;
- Business and industry;
- Coastal zone regulatory groups;
- Scientists and academic bodies;
- Civil society groups.

In conclusion, this paper suggests that a multidisciplinary approach involving several stakeholders on a common platform can stimulate integration of climate change concerns in the overall development planning process. Empowering stakeholders through collaboration could take the shape of establishing institutional processes with local civil society organisations and other stakeholders. Climate change as an issue is still relatively less understood and strengthening capacity through awareness is an important part of building resilience. Other activities include promoting the role of grass-roots level civil societies through the development of resource centres and creating local knowledge networks to raise the level of local development planning.

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Author Biography

Prakash Rao is Associate Professor of Energy and Environment at the Symbiosis Institute of International Business, Pune, India. He has a doctorate in Zoology from the University of Bombay and has over 27 years' experience in research and consultancy in natural resource management, climate change adaptation and mitigation issues. Previously he was a senior coordinator at the Climate Change and Energy Programme at WWF India. He has published more than 20 research papers and edited two books on natural resources and climate change in India. His current interests include urbanisation, water-energy linkages, and climate and development issues.

Chapter 22
Climate-Change Refugees in Nepal: The Need for Climate-Smart Capacity Building

Nam Raj Khatri

Abstract The Himalayan region of Nepal is relatively vulnerable to climate change. This is the first recognised case of climate change refugees in Nepal, affecting the village of Dhe in Upper Mustang in the western Himalayan region of Nepal. A total of 23 households are being relocated due to the adverse impact of climate change on the livelihoods of the people in the village. A feasibility study for possible resettlement with a water supply is underway. The new settlement would be the first model village for climate refugees. It would be solar-powered, have plenty of greenery and appropriate land allocation for public use, such as parks and a market. Dhe has been facing an acute shortage of water for drinking and irrigation over the last 6–7 years. There is hardly any greenery to be seen around the village. This chapter will examine possible alternatives for keeping people in the same location to which they have a sentimental attachment and have adapted in many other ways. Solar energy for pumping water from nearby sources, collection of rainwater from roofs for drinking (which provides about 5–10 L per person per day), collection of rainwater in ponds for irrigation, use of drip irrigation, and an EcoSan latrine can all be promoted. This chapter examines new thinking on preventing climate change refugees and enabling them to stay where they are with dignity and a more adaptive capacity using climate-smart technologies, and suggests how governments can invest in these areas, which contribute little to climate change but are more vulnerable to its adverse effects.

Keywords Climate change · Climate change refugee · Climate-smart capacity building · Climate resilience technology

N. R. Khatri (✉)
WHO Nepal, UN House, PO Box 108, Lalitpur, Nepal
e-mail: khatrin@searo.who.int; namrajk@gmail.com

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Background

Nepal is situated on the southern transitional terrain of the central Himalayas on the Asian continent of the globe. It is located in South Asia between two large countries, China and India. The country covers an area of 147,181 km^2 and is divided into three ecological regions based on altitude. These ecological regions—mountains, hills and *Terai* (flat land)—cover 35, 42 and 23 % of the total area of the country respectively. They are quite diverse in terms of climate, topography and socio-economic characteristics. The country's current population is 28 million. About 16 % of the total population lives in urban areas.

Nepal is one of the poorest, but environmentally richest, countries in the world, with very few carbon emissions of its own. Carbon emissions in Nepal are only 1.9 tons/person while world's average is 3.9 tons/person. Nevertheless, it is extraordinarily vulnerable to the effects of the changing climate. The temperature in the Himalayas is rising more rapidly than the global average temperature. The average temperature in Nepal has risen by 0.6° over the last decade, compared to an increase in average temperatures globally of 0.7° over the last 100 years. Scientists worry that the impact of what is happening in Nepal will be felt all over Asia. Nepal has three things it can do within the context of climate change. Firstly: take advantage of being environmentally rich, i.e. a low carbon emitter; secondly: think about adaptation; and thirdly: take more precautions so as to minimise further carbon emissions. This chapter deals with new thinking on how to prevent water-related disasters caused by climate change in the Himalayan region of Nepal leading to refugees termed as "climate change refugees" and enabling them to stay where they are with dignity and a more adaptive capacity using climate-smart technologies.

Overview of Climate Change Concepts

The solar radiant energy flux from the sun, just outside the earth's atmosphere, is 1.353 KW/m^2. If all of this energy is received and absorbed by the earth, then the black body radiation from the outer surface of the earth will be the same as the energy received. According to Stefan's law, the temperature of the earth for this amount of radiation would be about 5 °C. In fact the earth reflects about 30 % of all the incoming solar radiation back to outer space from the tops of cloud, icy surface and oceans. With this 70 % solar energy equivalent, the earth's temperature for black body radiation would be −19 °C. But the earth's average temperature has been maintained at about 15 °C. This means that the atmosphere is preventing the outward flow of radiant heat. To maintain the average temperature of 15 °C, about 14 % of radiant energy has to be retained. Put simply, energy radiation from the sun falls within the visible range and that of the radiation from the earth falls within the infrared range. Greenhouse gases (GHGs) have the ability to trap the infrared rays reflected by the earth. Therefore, the greater the quantity of GHGs, the more the atmosphere will be heated up. This phenomenon is essential for life on earth to exist by keeping the earth's average temperature at around 15 °C. However, more GHGs cause a rise in temperature compared to the present level, which is known as global warming.

From a pre-industrial concentration of 280 ppm, the present level of GHGs in the atmosphere has reached 430 ppm, and is increasing by approximately 2.5 ppm per year. The overall composition of GHGs in the atmosphere is: carbon dioxide (55 %), methane (15 %), nitrous oxide (6 %), CFCs (17 %) and other (7 %). In the atmosphere, methane is 20 times, nitrous oxide 200 times, and CFCs 12,000 times more effective in producing a greenhouse effect than carbon dioxide. As the volume of the CO_2 is much higher than other GHGs, it is more of concern in the context of global warming (Noel De nerves).

The current best estimate, based on a projection of all future GHGs, is that the mean temperature of earth will increase by 0.2 °C per decade. This will lead to a 2 °C rise in the earth's average temperature by 2,100, corresponding to a rise in the mean sea level of 6 cm/decade.

Effect of Climate Change on Water

Climate change will impact on some of the fundamental pillars of life, such as food, water, air and shelter. The warming of the earth is gradual, but the frequency and severity of extreme weather events such as intense storms, heat waves, droughts and floods could be abrupt and the consequences will be dramatically felt.

The global temperature rise will lead to an intensification of the hydrological cycle, resulting in drier dry seasons and wetter rainy seasons, and subsequently a heightened risk of more extreme and frequent flooding and drought. The changing climate will also have a significant impact on the availability, as well as the quality and quantity of water. Melting glaciers will increase flood risk during the rainy season, and strongly reduce dry-season water supplies to one-sixth of the world's population (Water Aid).

Water-Use Technology and Practices in the Himalayan Region of Nepal

The water-supply system in Nepal varies from one ecological region to another. About 50 % of people in Nepal have access to a piped water-supply system, including 30 % from spring sources, 10 % from stream sources and 10 % from deep tube wells. 30 % of the people use shallow hand pump systems, while the remaining 20 % still use traditional systems as their primary source of domestic water. In the Himalayan region, the main sources of water supply are springs and streams. A pipe system has been developed in areas where people are clustered. Due to cold temperatures, GI pipes burst when water freezes in the pipe during the night and melts during the day. One of the major problems with the water supply system is that small spring sources tapped for water supply are drying up or the springs are shifting away from their original location. Many stream sources coming from glacier lakes are also drying up (DWSS).

Irrigation is practiced in some areas of the Himalayan region to grow wheat, paddy rice and vegetables. Open channels with a vegetative lining are a common technology, but water is also lost this way. Flooding is a common means of irrigation, but requires a large quality of water for small areas.

Climate Change Refugees: An Example

This is the first recognised case of climate change refugees in Nepal. A total of 23 households in the village of Dhe in Upper Mustang, which lies in the western Himalayan region of Nepal, are being relocated due to the adverse effect of climate change on the livelihoods of the poor in the village. Two households from Dhe have already moved elsewhere within the last 3 years. A feasibility study for possible resettlement with provision of water-supply facilities is underway. The new settlement would be the first model village for climate refugees. It would be solar-powered and have plenty of greenery and appropriate land allocation for public use, such as parks and a market.

The village of Dhe has been facing an acute shortage of water for irrigation over the last 6–7 years. The total area of irrigated land has fallen over the period by more than 50 %, and animal husbandry (particularly goats) has declined by 40–45 %. Water sources have completely dried up. People in Dhe are using yaks and horses to bring in small quantities of supplies from the lower trans-Himalayan region for their families. There is hardly any greenery to be seen around the village, which just 7 years ago used to be very green. These are the symptoms of rapid climate change in the Himalayan region of Nepal impacting on the water cycle. It is not possible for local people to stop climate change, though they could think of adapting through appropriate measures and practices. The following causes can be linked to the resultant climate refugees or potential climate refugees in the future in the Himalayan region of Nepal (Sharma 2010).

Immediate causes: People have not explored alternative water-supply systems for drinking and irrigation, such as rainwater harvesting. They have also tried neither solar energy for pumping water from nearby sources nor efficient irrigation methods. Instead of trying to develop greenery using appropriate technology, they have consumed existing plants. They have not thought of alternative ways of making a living, taking benefit from the natural beauty of the place to promote tourism.

Underlying causes: People have not had any long-term planning to sustain them in their location. No development agencies have helped them to develop adaptive capacity. Instead, some agencies have become interested in developing a climate refugee site as a model. They could have been helped to adapt to living in the same place with all the technology and costs devoted to the new settlement area, which is in fact not feasible for everybody.

Root causes: The root cause of the problem is ignorance on the part of the government and local agencies regarding possible climatic threats which have otherwise been a matter of discussion for a long time. The government has not made longer-term plans regarding the adaptive capacity of the people in the Himalayan region. There are many funds dedicated to national adaptation plans of action in the light of climate change. Generally speaking, such funds are paper-based analyses dealing with general development activities of all kinds. Such funds should have been directly diverted to such areas. The government does not have a working policy or investment plan for such places and people, who contribute little to climate change but are unfortunately more vulnerable to its consequences.

Climate-Smart Capacity Building in Himalayan Regions

It is high time that possible alternatives be sought to sustain people in the same location to which they have sentimental attachment and have adapted in many other ways. The area is also naturally beautiful. It could be explored how their adaptive capacity can be enhanced using innovative tools for solving the problem of water for drinking and irrigation.

Rainwater harvesting: Rainfall in this area is very low, about 250 mm/year. Water can be collected in certain areas in cost-effective ponds. Stored water can be used for drinking, domestic use and vegetable growing. In Nepal, there are about 15,000 families using rainwater harvesting (RWH) from roof tops to obtain drinking water. The main cost of RWH is the collection tank. Low-cost techniques are also available, and outside support is also needed. Rainwater collections ponds are also being promoted by The International Centre for Integrated Mountain Development (ICIMOD) and other agencies.

Solar energy: Solar energy is gaining popularity in Nepal. Solar energy can be used for heating and lifting water from nearby streams for drinking and drip irrigation. Some examples can be seen of how communities located in difficult areas have benefited from solar-powered water supply systems in Nepal. The installation cost of solar power is not high. Since hydro power in Nepal is not sufficient to meet demand, the government is encouraging people to use solar power in rural communities. These climate change vulnerable communities should be supported as part of that mission. The cost of a solar system for a family for lighting, cooking and heating water is about USD 4,000.

Drip irrigation: Drip-irrigation technology delivers water directly to the plant root at required time through a system of plastic tubes, thereby preventing losses due to evaporation or run-off. Drip-irrigation systems are 90 % efficient, and therefore require minimal water for growing vegetables. This practice was first developed in Israel, and was modified by the International Development Enterprise (IDE)-Nepal, which has reduced the cost of the drip-irrigation system. The cost of equipment for a family with 0.25 hectares of land is about US$ 300. This technology has been used in Nepal for several years with the support of various agencies such as the Asian Development Bank (ADB), Swill Development Cooperation (SDC) and other organisations. More than 100,000 families are currently using this system (Dhakal).

Ecological sanitation: Ecological sanitation is based on the fact that most of the nutrients excreted by human beings are contained in urine. Hence urine is separated from faeces using special pans and then used for growing vegetables. This is more effective than fertiliser because it contains all kinds of trace metals which plants need. This technology will promote sanitation and recycle both nutrients and, to some extent, water. The urine is mixed with water at a ratio of 1:4 and used with a drip-irrigation system meets both water and fertiliser needs. Theoretically, the urine excreted by one person is sufficient to enough grow vegetables for one or two persons if animal manure is also used. An ecological sanitation system is in use by some 2,000 households in about ten clusters of Nepal. Darechowk in Chitwan District is being developed as an EcoSan village and resource centre. A study carried by the Department of Water Supply and Sewerage (DWSS) in 2009 showed that EcoSan technology is widely accepted by the people, and more than 50 % of people using an EcoSan toilet are making use of urine, while others are thinking of using it.

Green technology: There have been a lot of studies and pilot projects on growing greenery in the Himalayan region. Part of the region can be developed as a green area using water-efficient plants.

Other adaptation: There are many other technologies which can be practised for the purposes of adapting to climate change. Areas can be developed as tourist spots with a special effort on the part of government.

Conclusion

This is a water-related disaster caused by climate change. Local people cannot stop climate change, but it is possible to adapt to it. Keeping climate change in mind, there should be a discussion of how national development policy should be changed so that the specific problems of these people at a local level can be addressed. Solar energy for pumping water from nearby sources, collection of rainwater from roofs for drinking and in ponds for irrigation, and the use of drip irrigation can all be promoted. Ecological sanitation which provides urine as a fertiliser, and when diluted with water at a 1:4 ratio meets both urine as well as water needs can also be promoted. The government should invest in these areas, which contribute little to climate change but are more vulnerable to its effects so that the inhabitants do not need to be relocated but can, through adaptation, remain in areas to which they have a sentimental attachment.

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Author Biography

Mr Nam Raj Khatri is a resident of Nepal. He works as a National Programme Officer for a unit of the World Health Organisation (WHO) in Nepal and is responsible for environmental health, including water sanitation and climate change. He obtained a Master's degree in Environmental Engineering from the Tribhuwan University of Nepal in 2000 with a distinction. He has worked for the Government of Nepal in the field of water sanitation for almost 20 years. He has published various papers on climate change. Address: Thecho Ward No. 9, Lalitpur Nepal, Email: namrajk@gmail.com.

Chapter 23
Effective Policy Communication Strategy to Enhance Capacity Building for the Diffusion of Innovation in Climate Change Mitigation for Sustainable Disaster Risk Management

Wilson Okaka

Abstract The main objectives are to: present a brief synopsis of climate change communication initiatives in Uganda; describe the significance of an effective policy communication strategy in enhancing public awareness communication campaigns for climate change innovations and policy implementation; identify the key stakeholders who should be involved in the mitigations of the impacts of climate change in order to initiate policy innovations and dissemination for disaster risk management; establish the critical enabling factors and the practical challenges encountered in climate change policy innovations; discuss the lessons learned and make realistic recommendations, such as developing an effective national climate change policy communication strategy for sustainable indigenous communities in Uganda and the rest of Africa. This review collated published evidence on the use of, and effectiveness of, sustainability and behaviour change communications strategies for innovations in climate change awareness, adaptation, vulnerability, resilience, and mitigations among indigenous peoples in Uganda; using relevant search terms. Information was accessed using internet search engines and libraries. More data was sought from the databases of institutional, national, regional, and international agencies. Most of the severe problems of the increasing vulnerabilities related to the impacts of climate change in Uganda have come about because of the information gaps amongst most Ugandans about the correct use of environmental resources to curb climate change for sustainable development. All the key stakeholders in Uganda's development research process are aware of this. UNFCC addresses sustainable development issues with a focus on environmental concerns, access to north–south disaster technology transfers, financial aid, capacity building, and accessible information for sustainable community development.

W. Okaka (✉)
Department of Teacher Education and Development Studies, Kyambogo University, P.O. Box 29 Kyambogo, Uganda
e-mail: nupap2000@yahoo.com

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Introduction

Public communication campaigns are vital for any disaster risk management policy or communication strategy. This article highlights some of the key issues and factors that are instrumental to the development of effective risk communication strategy to mitigate the negative impacts of climate change on the environment. It identifies the key stakeholders in the process of developing public awareness communication campaigns, the major actors for climate change adaptation policy change, and factors that promote the achievements of any planned climate change policy innovations. It considers the common lessons learned and recommends the way forward.

Methods

In this review, we collated published evidence on the effectiveness of public communication strategy in enhancing capacity building for community vulnerability, adaptation, as well as mitigation innovations for climate change using relevant search terms. Information was accessed using internet search engines and libraries. All documents that were obtained during the review process were used to broaden the search for primary information sources. Initially additional information was sought from the databases of national, regional, and international agencies. In the searches, we looked for documents referring to public awareness communication strategy for climate change impacts and community vulnerability, adaptation, and mitigation, in addition to climate change policy diffusion and widespread adoption of innovations in science and technologies for community adaptation and mitigations. Firstly, retrieved documents were scrutinised for relevance and then carefully examined for evidence. The information was then consolidated and summarised to chart the way forward using the available resources for social, economic, environmental, legal and political applications.

Results and Discussion

Most of the severe problems of the increasing vulnerabilities to the impacts of climate change in Uganda have come about because of the information gaps among most Ugandans about the wise use of environmental resources to curb climate change for sustainable development. Most key stakeholders in Uganda's development research process are aware of this. Therefore, the Ugandan government implemented a project to raise knowledge, awareness, and adaptation and mitigation practices and actions in order to popularise the UNFCCC. A multi-stakeholder integrative sustainability planning project was launched. Uganda signed the UNFCCC on 13 June 1992 and ratified it on 8 September 1993. The implemented project adopted a national adaptation programme of action to communicate urgent adaptation strategies to combat the adverse impacts of climate change in the country. The convention addresses sustainable development issues. It emphasises environmental concerns, access to technology transfers, financial aid, capacity building, and information exchange. One of the key issues identified in Uganda was the limited public awareness of climate change initiatives so far implemented in Uganda (NEMA 2002). One of the key policy responses required to improve environmental management is to create greater awareness of environmental issues among the judiciary and the policy makers for national economic development (NEMA 2005b). Effective communication strategy will design, implement and evaluate climate change policy awareness goals, strategies, objectives, and adaptation (Okaka 2009a). The campaigns can help enforce compliance with the national environmental laws, policies, and international climate change protocols in Africa. Several studies have warned that Uganda could lose all its forest cover in the next 30 years if no effort is made to reduce the (current) level of deforestation. Uganda's forests have been degraded, and in some cases, the biodiversity has been eroded (Obua et al. 2010). Therefore there is a definite need for regular data updates on the status of the forests in terms of the real extent of the problem, distribution of the plantation species introduced, and the biodiversity. These are critical issues that are linked to climate change phenomena in Africa. On the basis of an analysis of the effects of climate change and the costs and benefits of action in this area, the EU climate change strategy would implement the existing policies, and prepare new measures to increase public awareness (EU 2005).

Developing an Effective Public Awareness Communication Strategy

Climate change has exacted several untold social, economic, environmental, and political miseries on almost every Ugandan and most other African populations. The most important reasons for the continued degradation of wetlands (carbon sinks) in Uganda are attributed to weak enforcement of the environment laws and low levels of awareness among policy makers and rural communities (NEMA 2005a). In a national survey of selected Ugandan districts, most (70 %) respondents who lived near wetlands reported that they exploited the resources for cultivation, hunting, grazing livestock, and furniture and building materials (NEMA 1994). Wetlands degradation has continued unabated (NEMA 2007) mainly because of low or lack of public awareness about the values, benefits, and functions of wetlands for socio-economic benefits and illegal “development” activities. The key areas of focus can be summarised as:

- Awareness campaign strategy
- Policy goals, principles, objectives, strategy, and action plans
- Message design approach
- Audiences and their environmental constraints
- Message delivery and message reach
- Gender concerns and ethical issues
- Channels and media choice
- Audience participation levels
- Research and relevant communication theories/communication models
- Performance evaluation and information dissemination
- Central government (the centre)
- Local governments (parish, sub county, county, district)
- Local communities (urban, per-urban, and rural)
- Donors/external development partners/key networks
- Civil society organisations (NGOs and CBOs)
- Private sector and investors (local and foreign)
- Households (families) and individuals
- Professionals, experts and specialists
- Regional and the United Nations systems.

Most problems of environmental information management are: weak community and institutional capacity, lack of dissemination guides, and data weaknesses (NEMA 2007). A study of knowledge, attitudes, and practices in Uganda, found that only just over a third of the population was aware of the functions and benefits of wetlands, though less familiarity was demonstrated with policies and laws governing their management and wise use (MLWE 2001). A study by Rogers (1995) found that the mass media is more influential in spreading awareness about adopting new possibilities and practices of innovations. The diffusion of innovations theory studies how, why, and at what rate new ideas spread through cultures.

Key Enabling Actors for Climate Change Adaptation Policy Challenges

A positive attitude is critical for early and widespread adoption of innovations by the target groups. A study of the Budongo forest reserve (Obua et al. 1998) confirmed that positive attitudes of local communities towards forest management practices are an essential prerequisite for local participation in forest management. Behaviour change communication programmes use various tools to provide information, informed decision making, and encourage community participation for behaviour change. Africa is already experiencing the devastating impacts of climate change as seen in frequent floods and droughts, as well as in the shift in marginal agricultural systems (Ngaira 2007), not to mention as communities struggle to adapt to the challenges of food insecurity caused by climate change, the diminishing and management problems of water resources (Ngaira 2009). When (Chun Knee 2008) climate change information is imparted to an audience, awareness is created and understanding takes place. The individual's willingness to commit to the action called for in the communication campaign will bridge the gap between awareness and the action gap (behaviour change). The following recommended actions were identified for public awareness in the initial national communication: planning national campaigns for public awareness on climate change for different sectors by use of both print and electronic media. The communication awareness concerns for widespread diffusion process are:

- Lack of awareness and information access
- Uncoordinated stakeholders
- Misconceptions and cultural (traditional) myths
- Superstitions and unscientific beliefs in witchcrafts
- Conflicting campaigns messages
- Distorted and conflicting messages
- Inaccessible information
- False or ineffective media and communications (channels)
- Media and audience scepticism
- Lack of a comprehensive communication strategy
- Financial and budget constraints
- Unsynchronised messages
- Lack of research information dissemination strategy
- Irregular gender policy messages
- Environmental constraints poverty, physical environment)
- Disempowerment (lack of skills, knowledge, inequality)
- Discrimination, exclusion, bias, stereotyping, prejudice
- Unilateral message design, message delivery, and evaluation
- Unprofessional conduct of the entire campaigns process
- Political, management, and administrative interferences
- Corruption and financial leakages and unsustainability
- Low and misdirected institutional policy priority to awareness
- Ignorance, false and negative attitudes, and behaviour.

The two main categories of communication (mass media and interpersonal) are often used together to reinforce a message (Okaka 2009b). Participatory research promotes the forging of a partnership between researchers and the audience (Sohng 1995), where the researchers and participants are actors in the investigative process, influencing the flow, interpreting the content, and sharing options for action. The communication strategy for the Jomo Kenyatta Grounds (LVTFJKG 2006) study found that the most critical communication problems in the entire LVB include: lack of access to public information by the public; a lack of systems to handle the policy information needs of the audience; poor flow of public information for sustainable development between the government, the civil society and the private sector. Conservation measures can be effectively implemented if all stakeholders are empowered to participate in the policy or legislation making (Okaka 2010a).

Enabling Actors for Climate Change Policy Innovation Success Stories

To make informed decisions about climate change, policymakers will need timely and useful information about the impacts, public perceptions of the impacts, all adaptation options, and the benefits of mitigating climate change (WHO 2002). The challenge for researchers is to provide this information in tandem with other global environmental stresses because climate change should be viewed as part of the larger challenge of sustainable development. Action on climate change consists of two complementary elements. The strategy to communicate the mitigation and adaptation actions should aim to raise awareness in the community of the opportunities and threats brought about by climate change, and to adapt to or mitigate against harsh climate change impacts. Public awareness is the key to making a real difference in the fight against climate change; as a result, the use of effective communication strategies can change behaviour towards climate change action. Climate change is one of the greatest environmental challenges facing the world today as the shifting of parameters such as rainfall and temperature regimes can trigger changes in land cover changes, land degradation and biodiversity (ICSU 2008). Some of the vital enabling factors to consider include:

- Awareness of gender concepts, issues, concerns, and needs
- Accessible gender information (e-readiness and ICT diffusion)
- Incentives for gender sensitive attitudes and behaviour
- Applicable gender policy and laws (enforcement/regulations)
- Political, management, administrative commitment and will
- Education and functional literacy levels
- Stable social, economic, legal, political, and natural environment
- Role models, appeals, credible messages, and media (channels)
- Scan and remove environmental barriers (constraints)
- Quality of messages and services
- Uniform messages of actors (target and intended audiences)
- Participation of key stakeholders (staff and students)
- Gender equality and equity
- Empowerment of women
- Participatory message design
- Harmonious messages

- Message reach to the intended audiences
- Multimedia approach and strategy
- Ethical conduct of campaigns process e.g. Cultural sensitivity
- Empowerment to performance
- Positive messages and encouraging appeals
- Access to services and products (outputs/results).

There is a need for science communicators to raise public awareness of emerging environmental science issues, boost interest in science innovations, and stimulate public understanding of the science they live with. Climate change is a risky and disastrous emergency that needs to be addressed.

Lessons Learned and Recommendations for Climate Change Adaptation

Most of the severe problems of the increasing vulnerabilities related to the impacts of climate change among the indigenous communities in Uganda have come about because there are still information gaps regarding the functions, values and importance of the wise use of natural and environmental resources by communities, institutions, and industries. The governments, researchers and research institutions, research networks, civil society bodies, communities and external development partners (donors) in the African Union are aware of this fact. So far, various approaches, initiatives, programmes, or projects have been unsuccessful in developing effective communication strategies to change behaviour in relation to both climate mitigation and adaptation, in order to allow a more sustainable development pathway in Africa (Okaka 2011).The information diffusion (diffusion of innovations) theory (Rogers 1962) has proved very successful in its application. Diffusion is the process by which an innovation is communicated through channels over time to the members of a society. Elements in the diffusion process are:

- Innovation (an idea, a practice, or an object that is perceived as new by anyone)
- Communication channels, time factors (innovation-decision process)
- Relative time with which an innovation is adopted by individuals or a groups
- Social system. The relevance of the theory or model to the study (research project) is to justify the importance of information dissemination as a precondition for creating awareness, attitudinal and behaviour change for adoption of new innovations or technologies by the audiences in the research sites for the diffusion of innovations in climate change for prudent or sustainable environmental governance (Rogers 1995).

The current low or lack of awareness of the values, benefits, and functions of natural resources is a big hindrance to sustainable conservation policies, programmes, and projects in East Africa (Okaka 2010). The objectives (Babu, 2010) of any global communication, education and public awareness network should be to:

establish and manage a global communication, education and public awareness network, comprised of new information technologies and traditional communication media; stimulate the creation of national, sub regional and regional communication and public awareness education networks; create synergies among all the stakeholders and communication networks. At the centre of climate change impacts are the people whose livelihoods are affected by the pressures created by climate change (UNFCC 2009). The communication strategy team recommended the use of civil society organisations and journalists to communicate climate change issues, because the lessons learned from this have proved to be positive (UNFCC 2009). Better communication of scientific and technological innovations to the public will help to transcend the diversity of experiences and enable constructive dialogue about the risks and benefits of scientific discoveries and technologies. This will also close knowledge gaps and will require the establishment of national strategies for scientific and technological development that are linked to effective policies (ICSU 2008). Some of the needs or lessons learned from the effective climate change interventions call for:

- The need to develop effective climate change campaigns strategy
- The need to coordinate stakeholders and key actors in climate change
- The need to blend mass media with inter-personal (inter-cultural communication) strategies
- The need to give top priority to participatory communication awareness strategies
- The knowledge that communication is a psychological, cultural, ethical, and courtesy issue
- Target the main campaign issues consistently
- Mainstream climate change policy issues and options
- Ensure audience participation in message design is at its best
- Infuse key gender, ethical and research issues
- Use a mix of multi-media campaign strategies
- Evaluate the implementation process regularly
- Give strong political and financial support and backing
- Avoid ‘flat’, incomplete, or conflicting messages
- Use participatory research methods
- Develop an action plan for national gender policy.

Ethical and Dissemination Considerations

A prudent climate change research project should be ethically and professionally driven by gender mainstreaming, respect for cultural and community values, audience empowerment and participatory approaches, requested confidentiality, and by obtaining informed consent by open communication policy for easy access to information. The target audiences should be given advance information about the rationale, objectives, and benefits of the study regarding climate change, environment protection, health, and sustainable natural resource governance. The dissemination of the research results should be guided by the relevant change theories or communication concepts. It is possible to form and coordinate multiple interdisciplinary platforms such as: presentation meetings, mass media, seminars, conferences, workshops, conferences, journals, distribution of information, education, and communication materials to the target audiences involved. The planned climate change goals (context), objectives, inputs and outputs should be well reflected in the project implementation schedule or log frame matrix. There is an urgent need for information gaps to be plugged and for the dissemination of information to be refined for climate policy and disaster risks management to have any impact in Africa.

Conclusion

Despite the vital role of human and natural resources in the socio-economic wellbeing of almost every family in Uganda, the country's natural resources are already facing the most unprecedented rapid and severe depletion levels to date, while its population growth rate is among the highest in the world, and the quality of the national health service is unacceptably poor. Low or lack of awareness surrounding the values, benefits, and functions of efficient rural energy technologies, as well as land and environmental degradations, will worsen the current devastating impacts of the HIV/AIDS scourge, the problem of conflicting land use and policy messages, and the climate change phenomena in Uganda and the rest of African Union member states.

Policy and decision-makers, researchers and scientists in Uganda should develop appropriate, coordinated and integrated mechanisms for an effective policy communication strategy for the sustaining of rural energy, for the population, better health and wellbeing, as well as clean and safe environmental services for local, national, regional, and global change. Effective policy communications campaigns can create, raise, develop and sustain the desired awareness, knowledge, attitudes, and behaviour for quality population, public health services, and ecological sustainability. Access to clean rural and urban energy security is the principal determinant of the quality of life in Uganda and the rest of the world. However, climate is the principal determinant of the quality of life, energy, and environment which humanity worldwide is entitled to on daily basis. *The following conclusions can be made from the findings obtained from the study:* the national public awareness campaign strategy used multimedia communication strategies to include: electronic media, print media and interpersonal communication, with a focus on popular media. These results confirmed the target audiences were able to identify with them accordingly. The audience exposure to the forms of media used varied from the highest level of exposure, electronic media, to the lowest level of exposure, popular media (entertainment).The audience exposure also increased with increasing levels of education, and reduced with low (decreasing) levels of education.

The media messages have impacts or effects on the audiences interviewed, although the impacts varied with levels of education, employment status, income levels and participation in the campaigns process. The messages received by the target audiences were generally of good quality as indicated by the findings. Most of the audiences were exposed to electronic media followed by print media. The lowest exposure was registered by the popular media. The audiences had positive attitudes about the campaign's messages but more improvements could have been done in terms of the message design and delivery, if relevant media theories or models were employed in the campaign strategies.

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Author Biography

Wilson Okaka is an Adjunct Professor/Lecturer dedicated to policy communication with research interests in environment, media, journalism, communication, health, energy, and ICT. He has travelled across Africa, Europe, Asia, and South and North America. He belongs to many national, sub-regional, regional, and international research and professional networks.

Chapter 24
Local Adaptation as a Future Flood Management Strategy in Rotterdam

Peter van Veelen

Abstract The areas outside the levees in Rotterdam, the so called unembanked areas, will face two important developments in the next few years. While climate change increases the risk of flooding of these unembanked areas, land use in these areas is also intensifying. The former port areas in Rotterdam are important inner city development zones and will fundamentally change the developed footprint of the Rotterdam floodplain over the next 50 years. Both developments aggravate the risks of future disasters, while at the same time the increased economic value could cause the possible consequences of flooding to become more severe.The city of Rotterdam has begun different studies (Veerbeek et al. 2010; Veelen et al. 2010a, b) to get better acquainted with the risk and consequences of the increased vulnerability to flooding. The present study, which started in February 2011, aims to develop a future water safety strategy for Rotterdam aimed at reducing the vulnerability by minimising the local consequences of flooding. This approach is set within the Dutch context, with a strong tradition of reducing the probability of flooding, considered to be a new and unexploited direction. This paper presents the results of an analysis of the vulnerability of the unembanked areas and presents the first principles to develop a local adaptive strategy in the case of Kop van Feijenoord in Rotterdam.

Keywords Adaptive strategy · Adaptive measures · Rotterdam floodplain · Flood management · Case study Kop van Feijenoord

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P. van Veelen (✉)
Urban Planning Department City of Rotterdam, Postbus 6575 3002 AN, Rotterdam, Netherlands
e-mail: pc.vanveelen@rotterdam.nl

W. Leal Filho (ed.), *Climate Change and Disaster Risk Management*, Climate Change Management, DOI: 10.1007/978-3-642-31110-9_24,

Local Adaptation as a Future Flood Management Strategy in Rotterdam

The areas outside the levees in Rotterdam, the so called unembanked areas, will face two important developments over the next few years. While climate change increases the risk of flooding in these unembanked areas, land use in these areas is also intensifying. The former port areas in Rotterdam are important inner city development zones and will fundamentally change the developed footprint of the Rotterdam floodplain over the next 50 years. Both developments aggravate the risk of future disasters, while at the same time the increased economic value could cause the possible consequences of flooding to become more severe.

The city of Rotterdam started different studies (Veerbeek et al. 2010; Veelen et al. 2010a, b) to get better acquainted with the risk and consequences of the increased vulnerability to flooding. The present study, which started in February 2011, aims to develop a future water safety strategy for Rotterdam, aimed at reducing the vulnerability by minimising the local *consequences* of a flood. This approach, set within the Dutch context of having a strong tradition of reducing the probability of flooding, is considered to be a new and unexploited direction. This paper presents the results of an analysis of the vulnerability of the unembanked areas and presents the first principles to develop a local adaptive strategy in the case of the Kop van Feijenoord in Rotterdam.

Vulnerability of the Rotterdam Floodplain

Calculations show that, although the risk of casualties is very low, for the lowest parts of Rotterdam, such as the Noordereiland and several parts of the district Kop van Feijenoord, the risk of flooding is relatively high. The vulnerability of these areas has been relatively limited, and has been greatly decreased by the building of the flexible sea barrier, the Maeslantkering. This situation is changing because of the rising sea level and increased river flows. In the Rotterdam–Dordrecht floodplain about 65,000 people (distributed over 46 municipalities) live in these unprotected districts along the Rhine-Meuse estuary (Provincie Zuid-Holland 2008). The Rotterdam port industrial complex, which is vitally important for the Dutch economy and that of the neighbouring countries, is also located outside of the levees.

Rotterdam's areas outside the levees are safe. The largest part of the land outside of levee protection has been raised to between 3.0 and 3.5 m above Amsterdam Ordnance Datum. Only a few areas containing historic buildings (Noordereiland and Heijplaat) run a high risk of sustaining flood damage. In the future, the rise in sea level will increase the risk of inundation in the areas that are located outside of levee protection. Extremely high water levels are controlled by the Maeslantkering. If this flood barrier fails to close (highly unlikely) the water levels in the areas outside the levees will follow the North Sea level. A storm surge at sea coinciding with peak river discharge could lead to high water levels that will impact the areas outside the levees. Modified and more intensive use of the areas outside the levees will significantly increase the potential damage and social consequences of inundation (Veerbeek et al. 2010).

The areas outside the levees differ widely in nature. Apart from a difference in altitude, there are differences in terms of the character and the level of depreciation of the existing buildings, as well as their use and the dynamics of their development. These parameters ensure that the so-called adaptive capacity takes on overriding importance in deciding on an adaptive strategy that is likely to be successful. Assessment of this adaptive capacity is an important step in the process of phrasing the adaptive strategy.

There is no legal standardisation for flood protection in unembanked areas. The central government claims not to be held responsible for damage caused by to fluvial flooding. Spatial developments in this area are permitted under certain conditions, but constructions take place at the owner's risk (Eshuis 2009). Due to the relative low risks of floods in the Rotterdam floodplains, the perception of these risks by households or building companies is low (Kennis voor Klimaat 2009). Traditionally, building stock in unembanked areas has been protected by elevating the ground. The main water safety policy for new developments in Rotterdam is an obligation to raise the ground to about four metres above sea level, which offers reasonable protection against storm surge flood events with a probability of more than 1/10,000. The existing and historical parts of the Rotterdam waterfront are located on lower parts of the river floodplain. These areas have to deal with a probability of flooding of 1/10 to 1/1,000. For these existing urban areas the city of Rotterdam has no additional policy of building regulations to minimise the effects of a potential flood.

Chancing Climate and Increased Frequency of Flooding

It is important to determine both the risk and the impact of flooding if we wish to be able to make any statements about the risks of flooding. Flooding outside of levee protection can be predicted fairly accurately, and is accompanied by low water levels and flow velocities in the areas concerned. Furthermore, the highest water level in the River Maas will soon drop again as a result of tidal movements. This means that the risk of death is not normally cause for concern, but material damage as a result of inundation could reach significant proportions.

The comparison of different climate scenarios with the current situation (Fig. 24.1) makes it clear that the circumstances that will lead to flooding of the unembanked areas are likely to occur more frequently as a result of climate change. For the moderate scenario G + 2050, with a proposed sea level rise of 15 cm, the flooding frequency increases by a factor of ten. For the more extreme scenarios, such as the Veerman scenario with a rising sea level of more than one

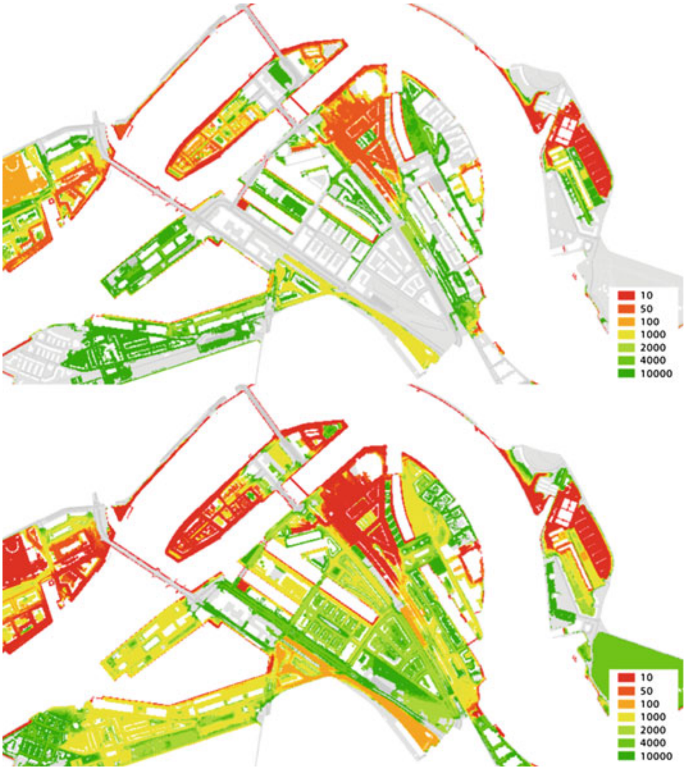

Fig. 24.1 Flood risk Feijenoord, current situation and moderate scenario G + 2050

metre, the probability of flooding increases by more than a factor 100. This means that the expected rise in sea level has a large effect on the probability and risk of the current Rotterdam floodplain. An important conclusion is that not only are lower parts of the city at risk, i.e. predominantly urban areas and historically valuable buildings, but also new development areas, such as the Wilhelminapier, will have to face the fact that in the long term the probability of an extreme flood event is increasing and water levels are rising. Most of these areas are not designed for flood conditions.

Mitigate or Adapt to Flood Threat

The question of how Rotterdam can best protect its existing and yet-to-be-built residential and industrial areas outside the dikes from flooding is therefore urgent. There are roughly two strategies with which we can respond to the consequences of higher water levels in the Rotterdam floodplain. The first, and one might say, the traditional Dutch water strategy, focuses on reducing the probability of urban fluvial and coastal flood risks by passive, robust solutions such as urban water defences and major interventions in the Dutch delta (Zevenbergen et al. 2008). A second strategy focuses on limiting the consequences of the flood. The option chosen will depend largely on political and administrative standpoints and will always be customised to suit the location concerned.

There are several reasons why there is a slow but clear shift away from the dominant approach of resistance (mitigation) to high water levels, to an approach of resilience, or adaptation to high water situations. First of all there is the growing awareness of the residual risk to the urbanised floodplain in the Rotterdam area caused by the large delta constructions, such as the Maeslantkering. The probability of flooding in Rotterdam is highly dependent on the probability of a failure with the Maeslant barrier; a lower likelihood of failure leads directly to less flooding and reduced safety measures for the primary dikes. The construction of new and even improved constructions would still cause a calculated residual risk of failure, with consequences for the built-up area in Rotterdam. A second reason for a changing attitude is the consideration that reducing the probability of floods by constructing additional and stronger barriers in the delta depends very much on a clear understanding of the effects of climate change on sea level. The effects of climate change are uncertain and the best knowledge we have is an estimation that varies by more than one metre. This means that designing appropriate constructions is difficult and requires a strong and centrally managed process as well as a significant budget. In a period where the central government is withdrawing from their central tasks and with a shortage of public funds, this scenario does not seem very likely.

Towards a Local Adaptive Strategy

How can we reduce the local vulnerability of floods by creating clever and more resilient urban areas?

The main strategy of Rotterdam and Dordrecht which involves elevating the main surface tends to be very costly. Large areas of unembanked land in future urban areas will have to be elevated by almost one or one and a half metres to meet the current standards Meyer and Hermans 2009. Apart from the high costs entailed, implementation is not always possible due to existing buildings and large investments to be made in quay constructions and underground infrastructures. One line of approach would be to make adjustments to the physical design of the built-up environment, in order to make buildings more flood-proof and to alert the users and residents to the risks involved. In the case of new-builds, the solutions may be sought in the set-up of the first residential storey, such that the damage and nuisance to residents and users remains at a minimum. One of the main discussions (Zevenbergen et al. 2008) will be the issue of scale and division of responsibility. Would it be more attractive to develop a water safety strategy on the scale of a whole district, where the local government guarantees the residents a certain level of safety against flooding, or would it be better to develop a strategy whereby residents are responsible for their own risk management and implementation of measures takes place at the site of the building?

In an exploratory survey (Veelen et al. 2010a, b; Meyer and Hermans 2009), we determined different aspects of a local adaptive strategy. The principles on which to base a successful strategy are as follows:

- Comprehensive: finding the right balance and clarifying the interaction between physical spatial measures, legal planning matters or communication measures is an important focus in developing a strategy.
- Resilience: a successful adaptive strategy responds to a changing reality—in defining an adaptive strategy, we should also consider the timing of various implementations, as well as any interdependencies and relationships between the various measures and the extent to which they allow adjustment of the selected strategy. The "Adaptation Tipping Point Approach" may prove useful in identifying and analysing dependability, robustness and flexibility of the measures.
- Politico-administrative considerations: establishing flood management standards—responsibility for flood management in the areas outside the levees is vested in the regional and local authorities. The task definition and opportunities for a storm surge resistant layout are directly related to the basic principles applied to the areas outside the levees with respect to flood management and flooding.
- Planned economy: storm surge resilience as part of the area development—innovations are required in order to establish a connection between the investments for short and long-term climate adaptation tasks. For this purpose, we should investigate ways in which the value of storm surge resilience can be included in the utilisation of the land.
- Perception: raising awareness of flood management and feasible adaptive measures—unfortunately, there is a downside to a relatively high level of safety provided by flood management. Overall awareness of the vulnerable position of the areas outside the levees is relatively low for residents and users. The strategy should find a balance between opportunities to raise awareness and the feasibility of adaptive strategies.
- Legal planning considerations: embedding and incorporating adaptive strategies and measures—in practice, laws and regulations often prove to be an impediment to the implementation of adaptive measures. The feasibility of any adaptation strategy will largely depend on innovations in laws and regulations, as well as current policy(Fig. 24.2).

Fig. 24.2 Impression of development plan area Kop van Feijenoord

Local Adaptive Measures: Case Study Feijenoord

These general principles are currently being investigated in a research study into the design of one of the most vulnerable locations in the urbanised Rotterdam floodplain, Feijenoord. This study will be finished by the end of 2012. The study area of Feijenoord is only partially raised to modern safety standards because the process of urban renewal came to a halt around the mid-1990s. The remaining nineteenth-century buildings are now being gradually renovated. Parts of this area are still very low, and due to the irregular shape of the old docklands it is expected that it will not be financially feasible to protect these areas through a retaining wall. Systematically raising the infrastructure and public space leads to unwanted altitude differences between public spaces and the remaining houses. Adaptive measures, such as a flood-proof mould or integrated flood protection in new buildings and small adjustments to existing buildings, seem to offer the most attractive solutions. The next phase of this research will focus on the interdependencies between these measures.

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Author Biography

Peter van Veelen Peter van Veelen is an urban planner at the department of planning in the city of Rotterdam and a PhD researcher at the Technical University of Delft. As a project manager of a research project “adaptive strategies for the Rotterdam floodplain” and project manager of a research project on multifunctional urban levees, he developed experience on the integration of local adaptation measures and strategies used within the urban planning processes. His PhD research focuses on the development of a long-term strategy for multifunctional urban levees.

Chapter 25
On the Way to a Flood Risk Management Plan

Natasa Manojlovic, Niloufar Behzadina and Erik Pasche

Abstract The Flood Directive EC 2007/60 specifies the structure and objectives of the flood risk management plan and the favourable mitigation measures to be taken for reducing the risk. However, little information is given about the strategy to develop and implement this management plan on a local level. There is an obvious need to find a good governance concept which best supports the implementation process and which will lead to acceptance and proper application of the new paradigm in flood risk management. Within the INTERREG IVb project SAWA (http://www.sawa-project.eu/) the authors have developed and implemented a participatory planning approach for the implementation of a flood risk management plan according to EC FD, which tries to meet the requirements of good governance through broad stakeholder involvement in the planning process. It uses Learning and Action Alliances (LAA) as a communication and decision making platform in which public and professional stakeholders can develop the plan together in a four-step cycle of awareness raising, understanding, experimenting, and evaluation. The software tool KALPYPSO Planer-Client, developed within SAWA, can be regarded as a corner stone in this decision-making process. It enables professional and public stakeholders to define their own scenarios of drivers, flood mitigation and adaptation measures, and to evaluate the impact and efficiency of these scenarios. This new governance approach will be demonstrated

N. Manojlovic (✉) · N. Behzadina · E. Pasche (posthumous)
Institute of River and Coastal Engineering, Hamburg University of Technology, Denickestrasse 22, 21073, Hamburg, Germany
e-mail: natasa.manojlovic@tuhh.de

N. Behzadina
e-mail: behzadnia@tu-harburg.de

E. Pasche (posthumous)
e-mail: pasche@tuhh.de

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with a real case study—the Wandse urban catchment, Hamburg—and the results and experiences will be discussed.

Keywords Participatory planning · Bottom up governance · Flood risk management plan · Learning and action alliance · Decision support systems · Capacity building of stakeholders

Background

The Flood Directive EC 2007/60 specifies very clearly the structure and objectives of the flood risk management plan and the favourable mitigation measures to be taken for reducing the risk. However, little information is given about the strategy to develop and implement this management plan on a local level. There is an obvious need to find a good governance concept (here governance is defined as the process of decision-making and the process by which decisions are implemented [UN—Economic and social commission of Asia and the Pacific]). It should best support the implementation process and lead to acceptance and proper application of the new paradigm in flood risk management. A fundamental issue that is still to be resolved is how the necessary multi-stakeholder participation in the decision-making process can be carried out cost-effectively and in a timely manner, so that the results are not only technically, but also socially, acceptable. The Flood Directive EC 2007/60 does not give any guidance in developing a good governance concept for the implementation of the flood risk management plan. It only requires the participation of the public (Article 10 [2]) in the development and implementation process. "Member States shall encourage active involvement of interested parties in the production, review and updating of the flood risk management plans referred to in Chap. 4." Two different ways are possible, a top-down and a bottom-up approach of decision-making. In the first case, the plan is developed by professionals. The general public's opinion and input is only requested through public hearings and written objections at the end of the approval process. According to Article 10 (1), this scope of public participation is in line with the flood directive. But Article 10 (2) encourages seeking active involvement of stakeholders in the planning process. This public involvement represents a bottom-up approach. Here, all stakeholders, professionals and member of the public are involved right from the start, and together they develop the plan in a continuous and collaborative process. Particularly in an urban environment where many conflicting interests overlap, this broader involvement of the public stakeholders is crucial for effective flood risk management planning.

Participatory planning is often regarded as an annoying factor in well-established systems (Fürst and Scholles 2008, p. 163). Planning and decision making processes seem to be more time-consuming as conflicts have to be settled in the planning process. These drawbacks are frequently perceived as stronger than the advantages, which are:

- The potential for better solutions as pros and cons are discussed more openly;
- More options for action as more people with different backgrounds, knowledge and experiences contribute their ideas;
- Due to a higher degree of democracy, stakeholders show readiness for consensus finding and a broader acceptance of solutions;
- Less conflicts in the realisation process.

Participatory planning has already been applied in urban and landscape planning for more than 30 years, however, water management experience in participatory planning in particular has been gained in the implementation process of the EU Water Framework Directive (EC-WFD), leading to innovative strategies and new knowledge about more efficient involvement of stakeholder groups in the planning process (Pahl-Wostl et al. 2008). Further EU-based research within the Eranet-Crue and FP6 initiatives has focused on stakeholder involvement in flood risk management (Pasche et al. 2008, Samuel et al. 2009). Examples of good practice in participatory flood risk management are still scarce and theoretical guidance is not readily available.

Another key problem in participatory flood risk management is that the new Flood Directive replaces traditional flood defence strategies through a risk-based management concept which requires that the technological entrapment (Walker 2000) of "stationary" design and operational assumptions, as well as the continuing "traditional" investments of large technical systems, have to be broken (Ashley and Blanksby 2007). Professional and public stakeholders need to build up their capacity in the application and understanding of flood risk management by non-structural responses (Pasche et al. 2008). They are not a fixed set of tangible measures but an evolving process of transfer to a more adaptive flood risk management, in order to cope with the emerging uncertainty due to climate change.

These challenges inherent in the flood risk management call for new forms of stakeholder involvement right from the beginning and all the way through to participatory planning. They require "active learning" by all stakeholder groups to both accept a different view on risk and performance, and also to be able to utilise different types of response and at different times of implementation.

It is the objective of this paper to present a new concept of stakeholder involvement in flood risk management planning by involving them from the beginning of the planning process. It shows the role of communication and capacity building of stakeholders, outlines the role of sophisticated modelling tools in the decision making process and gives guidance on how to motivate stakeholders, as well as how to come to integrative solutions.

The Concept of Participatory Planning Through Learning and Action Alliances

General Structure

Nowadays, the majority of professional stakeholders are still thinking and acting in a sectoral way. Cross-disciplinary cooperation and integrative planning are rarely found. They are confronted by a public stakeholders group, which regards their role as one of controlling institutions, complaining in case of malfunctioning, or if their interests are not being properly represented, in plans and regulations. Thus the cooperation of all stakeholders in planning teams will not function without raising their level of social competence, which has to include the understanding of the responsibilities and interests of the other stakeholders, and to acknowledge limits of their own interests, as well as the priority of other societal interests. An appropriate collaborative platform for breaking entrapped ways of doing things and accepting new solutions seems to be a "Learning Alliance" (LA), which (Batchelor and Butterworth 2008) define as a group of individuals or organisations with a shared interest in innovation and the scaling-up of innovation in a topic of mutual interest. This concept of LA has already been developed within the EU 6th Environment Framework project SWITCH (http://www.switchurbanwater.eu/la_switch.php) and has been extended and adapted by Ashley and Blanksby 2009 to fit the needs of flood risk management planning, creating a new unit—Learning and Action Alliance (LAA). This concept of LAA has been designed as a cyclic process subdivided into four main phases: "scoping", "envisioning", "experimenting" and "testing and evaluation" as given in Fig. 25.1. This concept has been taken up and further adapted in the INTERREG IVB project SAWA (www.sawa.de) to meet the needs of the Flood Risk Managing Planning within the context of the EU Flood Directive.

Flood hazard and risk maps are valuable instruments in raising awareness of flood risk along rivers. However the consequences for the risk management in the different risk zones are not easily understood by the stakeholders. Thus a key objective of the LAA must be to understand the risk and to interpret the flood risk maps in phases 1 (scoping) and 2 (understanding). A good issue to discuss openly will be what an "acceptable risk" means, which is more of a social issue than a question of expertise. At the end of this learning phase, all stakeholders will be aware of the flood risk and the group will have developed consensus in the assessment of the flood risk problems along the river under consideration, which will mark the first milestone of the learning cycle.

Prior to envisioning the objectives and strategies to manage the flood risk in the planning area within the LAAs, the capacity of the participants is to be raised towards the understanding of the "Concept of Risk Management" and the application of non-structural measures (NSM) in flood risk mitigation. This phase of the LAA is the key to the opening-up towards flood risk management planning, as stakeholders have to give up their traditional ways in dealing with flood issues and

Fig. 25.1 General framework of participatory planning in an LAA

to develop new skills and understanding. This process of transfer to new knowledge and practices will need time and continuous support by the stakeholder group of researchers. At the end of this process the stakeholders need to demonstrate their newly acquired knowledge by developing their vision on how to deal with the flood risk along the river being considered by reducing it to the defined "acceptable level", considering both the current situation and drivers of future developments such as climate change and urbanisation (the second milestone of the LAA).

After a consensus on the objectives of flood risk management in the future is reached, the stakeholders will begin with the "concrete planning phase". They will make use of their newly acquired knowledge by selecting the appropriate flood mitigation and adaptation measures. A great potential of hitch-hiking will exist for the FRMP by taking measures already agreed on in the River Basin Management Plan (RBMP) and by extending them to the needs of the FRMP. At the end of this planning phase a set of various options on flood risk management will exist which marks the third milestone in the governance process.

The final phase of participatory planning will be the process of consensus building by agreeing on one set of mitigation and adaptation measures. In this phase the members must agree on the relevant criteria in assessing the various options of flood risk management. Again, experts will have to coach this process by introducing the theory of Multi-Criteria-Analysis (MCA), developing an assessment matrix of relevant criteria and providing a decision support tool which all stakeholders can use to select and modify options of flood risk management and to determine their efficiency, benefits, and conflicts. Good guidance will be necessary to explore the possibilities of minimising remaining conflicts of interest between the different stakeholder groups. It is probable that that not all conflicts can be avoided and that in the end the stakeholders have to agree on an "acceptable level of conflict" by defining priorities.

Within the whole process of FRMP the LAA should not be acting as a closed shop but should inform the public, and especially decision makers and politicians, about their activities and invite them to temporarily participate in workshops or to comment and discuss through a public forum.

Selecting Stakeholders and Assigning Their Role

The selection of the relevant stakeholders and the determining of their role in the LAA is not a trivial issue and thus needs careful preparation. As each region has its own institutional and legislative framework a detailed stakeholder analysis has to precede the selection process. Especially in urban areas, many stakeholder groups will be affected by the actions to be taken in a flood risk management plan. They can be categorised according to Table 25.1. The stakeholder analysis should provide the existing political, social and institutional structure with special reference to the organisational structure of the flood and drainage management within the area of interest.

All stakeholder groups have to be understood in their responsibilities, temporal and spatial scale of activity, and their relationships with each other. On this basis it will be possible to detect overlapping responsibilities, institutional obstacles and barriers as well as competition and redundancy in competence between stakeholder groups, which are indicators of emerging conflicts in the cooperation of stakeholder groups. Table 25.1 gives the main aspects to be covered in this stakeholder analysis. It will help to select the relevant stakeholder groups and to assign them an adequate role within the LAA (Table 25.2).

The development of shared vision requires an innovative environment of understanding, willingness to remove barriers, and facilitation of a "scaling-up" of responses in space and time. The creation of a "cooperate identity" will be a real challenge for the LAAs as stakeholders have to move away from institutional fragmentation and towards cooperation.

It has to be considered that LAAs are alliances in which their members participate more or less on a voluntary basis. They need flexibility and openness towards their activities and involvement. However some formal structure has to be given to LAAs to keep them efficient and to optimise cooperation. Priority should be given to clearly define the role taken by each stakeholder within this alliance. It is dependent on the objectives and expected outcomes of each LAA, as well as the special stakeholder situation in the area under consideration. Some general guidance for stakeholder grouping in LAAs has been given by Ashley and Blanksby (2009). They suggest grouping stakeholders according to their key interest in catchment based groups, interest based groups, functional groups, and research led groups.

In the catchment-based groups all stakeholders which act on a regional level are integrated (ministries, national agencies) and thus have an interest that regional aspects are considered, and that ideas and consequences resulting from the LAA are transferred into regional planning. The largest group is the interest-based group which integrates all stakeholders that have specific interests in the area under consideration (e.g. spatial planning, ecology, dwellings, NGOs, and water utilities). Their role will be to contribute with their specific knowledge and expertise to the development of the FRMP, raise awareness of conflicts, and to contribute in finding ways to avoid or compensate them. The functional group integrates the

Table 25.1 Categorising stakeholder groups in LAA

Categories of stakeholders
Strategic flood and drainage management
Implementation and maintenance
Urban development
Agriculture
Public transportation infrastructure
Urban and landscape design
Environmental protection and nature conservation
Emergency services
Politicians
NGOs
Public interest groups
Economy and industry
Research

actors, which are responsible for the development of a FRMP, e.g. water boards, water authorities, and communities. They have the most active part in the LAA, as they have to develop the measures of flood risk management and to integrate them into a consistent plan. The research led groups integrate universities and other research organisations which are active in this area. Their role is to support the transfer process of innovative systems. They need to assist stakeholders in their capacity building.

Instruments and Material Supporting LAAs

The participatory planning cycle of the LAAs given in Fig. 25.1 includes several tasks which need the support of instruments. The implementation and operation of LAAs requires social science instruments, which support the selection of the members and the development of their social and communicative competence. They are given in Table 25.3.

Technical instruments are needed to build capacity and to assist the decision-making process. In total these instruments should support

- Raising awareness of flood risk and the main drivers (identification of the complex problems in FRMP)
- The development of shared visions and assessment of the problem
- The development of alternative integrative plans
- The assessment of the efficiency and effectiveness of mitigation and adaptation measures
- Conflict analysis of stakeholder interests
- The development of consensus through conflict minimisation, improving on-going activities, and finally prioritisation of interests.

Table 25.2 Parameters characterising conflict potential and shared interests

Parameter	Description
Level of impact	Shows in which way and to what extent the stakeholders are affected by implementation of FRMP. It can be differentiated as *direct* or *indirect*. This parameter implicitly contains the motivation of the stakeholders to participate in the FRMP process and as such it is one of the key parameters for their selection
Level of understanding/ knowledge	Assessment of the present knowledge and background of the stakeholder groups. It addresses the following aspects: • Flood risk awareness and understanding of the flood situation in the area • Understanding the paradigm "living with water" reflected in the Flood Risk Management (understanding risk in the sense of EU Flood Directive- risk assessment, flood risk mapping etc)
Need for capacity building	Based on the knowledge available, their interest and possible role in implementation of FRMP, the requirements for capacity building are assessed stating the thematic units related to it and if possible which measures of capacity building should be applied to address the stakeholders
Overlapping (unclear) responsibilities	Clashing interests or ambiguities among institutions/individuals
Diverging interests—conflicts	Description and assessment of the conflicts due to the implementation of the FRMP
Congruent interests	Description and assessment of shared interest between stakeholders to develop FRMP

Table 25.3 Tools and instruments for the support of the collaborative platform

Development of methods for collaborative platform	Guidance for role assignment Social learning moduls	Social
	Decision support tools Methods for capacity building	Technical

Within the following sections a framework of these instruments is given and their functionality, methodology and structure are discussed and illustrated by examples.

Learning and Social Science Instruments

Stakeholders need assistance to improve their communicative and cooperative skills in order to perform effectively on the collaborative platform. As the background and educational level of the stakeholders vary considerably, this task needs didactic competence and experience. In the end an atmosphere of mutual trust, respect and openness has to be established. Social scientists can be supported in this task through instruments such as "social games", bilateral discussion panels or workshops. They must give the stakeholders an active role, activate oral and written communication and invite active listening. Access to autodidactic learning tools and all material produced or delivered during the learning sessions are most important. This implies the application of modern web-based communication platforms equipped with e-learning tools and discussion forums.

Decision Support Tools

Successful participatory planning requires understanding the interactive structure of the components contributing to flood risk. This includes, in urban river basins, the understanding of the dominating hydrological processes, the impact of anthropogenic changes on the flood risk and its feedback with the socio-economic situation. Due to the complexity of these processes and system functions, instruments are needed in the decision process, which give stakeholders the possibility to define and test scenarios, and study the impact on the hydrological and socio-economic system.

Such decision—support systems are computer models in which a non-expert gets the possibility to analyse complex problems and to find appropriate solutions (Hahn and Engelen 2000). They range from simple assessment tools to complex systems in which scenarios of different solutions can be easily generated, their efficiency quantified by mathematical models, and generated via a multi-criteria analysis of preferences. In all cases, the user is the centre of the system and determines the capabilities of the system. Since the Interreg III project FLOWS the authors have been continuously working on the development of such systems. This research work has led to the Open Source software tools *KALYPSO Planer-Client* (Pasche et al. 2004) and *FLORETO* (Manojlovic et al. 2009). They are equipped with a high-level user interface, which guide spatial planners and decision makers or private stakeholders through the assessment of the flood risk and mitigation options.

As flood risk is the product of probability of occurrence multiplied by its impact the procedure for flood risk assessments is composed of three tasks, the determination of the probability of flood, the flood prone area, and the damage (Table 25.4).

Mathematical models support all three procedures. In general, simple models are preferred to keep the costs low. But the experience has shown that a poor reliability of the determined inundation areas reduces the acceptance of the stakeholders and often ends in rejection of the results. The EU COST initiative C22—Urban Flood Management has gathered the state of the art in hydrological and hydraulic modelling, which has been used as a guideline and basis for the selection of hydrological and hydraulic models within the KALYPSO Planer-Client tool (Pasche et al. 2007).

According to the EU Flood Directive (EC FD, [4]) ecologically oriented measures should be preferred in a FRMP to reduce the flood probability in urban

Table 25.4 Procedures and methods for flood risk assessment (according to Pasche et al. 2007)

Procedures	Methods
Determination of flood probability	Rainfall-runoff modelling flood frequency analysis
Determination of inundation	1 and 2-dimensional hydrodynamic modelling
Assessment of damages	Modelling of the annual probable damage (on monetary basis)

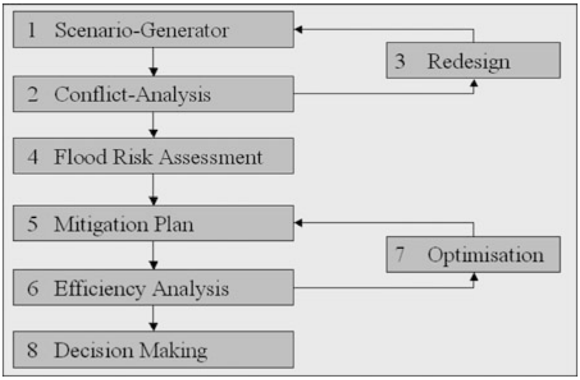

Fig. 25.2 Scenario-Analysis loop within the KALYPSO Planer-Client

environments. They include measures such as SUDS (sustainable drainage systems), local scale retention (green roof, detention ponds) and restoration of floodplains, and natural geomorphology of the watercourses. Within KALYPSO Planer-Client, a new theoretical concept has been developed for quantifying the retention and flood attenuation effect of SUDS through rainfall-runoff models. It integrates the most relevant components of on-site storm water management: retention in ponds and swales, infiltration into the ground and drainage through perforated pipes. The theoretical concept for modelling this sustainable drainage element is given in Brüning et al. 2009.

The procedures of flood risk assessments are incorporated into a loop of scenario analysis, which includes further procedures for the decision-making process as depicted in Fig. 25.2.

The members of the LAA will not have the time and expertise to define the data model for a rainfall-runoff model or the hydraulic models. This work needs to be done by an expert with a thorough hydrological and hydraulic background. The input and modelling interest of the LAA is confined to the definition of the changes in the existing data models according to the planning intention. This must include the possibility to define mitigation measures to compensate for the effect of planning on the hydrological cycle. They need to be defined and marked in a map. Therefore GIS-functionality has been included in the KALYPSO Planer-Client. Within the conflict analysis tool a spatial analysis of the planning intention defined in the scenario is carried out. It contains Boolean functions, through which the overlapping of the planning domain with conflicting regions or functions of the landscape is detected. The intensity of conflict can be defined by a five-step classification scheme ranging from knock-out to severe, moderate, little and no conflict. Within the conflict analysis tool a pre-qualification of the planning is offered which selects all areas with knockout criteria, indicating that the intended plan is not feasible and needs modification. In this case KALYPSO Planer-Client refers back to the scenario generator requesting a redesign (3). In step 4 the flood risk assessment of the final planning will be performed according to Fig. 2(5).

Instruments for the Capacity Building of Stakeholders

The development of innovative solutions and concepts for integrative flood risk management requires that engineers and spatial planners in particular give up some of their traditions and common practices of river management and urban development. Social science research has shown that stakeholders behave conservatively and do not change their habits despite better solutions (Walker 2000). This *Entrapment Effect* (Ashley et al. 2007) marks a key barrier in the transfer process in urban river basin management. Thus a learning program needs to be applied within LAA to overcome these barriers and to foster stakeholders' social, technical, cultural, economic and ecological capacity. It will take up the concept of the Interactive Learning Programme (ILP) which has been developed within the Interreg project FLOWS and has been further extended by Manojlovic et al. 2009 within the Era.net Crue project SUCA (Pasche et al. 2008).

The ILP is based on the learning cycle of (Kolb and Fry 1975), divided the learning process in four steps from concrete experience trough reflection followed by the abstraction of the concepts learnt, to testing the acquainted knowledge in new situations Fig. 25.3.

The single steps together form a closed learning cycle, which can be repeated if necessary and can be applied to any selected stakeholder group. Within the ILP the learning cycle is regarded as a continuous process with smooth transitions between the learning phases (Fig. 25.3). Apart from the face-to-face sessions that are following the Kolb's cycle, this learning concept involves intermediate phases comprised of the on-site events and the autodidactic learning, supported by the web strategy KalypsoInform. It contains the modules with tailored access to the information depending on the users' interests and knowledge level, including: Tutorial, Knowledge Base and Virtual Trainer, (Pasche et al. 2006). The continuity and combination of different learning tools strengthens the motivation of participants and improves the pace and dynamics of the learning process.

This concept is generic in enabling different stakeholder groups to be addressed and tailoring the program to their needs and required expertise. The tools for visualisation such as the Flood Animation Studio (Pasche et al. 2008) are used not only to increase awareness, but to give a local context and relevance of flood problem by using local flood maps and giving the possibility to participants to have a "hands-on" approach for the local food situation. They can be used as a standalone application or as a part of the ILP (Table 25.5).

Fig. 25.3 Concept of the interactive learning program (ILP) and flood animation studio (FAS)

Application and Results

The general structure of the LAA has been taken for developing a participatory planning concept within the INTERREG project SAWA. It is being used for the development of a Flood Risk Management Plan at the River Wandse, a small urban river in the City of Hamburg.

Three different streams of project activity have been carried out in parallel as depicted in Table 25.6. The first stream covers the implementation and operation of the LAA. The second one deals with the development of the tools and instruments to support the participatory planning procedure, and the third one focuses on consultancy support which is needed in the planning process of the LAA, e.g. development of simulation models, hydraulic design and the planning of site specific measures out of the group of FReM and FPR, and their integration in thematic plans of river restoration, urban drainage and urban development.

Experience and Results After the Scoping Phase: LAA Wandse

Recruitment of Stakeholders

For selecting and addressing the stakeholders, a stakeholder analysis had been carried out according to the procedure explained in the section "*Selecting stakeholders and assigning their role.*" While it had been rather straightforward to recruit the professional stakeholders some challenges have been encountered in selecting and motivating the right persons out of the public. There should not be too many stakeholders, representing and reflecting the dominating opinion of the public. A public interest group has been recruited which is active in supporting a

Table 25.5 Phases and corresponding methods of the interactive learning program

ILP Phase	Objective	Methods
1. Concrete experience (p1)	Triggering motivation, raising flood awareness, evoking memories on flood experience	Haptic models, "hands-on" experience such as Flood Animation Centre (FAC)
1a Concrete experience to reflection" (ip 1–2)	Personal identification with the problem initiation of the reflection process	Involvement of a narrator—a member of the key SH group, sharing his experience Autodidactic preparation—KalypsoInform
2 Reflection (p2)	Demonstrating complexity of FRM (RBE) focusing on the SH group specific issues	Presentations on FRM, short videos, discussions with the key stakeholder groups
2a Reflection to forming abstract concepts" (ip 2–3)	Demonstrating deficiencies of local FRM and current practice relevant for the role of the targeted SH group, supporting the logical "jump" to abstraction	Visits to the local bottlenecks and vulnerable sites of the local FRM (e.g. pumping stations, weirs), Autodidactic preparation of the selected chapters in Kalypso Inform
3 Forming abstract concepts (p 3)	Making stakeholders aware of the course of action i.e. possible strategies and general concepts of FRM and their role in FRM *"what can be done"*	Presentation and discussion on local scale measures, their pros and cons, preconditions for their application using the examples from *ip* 2–3 for generalisation of the concepts
3a Forming abstract concepts to testing (ip 3–4)	Demonstrating application of strategies and concepts delivered in *p 3* on concrete examples *"what can I do?"*	Showing concrete examples of applied measures, implemented planning procedures in the area, Autodidactic preparation—Kalypso Inform
4. Testing (p4)	Testing acquired knowledge on FRM on practice relevant cases	Developing own solutions for selected problems (sketch, plastic 3D models)
5. Assessment of resil. perform	Assessment of any behavioural changes after the ILP	Questionnaires, oral feedback, phone interviews within a year after the ILP

larger nature reserve area at the upstream part of the River Wandse. In addition, representatives of an NGO, which are active in the ecological improvement of the River Wandse, are committed to their participation followed by some citizens living close to the river. Their motivation was the concern about sufficient flood management along the river. In the end 23 stakeholders could be recruited with a good representation of all relevant stakeholder groups. The public representatives in particular turned out to be very beneficial as they seemed to be leaders in public opinion and serious to learn and cooperate within the team. The group is meeting on a regularly basis (once in 2 months) for a 2 h session either in the form of a workshop or on a site visit to the river.

Table 25.6 Main work phases within the governance process of FRMP

Governance		Research	Consultancy
Phase	Actions		
Scoping	Selection of members, development of CI, raising flood awareness, shared vision of the problem	Guidance document for stakeholder selection, learning material for social competence building, development of flood animation material (FAC, flood symbols, etc.). development of first phase of ILG	Developing mathematical models of the river basin under consideration (rainfall-runoff, hydraulic and damage model), development of flood risk maps
Understanding and envisioning	Capacity building in risk management and NSM, shared vision of where to get to	Learning material for capacity building in the flood risk management inventory of best practice of adaptive measures (NSM) Integrating material to 2nd phase of ILG	Assisting in the ILGs
Problem resolution and experimenting	Active planning on the river level, experimenting with NSM on a local level, setting up different thematic plans, discussion on different planning options, exploring the improvement options with RBMP	Integrating mathematical models into a decision support tool, assisting in the experimenting phase by introducing the application of the decision support tool	Designing NSM on a local level, integrating single measures to alternatives plans on urban drainage, river restoration and urban development, assisting in the ILGS
Testing and evaluation	Agreement on multi-criteria approach and assessment parameters, assessment of alternatives by decision support system, minimisation of conflicts, consensus finding by prioritising interests	Development of an assessment matrix for MCA coaching in the process of consensus finding	Assisting in the ILGs, coaching in the process of consensus finding
Feedback and recycling	In case of no final consensus: explore deficits in understanding of problem, in flood risk management and application of adaptive NSM		

Fig. 25.4 Development of social competences (*left image*) within the LAAs (*right image*)

Developing Trust and Team Spirit

At the beginning the stakeholder group was rather fragmented. Some of them wanted to sit at one table or admitted that their main intention in contacting the government agencies lay in raising objections or to complain. Thus there has been no way of working together. At the beginning the focus lay with the development of trust between the parties. At the first workshops most activities concentrated on social gaming, exchanging their motivation and interests in the LAA Wandse. While the public stakeholders were reacting positively to the social games, the professionals expressed their doubt and complained about a "waste of time". But the concept has not been given up and became a continuous concern in the following workshops. In the "balloons" social game, the participants had to create groups based on the balloon colour they picked up instead of based on their background and further act as a group to perform certain tasks (Fig. 25.4). This especially contributed to the taking off of the institutional hats and the increasing collaboration within the LAA. A set of charts mapping their current relations from "ask for approval from" to "collaboration and participatory planning" showed the current relations between the groups and triggered reflection on its improvement. Also the discussion about each professional background and interest at the River Wandse was most supportive in creating understanding and team spirit. The communication among participants between the LAA sessions is supported by a central communication and information platform (http://laa-wandse.wb.tu-harburg.de/) giving access to all materials, presented or created in the workshops standing for one of the basic principles of the LAA that all information that is available will be given to stakeholders and discussed and evaluated in the most objective and fair way. The participants are also encouraged to express their opinions in the forum provided within the platform.

Raising Risk Awareness

The last extreme flood at the River Wandse was several decades ago. Thus just a few of the participating citizens had experienced a flood event at this river. Therefore the risk awareness of the members, even that of the water authority, was rather low. A Flood Animation Studio (Manojlovic and Pasche 2011) has been used to give the stakeholders a feeling of flood. Like in a studio a living room is flooded in a 2 m^3 cube within minutes. A person (which could be an LAA participant) is "living" in this room and has to respond to this flood by securing all valuables (computer, laptop, passport etc.) in the room. The other stakeholders are standing around the box and observe the event. The actor is usually helpless and reacts in the box without strategy. The observers regard the event first as "fun" but once they realise the incoming water under the door and the helplessness of the actor they are touched as well as excited.

As the urban development at the River Wandse had propagated further towards the river and grabbing at the flood plains, the vulnerability on the floodplains had been considerably increased. Furthermore, several constructions at bridges and weirs exist where the risk of blockage by debris increased over the last few years as restoration measures have led to the development of dense wooden vegetation on the riverbanks and high production of dead wood in the river.

The flood hazard and risk map did not reflect these threats as they are based on a well-functioning river network without any blockages. By simulating the consequences of failures as blocked culverts, the vulnerability of the adjacent urban development became apparent. Through a field trip the LAA members could assess the probability of such failures and the consequences (Fig. 25.4b). In the end they understood this high risk and the need for improvement.

Spatial planners and researchers were informed about the important drivers of urban development and climate change in a very objective and open way. With the decision support tool KALYPSO, the consequences on flood risk were quantified and visualised in risk maps. At the end of the first phase the main conclusion by the group was that *The river needs more space!* Based on the analysed future risks in the area, and considering the failure modes, the acceptable risk has been defined and represents a basis for further flood risk management planning.

Outlook

In the following phases, the adaptive non-structural measures being Flood Probability Reduction Measures (FPRM) and Flood Resilience Measures (FReM) are to be presented to the participants and their potential to mitigate flood risk discussed within the group. The harmonisation with the Water Framework directive is to be emphasised and the synergetic measures identified and considered for the FRMP. In the experimenting phase, the measures are to be applied in an integrative way to the River Wandse. This participatory planning phase will be dominated by experimenting and learning, as most of the stakeholders have no or little experience with the application of the innovative flood risk management approaches. Furthermore, the developed FRM planning options, as a set of measures, are to be quantified in their efficiency and cost effectiveness. Finally, the FRMP option with the lowest conflict potential will be adopted by the LAA Wandse group and conveyed to the decision makers in the area.

Conclusions

New concepts are required to support the active participation of stakeholders in the development of flood risk management plans in the sense of the EC Flood Directive (EC 2007). Bottom-up approaches are likely to fulfil this requirement. A four-stage approach has been developed and applied to develop a flood risk management plan for the River Wandse, Germany, based on two dominating processes of decision-making and capacity building. Development of mutual trusts and open atmosphere turned out to be a crucial factor for proceeding with planning, but it took longer than anticipated. Analysis of the system sensitivity to floods and its failure mechanism (e.g. blockage of the bridges) is a necessary extension of the obligatory flood maps in order to understand the system's limits, enabling stakeholders to assess risk more realistically. The objective of the LAA has to be made clear and visible to everyone at any point, as the process takes a long time and the single groups can get trapped by own or local interests, losing the "big picture" or common interests. Harmonisation with the other directives and planning procedures (e.g. WFD) has to be made at an early stage, introducing already planned synergetic measures as an element of the flood risk management planning. Sophisticated modelling and decision support tools are required, quantifying the failure mechanisms but also the efficiency and effectiveness of the planned measures, which is one of the key criteria for final adoption of the planning option. Capacity building processes should be adapted to the decision-making processes, delivering the tools and materials required by each decision support phase. As this is a knowledge and resources-intensive process, the expertise of different groups is required, including social scientists or civil engineers, as well as modelling experts. The role of research is seen in conjunction with the process and development of tools and guidance documents, whereby the consultancy should support the process by quantifying planning effects by applying modelling and decision-support tools, producing flood maps and developing site-specific solutions which can be integrated into certain thematic plans, such as river-restoration plans, urban-drainage plans, and urban-development plans.

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Author Biographies

Natasa Manojlovic, MSc, is a senior researcher at the Institute of River and Coastal Engineering at the Hamburg University of Technology, Germany, and is a visiting researcher at the UNESCO-IHE in Delft, the Netherlands. She achieved academic qualifications at the Faculty of Civil Engineering at the University of Belgrade (BSc) and Hamburg University of Technology (TUHH) (MSc). Additionally, she holds a Professional Master's Degree in technology management obtained at the Northern Institute of Technology—NIT, Hamburg. Her research and teaching is focused on flood risk management (flood resilience technology, systems and tools, and capacity building of stakeholders), environmental hydraulic engineering, and urban hydrology. Manojlovic is involved in several EU and national projects, including: the FP 7 Project SMARTeST and the CORFU INTERREG Projects SAWA and MARE, and is also a work group leader in the research cluster "KLIMZUG-North" sponsored by the German Research Foundation BMB. Manojlovic has authored a number of publications on flood resilience and flood risk management.

Dipl. Ing. Niloufar Behzadnia is a research associate at the Hamburg University of Technology (TUHH), where she also achieved her academic qualification. Behzadnia has been involved in various EU and national projects, the most important being CRUE ERA NET project SUCA and the Development of the Flood Risk Management Plans within the EU INTERREG IVb SAWA Project (http://www.sawa-project.eu/). Her work is mainly focused on the application of hydrologic and hydraulic models, flood risk management and capacity building of stakeholders.

Prof. Erik Pasche (1955–2010) was the founder and director of the Institute of River and Coastal Engineering (1998–2010), and a professor of hydraulic engineering at the Hamburg University of Technology (TUHH). Dr Pasche was a visiting professor at UNESCO-IHE in Delft and vice chairman and German representative of the COST-Initiative C22—Urban Flood Management. Dr Pasche was also chairman of the BWK Expert Group Hydraulic Modelling of Natural Rivers from 1997, and chairman of the BWK Expert Group Movable Flood Defence Systems in the period 2001–2010. He was the scientific coordinator of the research cluster "KLIMZUG-North" sponsored by the German Research Foundation BMBF, INTERREG IV b project SAWA (http://www.sawa-project.eu/) and EU FP 7 Projects SMARTeST (http://www.floodresilience.eu/) and CORFU (http://www.corfu7.eu/). His research and teaching was focused on flood risk management, environmental hydraulic engineering, river hydrology, hydrodynamics, and mathematical modelling of hydrological and hydraulic processes, including the measurement of sedimentation and erosion rates.

Chapter 26
The Essential Role of Employment and the Workplace in Climate Change Policy and Effective Disaster Risk Management Planning

Peter J. Glynn and Roslyn Taplin

Abstract The transition to a low carbon economy will occur over the next generation. During this period governments will determine law and policy that includes greenhouse gas emission targets and defines emission management strategies and strategies to manage the consequences of the increased frequency of extreme weather events. This paper explores the implications of climate change policy for employment and the workplace, and its role in effective disaster risk management planning. Climate change is a significant concern being addressed both globally and domestically. Regulations will be designed to ensure consistency with government policy. Business and actors in the workplace will, by necessity, adapt to the new requirements. The challenge is to ensure regulators' objectives are matched with the requirements for business continuity, the labour market, a just transition and in the context of disaster risk management the ability to earn sufficient income to meet the basic daily needs of the individual or family. Ecological modernisation theorists support the school of thought that environmental outcomes are achieved through the relationship between the nation state, the economy and innovation, and social movements. Ecological modernisation provides a suitable framework within which to analyse these relationships. This paper will address issues associated with climate change policy including disaster risk management in the context of ecological modernisation theory with a particular focus on the role of industry and the impact on employment and the workplace.

P. J. Glynn (✉)
Institute of Sustainable Development and Architecture, Bond University, Gold Coast, QLD 4229, Australia
e-mail: pglynn@bond.edu.au

R. Taplin
University of New South Wales, Sydney, Australia
e-mail: ACSMP@unsw.edu.au

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Introduction

This paper sets out to investigate the essential role of employment and the workplace in effective disaster risk management. The contention that underpins the paper is that disaster risk management as a tool for climate change adaptation and mitigation must provide for the resumption of business and facilitate the timely return to work and normality of daily life.

The evidence of climate change impacts in the short to medium term will not be from rising mean temperatures or rising sea levels, but rather from increased variability of weather and more frequent and extreme events like storms, droughts, floods and heat-waves (Sanchez and Poschen 2009). It is only in recent times that natural disasters and vulnerability adaptation have been spoken about in the same context as climate change. The two have been drawn together by the rapid developments in climate science and the increasing incidents of extreme weather events, international agreements, and strategies for climate change adaptation and mitigation that now extend across the established programs for natural disaster and vulnerability management.

The link between climate change and the labour market was formally accepted by governments and experts when they adopted the recommendation of the United Nations Framework Convention on Climate Change's (UNFCCC) Adaptation Working Group (AWG LCA) to include the commitment to provide for a just transition and decent work in the Conference Agreement (UNFCCC et al. 2009). The four tenets for decent work as articulated by the International Labour Organisation (ILO) are creating good jobs, guaranteeing the respect of workers and recognition of their rights, extending social protection and promoting social dialogue (ILO 2011a, b). These are not remote concepts and it should be expected they will be provided in the disaster policy and planning.

A number of studies provide empirical evidence of the nature and quantity of the changes in the labour market that will occur as a consequence of climate change (GHK Consulting 2007; NIEIR, 2010; Worldwatch Institute, 2008). The UNEP Report finds that the labour market is already changing, that there will be net employment growth, that jobs will be created, that employment will be substituted (move from one industry to another), that jobs will be eliminated, and that existing jobs will transform into green jobs (Worldwatch Institute, 2008). The report's findings and policy messages, published separately, contended that there will be a redefinition of many jobs across the board (UNEP 2008).

The changes occurring in the labour market are not only a reflection of the industrial revolution as industry moves to adapt to the new conditions, but also of the extreme weather events that are significantly impacting industry and its workforce. In 2005 economic losses from natural catastrophes resulted in direct financial losses of about USD$230 bn, representing 0.5 % of global GDP (OECD 2009). The tsunami that hit Fukushima, Japan resulted in the death of more than 12,000 people and cities have totally disappeared. The economic and social consequences are significant; Japan's industrial base is impacted, and the employment and skills profile of the region has changed and will continue to change as the cities are rebuilt to an urban model that ensures greater resilience (new ref). The UNEP report's description of the changing labour market holds true for Fukushima, it will see "*net employment growth, jobs will be created, employment will be substituted* (*move from one industry to another*)*, jobs will be eliminated and existing jobs will transform into green jobs.*"

Fukushima is an extreme illustration, but all disasters have the same effect, there are only variations in the degree and the nature of the disaster. The drought that affected eastern Australia during the first decade of this century had its greatest impact on workers in health and emergency services. The temperatures and conditions under which they were required to work were unprecedented and created conditions that required different equipment, work patterns and safety measures. In Bangladesh, the strategy in response to its persistent drought was to shift the economy away from agriculture to garment manufacturing (Stern 2007).

There is a demonstrated link between climate change and disaster risk management policies and strategies for adaptation and mitigation. It is essential that the employment and workplace relations impacts of climate change policy are also included in those policies and strategies.

The Relationship Between Climate Change and Disasters as They Impact on Employment and the Workplace

The impact of climate change on employment and the workplace has been widely researched and reported. The UNEP Green Jobs Report (Worldwatch Institute 2008), the EU Report *Links between the environment, economy and jobs* (GHK Consulting 2007), and the Australian Council of Trade Unions (ACTU) Report *Creating Jobs-Cutting Pollution: a roadmap for a cleaner, stronger economy* (NIEIR 2010) established that there will be a major adjustment in the labour requirements across sectors due to climate change.

The UNEP (2008) report's findings emphasised the need for policy to ensure that change could be achieved efficiently and fairly. It also made the point that "coherent environmental, economic and social policies are critical and will require commitment at the highest political level" (UNEP 2008 p. 24). In commenting on workplace issues the report emphasised the need for social reform and the goal of a just transition in the policy framework. It defined a just transition as "a new mode of production and consumption that allows for greater social inclusion, equity and opportunity" (Worldwatch Institute 2008 pp. 278–280) embracing workers' rights, decent work, social protection, social dialogue and sustainable business

The impact of disasters is also widely reported and, whilst the impact on employment and the workplace is apparent, the commentary is invariably about the tragedy. The Hyogo Framework for Action observes that natural hazards can affect anyone and the recent events have cost millions their livelihoods (ISDR 2005). In that same framework document, the UN Secretary General outlines the goal to build resilience in the social, economic and environmental assets by 2015.

Adherence to the UN Secretary General's goal and those of the Hyogo Framework are reflected in recent post disaster assessments and provide some guidance as to the scope of requirements from future disaster management plans. The OECD (2009) observes that several countries are starting to combine the knowledge of the "hard" sciences with economics, sociology and psychology. The UN Pakistan Disaster Risk Management Joint Programme requires outcomes of improved livelihoods and local economies in affected areas, improved household incomes through development of entrepreneurial skills, as well as income generating activities and diversified livelihood opportunities (UN Pakistan, 2010). The UN report of the Wenchuan earthquake recovery and reconstruction finds that future disaster risk management must provide for each earthquake-affected family to have income sources and the chief labourer of the family must have a secure job. It concluded that this helps sustain social stability and it also reduces the stress on government finances (ISDR 2010 p. 46). The UN policy brief on adaptation to climate change "emphasises employment in recovery from climate related disasters, as well as the role of labour institutions, workers and employers in designing and implementing adaptation policies…" (ILO green jobs 2011).

While the commitments to action are encouraging and the declaration of higher order outcomes such as human rights and decent work defines the objectives of policy, the available policy and implementation strategies are less obvious, complicated by the fact that the situation to be dealt with will not be known in advance. The certainty is that there will be change and the policies and strategies can be framed accordingly. They should not disturb the priorities of the disaster risk management, but certainly should form part of it, as they should with climate change policy.

Incorporating the employment and workplace considerations into disaster risk management requires a revision of the traditional approach. The Hyogo Framework describes disaster risk management as the risk management process to address the specific issue of disaster risk such as improved coping capacities in order to lessen the adverse impacts of hazards and the possibility of disaster (ISDR 2005). The OECD has moved further reporting the inclusion of economics, sociology and psychology in the process (OECD 2009). The CLUVA project in Africa contextualises the climate change policy framework, placing the role of disaster risk management within it and embracing employment and workplace issues (CLUVA 2011).

How the disaster risk management should be impacted will be dependent on the anticipated risk. The objective should be the opportunity for the resumption of employment and the payment of wages. Stern (2007) spoke of safety nets, citing the programmes that were announced in Indonesia in response to the economic, natural and political crisis in the period 1997–1998. The employment creation programmes which relied on self-selection targeting were found to be far more efficient in reaching the vulnerable households than programmes based on health subsidies and rice sales. Equally, the Employment Guarantee scheme in the Indian state of Maharashtra has provided wage labour opportunities since the 1970s which act as a buffer against the adverse impacts of climate change and climate variability, and support a transition to other households from the effects of poor harvests and other negative shocks. In order to promote employment in the earthquake-affected areas of Wenchuan, the Ministry of Human Resources and Social Security of China issued a policy paper soon after the disaster to help the people to find jobs. The paper formulated three policies to subsidise employment promotions. The three policies included a vocational training subsidy, a travel cost subsidy for people who found jobs outside the affected areas, and a pension subsidy (ISDR 2010).

The ILO (2011a, b) has submitted that disaster risk management strategy should aim at creating conditions that will ensure "those whose livelihoods, income and employment are affected by livelihoods, income and employment. This support needs to take place in a framework that includes a fair distribution of costs, representation and employee involvement; long-term planning; and security against direct losses. In addition, there is a need to maximise the socio-economic impacts of the climate adaptation policies and measures taken globally at the national and local level" (ILO, p. 1).

The Livelihood Assessment Toolkit (LAT) is one of the tools available for analysing and responding to the impact of disasters on the livelihoods of people (FAO and ILO 2007). It was presented to UNFCCC Cancun Adaptation Planning Process as a tool to enable a more effective response. Engagement with business organisations and trade unions on the grounds that "national plans (for climate change and disaster adaptation) developed through social dialogue have been shown to be more inclusive and widely supported" was also referenced in that intervention (ILO 2011a, b) Fig 26.1.

At the micro end of the policy scale are the workplace issues which, in the context of economic and social sensitivity, are very important elements of the policy framework. The workplace is a highly regulated aspect of economic and labour activity, displaced only when emergency powers are enforced and only for their specified duration. At the centre of labour regulation and administration are the core labour standards of freedom of association and the right to collective bargaining; the elimination of forced and compulsory labour; the abolition of child labour; and the elimination of discrimination in the workplace (ILO 2009). The disaster does not change the dynamic of the workplace over which the law prevails. Issues of fair wages, occupational health and safety, respect for the worker and protection of his and her rights cannot be over-ruled. After the Wenchuan

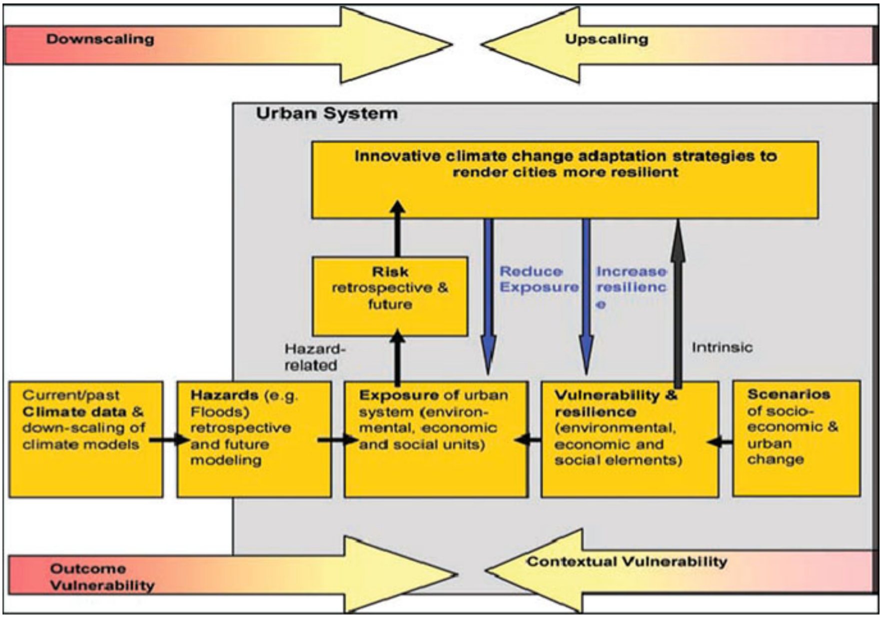

Fig. 26.1 Climate change and urban vulnerability in Africa, 2011

earthquake, the government sought the prompt restoration of daily services, including the "arbitration of labour disputes, labour disability issues, on-the-job injury identification, and restoration of data and information systems for public access to employment opportunities and social security provisions" (ISDR 2010).

The occupational health and safety issues are an ever present responsibility, and more so in relation to disaster management. European Commission studies have reflected on the psychological impact on those who are affected, the victims, and also the survivors (Social Agenda 2011). The WHO research has found that exposure to heat in the workplace impacts not only on worker productivity but also physical health, stress and depression.

The representative organizations of employers and workers have an important role to play in this regard. Often they are the most informed about the workplace and the issues that are current and pending, not only about the employer–worker relationship but also as the advocate for the groups on statutory and technical standards in play. The ITUC was a particularly vocal advocate for workers when it accused business groups and companies of pushing to reduce protection from hazards at work. It cited the disaster at the Fukushima complex as a lesson of how regulation and enforcement is of critical importance (ITUC 2011a, b, c).

Theoretical Framework, the Role of the Nation–State and Civil Society

Ecological modernisation has been chosen as the theoretical model because of its fit with the research contention and it provides a framework to explore the roles of actors in society in the process towards achieving best practice environmental outcomes. Ecological modernisation refers to the relationship between economics and innovation, the interventions of the nation–state and the involvement of non-state actors in decision-making to achieve environmental outcomes (Mol and Sonnenfeld 2000). The concept of ecological modernisation is increasingly being used in policy analysis (Christoff 1996; Spaargaren et al. 2009).

Article 2 of the Kyoto Protocol (UNFCCC 1997) provided that "in achieving its quantified (greenhouse gas) emission limitation and reduction commitments … (signatory governments) shall implement and/or further elaborate policies and measures in accordance with its national circumstances…" However, there are a range of variables to be considered when determining the policy that will meet this commitment including the stage of economic development, dependence on fossil fuels, cultural background, and political structures. There is no one solution as each situation and each disaster is different.

In ecological modernisation theory the nation–state is the essential counterbalance to the unfettered behaviour of the market, and its role as an active regulator is fundamental to effective environmental policy. It is also a widely held view that innovation in technology is necessary if the environmental targets are to be met in a constrained timeframe. The two are not mutually exclusive, and it is argued that the optimum situation is one where the nation–state provides clear standards and policy goals while allowing flexible means for industry to achieve the goals (Ashford 2002). While articulated in different ways by the theorists, there is a consistent thread that binds the contribution of enterprise with strict monitoring of performance. Stern held the view that effective adaptation may require governments to address specific market failures and barriers that limit effective adaptation (Stern, 2007). The research conducted by Esty and Porter (2005) found that environmental results were not merely a function of economic development but also a consequence of policy choices. They concluded from their research that, amongst other things regulatory stringency and regulatory structure were highly significant.

Understanding how the "critical risk issue" is introduced into public policy was the subject of research by Lange and Garrelts (2007) who found that although ecological modernisation was the most effective theoretical approach to the environmental problem, public policy often occurred as the result of opportunity. Ashford (2002) also believed that circumstance was an important factor, observing that willingness, opportunity, and capacity are the necessary components for change. The Lange and Garrelts (2007) studies were undertaken where the natural disaster concern was flooding, the options for management were based on safety and risk, and the management tools were administrative authority and public policy implemented through statute. Ecological modernisation, which was the theoretical model applied in the latter case, was found to be the effective approach. Interestingly, they concluded that effective intervention in the development of policy did not necessarily reflect the quality of the argument but rather what kind of window of opportunity was open and the influence exerted by civil society.

The theory of ecological modernisation would suggest that the environmental outcome is achieved by the cooperative efforts of the nation state with civil society and is less likely to be achieved if they are acting unilaterally. The Hyogo Framework for Action implementation strategy relies on cooperation among governments, organisations and civil society actors and it uses the International Strategy for Disaster Reduction (ISDR) system to bring them together and ensure the best use of resources are applied to its goal of "substantial reduction of disaster losses, in lives and the social, economic and environmental assets of communities and countries" (ISDR 2005). The EU (2006) also acknowledges the benefits of a cooperative effort in disaster risk management, adopting the creation of an enabling environment through dialogue between donors (civil society) and governments as a crosscutting objective, and the use of existing policy mechanisms to facilitate policy windows and forums for discussion.

Ecological modernisation theorists' references to civil society are often directly or by implication a reference to environmental activists (e.g., Christoff 1996; Howes et al. 2010). Similarly, disaster risk management literature singles out donors and other providers of emergency support such as the WHO, UNHCR and ISDA as relevant interests. In practice the scope and interests can be much broader. Young has written extensively about the role of civil society and believed it was integral to the infrastructure of the international climate community (Young, 2003). At international level and in respect of policy development the UNFCCC provides a guide as to the accepted interests and includes amongst them business organisations and trade unions. In March 2011 the UNFCCC had formally admitted *"… over 1,297 NGOs … from business and industry, environmental groups … labour unions, women and gender and youth groups"*. In disaster risk management the spread of civil society interests is unlikely to be as vast, but nevertheless, and as it relates to the employment and social dimension being promoted by the UN and some of its agencies, labour institutions are an important interest group (ILO green jobs, 2011).

There are many demonstrations of the participation of civil society formally and informally in disaster risk management. The OECD Disaster Risk Management Manual (OECD, 2010) recommends of the corporate sector leadership by example and the provision of employee education programs, risk reduction measures and business continuity plans. It also identifies supply chain management as a means of encouraging suppliers to adopt sound business continuity practices, thus ensuring the resilience of the supply chain (OECD 2010). The International Chamber of Commerce has taken roles in activities such as the UN High Level Expert Panel on Water and Sanitation, declaring that "the global (business) community has committed itself to the principles of coherent disaster prevention and response" (UNSCAB, p. 7). The UNSCAB not only welcomed contribution, but sought to extend its reach and the influence of its work by asking the ICC to pass the relevant information about its work to its membership.

The ITUC through its Solidarity Fund received donations of over USD$1 million which it resolved to apply to the provision of vocational skill to those affected by disasters. It signed an MOU with the ILO to provide the necessary infrastructure to support the delivery of the training. In the period since the disaster at Fukushima it has initiated a campaign to ensure that disaster risk management recognises the proper role of business regulation and its enforcement to protect workers from health and safety concerns. To this end it presents the benefit of "harnessing the on-the-ground knowledge of workers, backed by their unions" (ITUC 2011a, b, c).

The research for this paper is part of a programme to better understand the roles and relationships between the economy, nation state and civil society. Particular attention is being paid to the work of business organisations and trade unions in achieving the desired environmental outcome. To that end it is believed that the findings here add weight to the contention that they, through their role in labour markets and the workplace can contribute to achieving the objectives of ecological modernisation.

Conclusions

This paper has sought to demonstrate the impact of climate change policy on employment and the workplace, and the role of civil society in particular business organisations and trade unions in the management of that process.

As climate change is also giving rise to an increased number of natural disasters, so has the importance of disaster risk management. In post disaster management, priority is being given to labour market planning and the creation of employment opportunities, and the contribution that an income for a disaster affected family can make to the overall recovery effort. Accordingly, pre disaster risk management should emphasize measures to facilitate business resumption and continuity in the supply chain that in a post disaster situation are essential to the provision of employment and with that social stability.

Ecological modernisation theory, when overlaid on the activities of the nation state and civil society in disaster risk management and post-disaster management, can provide the framework that facilitates the relationships between the actors to achieve the required environmental and programme outcome. The beneficial interaction of civil society and the nation state was demonstrated by the ITUC demand for enforcement of regulation to ensure the safety of workers which it says do not have to be compromised because of a disaster situation.

The important role of business organisations and trade unions in the disaster risk management process is emphasised by the United Nations and its agencies which respect the expertise they bring to the process and also the mediation role they can play between planners, business and the workforce at the implementation phase.

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Author Biographies

Peter Glynn's professional background is in industry association management, with specific expertise in labour relations and labour market management. Prior to commencing doctoral studies he was engaged by the International Labour Organisation and the International Organisation of Employers in the development of policies and tools to guide the implementation of labour market strategies to manage the impacts of climate change policies.

His doctoral research addresses the question of how industry (employers' organisations and trade unions) can ensure the impacts on employment and the workplace are considered in climate policy.

Professor Roslyn Taplin is Research Director of ACSMP at the University of New South Wales, Sydney. She was formerly Professor of Environmental Management at Bond University and prior to that, Director of the Environmental Management Programme and Director of the Climatic Impacts Centre, Macquarie University. She has also held positions at the University of Adelaide and RMIT University, Melbourne. Her current research interests include: sustainability and mining practices, corporate responses to climate change, climate change adaptation decision-making, renewable energy policy, climate change mitigation approaches including the Clean Development Mechanism, and emissions trading.

Chapter 27
Understanding the Dynamics of Climate Change Impacts on Forest-Dependent Livelihoods in Rural Ghana: Implications for Climate Change Resilient Policy

William Kwadwo Dumenu, Elizabeth Asantewaa Obeng, Sparkler Brefo Samar, Ebenezer Owusu-Sekyere and Emmanuel Asiedu-Opoku

Abstract Forest resources and rain-fed agriculture play key roles in the livelihoods of the majority of rural dwellers in Ghana. Climate change and variability, characterised by several consequences, is expected to adversely affect forest dependent-livelihoods. This study was conducted to examine the impact of climate change on forest-dependent livelihoods and rural communities' socio-economic vulnerability levels as well as their adaptation strategies. Questionnaires, interviews and direct observations were used to collect data from respondents in four ecological zones. The socio-economic vulnerability assessment of the four ecological zones was estimated using six socio-economic indicators and subsequently ranked using the "Three Category Ranking Method". The Transition and Sudan Savannah zones were ranked the most vulnerable to climate change out of the four ecological zones. The zones' vulnerability was due to interacting socio-demographic and socio-economic factors such as high illiteracy level, limited range of income sources, and low access to climate change information. Crop diversification, household income diversification, peri-urban migration and an increase in farm size are among the different measures adopted by communities to cope with the effects of climate change. To enhance rural

W. K. Dumenu (✉) · E. A. Obeng ·
S. B. Samar · E. Owusu-Sekyere · E. Asiedu-Opoku (✉)
Forestry Research Institute of Ghana, P. O. Box Up 63, Kumasi, Ghana
e-mail: kdumenu@gmail.com

E. Asiedu-Opoku
e-mail: asiedupoku@csir-forig.org.gh

E. A. Obeng
e-mail: amadanso@yahoo.co.uk

S. B. Samar
e-mail: samasass@yahoo.com

E. Owusu-Sekyere
e-mail: eosekyere@csir-forig.org.gh

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communities' resilience, fundamental issues such as illiteracy, options of non-climate dependent livelihoods, access to climate change information and sustainable agricultural practices are key areas for policy intervention.

Keywords Climate change · Forest dependent livelihood · Vulnerability · Adaptation · Policy

Conceptual Framework

Climate change is often considered a key threat to the forest ecosystems across the globe. Socio-economically, climate change will have a significant impact on forest communities whose livelihoods critically depend on forest resources. However, the severity and magnitude of the impact are influenced, among others factors such as socio-demography factors, by income level and diversification of incomes sources, presence of infrastructure and adaptive capacity. Therefore, in studying the dynamics of climate change impacts on livelihoods, it is necessary to take cognisance of factors that predispose, expose and reduce people and systems' ability to cope and deal with climate change and variability. These factors, no matter the form they take, mostly, if not all the time, border on issues of vulnerability.

Vulnerability is the degree to which a system is susceptible to, or unable to cope with the adverse effects of climate change, including climate variability and extremes. The climate change research domain defines vulnerability as a function of exposure, sensitivity and adaptive capacity (Adger 1999; IPCC 2007; Smit and Pilifosova 2003; Yohe and Tol 2002). There are both physical and social sources of vulnerability. Physical conceptions of vulnerability focus on exposure and sensitivity to environmental stressors. Social conceptions of vulnerability draw attention to factors such as income distribution, assets, sources of livelihood, ethnicity, gender and poverty as engendering and characterising vulnerability (Watts and Bohle 1993; Turner et al. 2003). Social vulnerability can be defined as the interplay between social, economic, and demographic characteristics that determine the resiliency of individuals and communities to climate change.

Literature has shown that, a number of economic factors can increase vulnerability. These include level of education, (Cutter 1996), occupation and employment type (Cutter 1996; Hewitt 1997; Mileti 1999), and income (Burton et al. 1993; Blaike et al. 1994; Hewitt 1997).

Therefore, it is in the context of social vulnerability that this study sought to understand how climate change and variability impact differently on forest dependent communities in different ecological zones in Ghana. Vulnerability indicators that focused mainly on the exposure of forest-dependent communities to the impact of climate change were developed and used in the understanding of the dynamics of climate change impacts.

Table 27.1 Distribution of respondents across the eight districts in the four ecological zones of Ghana

Ecological zone	District	Name of village	Number of respondents
Forest zone	Amansie Central	Biribiwomang	14
		Akasunimu	14
		Asikasu	14
Transition zone	Ejura Sekyedumase	Akasunimu	14
		Aframso	14
		Babaso	14
Guinea Savannah zone	Central Gonja	Ntreso	14
	Builsa	Chuchuliga	14
	Talensi-Nabdam	Balungu	14
		Pwalugu	14
Sudan Savannah zone	Bawku-West	Kobre	14
		Tessi	14
	Bongo	Apuwongo	14
	Garu-Tempane	Bugri	14

Methodology

The Study Area

The study was conducted in 14 rural communities in eight political districts spanning four ecological zones in Ghana. Different ecological zones were selected in order to analyse the most vulnerable zones and determine the dynamics of coping measures employed in the different zones. Table 27.1 presents the study areas in their respective districts and ecological zones.

Data Collection and Analysis

Sampling of respondents was done by simple random selection. Structured questionnaires were used to collect primary data from 196 heads of households across eight districts in four ecological zones. Information on socio-demographic factors influencing communities' vulnerability to climate change and adaptation strategies adopted by communities was gathered through focus group discussions and from key informants.

The socio-economic vulnerability assessment was estimated using six socio-economic indicators, namely, household size, level of awareness/access to climate change information, level of literacy, dependence on climate sensitive occupation, diversification of occupation (non-climate sensitive) and dependence on forest resources. The selection of these factors was informed by previous studies that proved the relationship between vulnerability and socio-economic factors (Cutter

1996; also cited in Cox et al. 2006). The total score of the four ecological zones indicated as Vulnerability Indices (VI) were then classified using "Three Category Ranking Method" (TCR) (Lama and Devkota 2009). The socio-economic vulnerability of the ecological zone was calculated by combining the six VI and subsequently ranking their vulnerability status.

Results and Discussion

Socio-Demographic Characteristics

Several studies have shown the relationship between socio-demographic characteristics and climate change vulnerability and adaptation (Deressa et al. 2009; Gyampoh et al. 2008). For instance socio-demographic characteristics such as level of education, sex, age, and household size are found to increase the probability of adaptation. Knowledge of the socio-demographic factors influencing climate change vulnerability and choice of adaptation strategies enhances the development of climate resilient policies. This section presents findings on some relevant socio-demographic characteristics of the four ecological zones that were found to influence vulnerability and adaptation to climate change.

Household Size and Level of Literacy

The mean household size of the respondents was 6.3, with household size ranging from two to 16. The Sudan Savannah Zone had the highest mean household size, which were 7.4. The Forest Zone had the lowest mean household size, which was 5.5 (Table 27.2). The analysis of variance (ANOVA) showed a significant difference ($P = 0.001 < 0.05$) in the household size for the different ecological zones.

With regard to literacy, there was generally a low level of literacy in all ecological zones (Fig. 27.1). Close to half (46.7 %) of respondents had no formal education. The Transition Zone had the highest illiteracy level (64 %), with the Forest Zone recording the lowest (30.8 %). Pearson's Chi-square tests showed significant differences ($p = 0.031 \leq 0.05$) in level of education among the ecological zones.

Table 27.2 Household size in the selected ecological zones

Household size (number of individuals in the family)				
Ecological zones	Minimum	Maximum	Mean	Standard deviation
Forest zone	2	10	5.5	2.1
Transition zone	3	13	6.3	2.5
Sudan Savannah zone	3	16	7.4	3.2
Guinea Savannah zone	2	10	5.6	1.8
Total	2	16	6.3	2.6

ANOVA ($P = 0.001 < 0.05$)

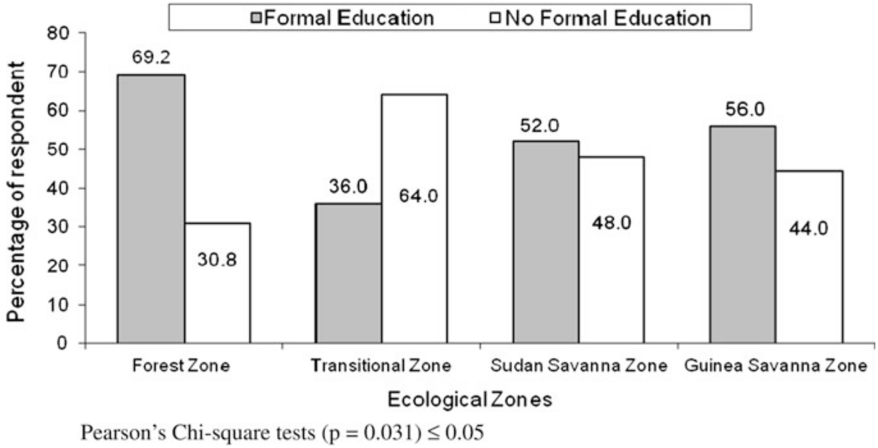

Fig. 27.1 Literacy levels for respondents in the four ecological zones. Pearson's Chi-square tests ($p = 0.031$) ≤ 0.05

Perception and Level of Awareness of Climate Change in Rural Ghana

The Intergovernmental Panel on Climate Change (IPCC) expects the increase in average temperatures in Africa to place severe pressures on forest ecosystems' ability to supply essential ecosystem services (Eastaugh et al. 2010). Such decline reduces the ability of forest-dependent people to meet their basic needs for food, clean water and other necessities. As a result, poverty may deepen, public health will deteriorate, and social conflicts will increase. The National Climate Change Adaptation Strategy (NCCAS) Report argues that education and awareness about climate change among governments, institutions and individuals are viewed as a necessary step in promoting adaptation to climate change. Therefore, determining perceptions and levels of awareness of climate change among forest-dependent rural communities is crucial.

From the study, nearly all respondents (89 %) acknowledged phenomenal changes in climate over the past 15 years. However, 11 % mentioned that climate

Table 27.3 Level of knowledge on climate change and variability

Ecological zones	Level of awareness of climate change			
	High level[1] (%)	Moderate level[2] (%)	Low level[3] (%)	Non-existent/ Superstitious[4] (%)
Forest zone	10.3	28.2	51.3	10.3
Transition zone	12.8	33.3	35.9	17.9
Sudan Savanna zone	7.7	55.8	26.9	9.6
Guinea Savanna zone	17.3	42.3	32.7	7.7
Total	12.1	41.2	35.7	11.0

Rank: 1 = High knowledge of basic climate change science; 2 = Moderate level of knowledge on climate change science; 3 = Only aware of phenomenal change in climate; 4 = Unable to explain basic climate change science (spiritual phenomena, no change at all)

has not really changed and that the changes are spiritual. To ascertain the basis of their perception, respondents' level of knowledge and how informed they were on basic climate change issues was assessed using a ranking method. The results showed low level of knowledge (35.7 %) on fundamental issues of climate change among respondents. The Forest Zone recorded the lowest level (51 %) while the Savannah zones scored fairly moderately to high (42–56 %), refer to Table 27.3.

The generally low level of respondents' knowledge on climate change shares sentiments with the British Broadcasting Corporation World Service Trust (2010). The report stated that many Ghanaians do not understand the science of climate change, although they have noticed changes in the weather and seasons. They tell of rising temperatures, extended periods of drought and increasing variability in seasonal rainfall. However, most people do not connect these with global climate change. Effects of climate change are observed and perceived by many in the form of drought, reduction and change in rainfall pattern, and reduced crop yield. It is very challenging for people to isolate broader consequences of environmental degradation and unsustainable natural resource management from those related to climate change. Opinion leaders allude to the need to raise awareness of climate change.

Reasons contributing to the low level of knowledge on climate change issues are as follows:

Climate change terminology is poorly understood and does not have standard translations into local languages;
Lack of information and technical expertise on climate change within the media sector;
Lack of comprehensive national climate change communication strategies to effectively inform the public.

Thus far, it is evident that public awareness and understanding of global climate change concepts is limited in Ghana. However, since the effects of climate change are already experienced by rural dwellers who are most vulnerable and often the

Table 27.4 Responses on the general impact of climate change in the four ecological zones

Climate change impact	Ecological zones				
	Forest zone (%)	Transition zone (%)	Guinea Savanna zone (%)	Sudan Savanna zone (%)	Total (%)
Drying of rivers and streams	43.6	56.4	50.0	59.6	52.8
Shift in crops' growing season	92.3	71.2	63.5	40.4	64.8
Reduction in crop yield	66.7	79.5	69.2	90.3	78.0
Extremely warm conditions	35.9	15.4	34.6	17.3	25.8
Decline in dependent forest resources	61.5	17.9	48.1	59.6	47.8
Frequent flooding	30.8	43.6	73.1	42.31	48.9

least informed, there is a need to provide more information and education about climate change and how best to respond effectively to the changes.

Impacts of Climate Change on Forest-Dependent Livelihoods in Rural Ghana

The areas mostly affected by climate change are: agricultural productivity, water resources and livelihoods. In Ghana, projected outcomes of climate change are likely to include more variable weather conditions and extended periods of drought, with potentially devastating implications for water and food security (Allison et al. 2009). Assessing potential climate change impacts is urgently needed for the survival of rural communities. For policy makers and climate change science experts, improved understanding of the risk they are facing is essential for the enhancement and development of local specific adaptation strategies. This section presents the impact of climate change on forest dependent livelihoods.

From the perspective of respondents, the most significant impact observed in all ecological zones is reduced crop yield (78 %). Shifts in cropping season (64.8 %) as a result of erratic rainfall and prolonged drought, impacted negatively on the primary livelihood (farming) of forest-dependent rural communities. Another significant impact as a result of prolonged drought and reduction in rainfall is the drying of rivers and streams (52.8 %). Almost half of respondents in every ecological zone described this impact as a major livelihood challenge. Gyau-Boakye (2001) mentioned that due to climate change effects, water bodies which in the past never dried up have recently been experiencing seasonal drying and water level decline. Other impacts mentioned include frequent flooding of farms (48.9 %) and a decline in forest resources (47.8 %). See Table 27.4.

Socio-Demographic Factors and Vulnerability to Climate Change

The United Nations Framework Convention on Climate Change (2007) identifies poverty, illiteracy, lack of technology and information among the many compounding factors that reduces Africa's ability to cope with impacts of climate change as. Ghana's dependence on climate-sensitive sectors such as agriculture and forestry, limited use of irrigation facilities and rural communities' low levels of literacy make it highly vulnerable to climate change. Therefore, identifying and assessing vulnerability levels and the factors influencing them are essential in developing effective adaption strategies and climate change resilient policies.

Although the complexity of natural and human systems has become a formidable barrier to quantifying climate change impacts and vulnerabilities, indicators such as socio-demographic factors were used in assessing vulnerability.

Using the TCR method, vulnerability levels of the rural communities were assessed in relation to six socio-demographic indicators. Below are the indicators and the underlying assumptions:

Household size (HH): Higher household size is associated with higher vulnerability.
Literacy level (LL): A lower literacy level is associated with higher vulnerability.
Level of Awareness/Access to Climate Change information (ACI): Lower access to climate change information is associated with high vulnerability.
Dependence on climate-sensitive primary occupation (DCO): Higher dependence on climate-sensitive occupations is associated with higher vulnerability.
Diversification of occupations (non-climate sensitive secondary occupation) (DO): A greater diversification of occupations is associated with lower vulnerability.
Dependency on forest resources (DFR): Higher dependency on forest resources as source of household income is associated with higher vulnerability.

Based on the six selected socio-economic indicators, the results revealed that the Transition Zone is most vulnerable among the four ecological zones, followed by the Sudan Savannah and Guinea Savannah, and the Forest Zone, which is the least vulnerable. The Transition Zone showed the highest mean household size (6.3 %), lowest literacy level (36.0 %), highest number of respondents (100 %) depending on rain-fed agriculture as their primary occupation, least number of respondents (15.4 %) engaged in a non-climate sensitive occupation, moderate access to climate change information (33.3 %), and fairly high dependency (46.2 %) on forest resources (Tables 27.5 and 27.6).

The high vulnerability status of the Transition and Sudan Savannah zones in Ghana is of little wonder since communities in these ecological zones depend highly on natural resources and primary occupations (farming) in order to obtain their livelihoods. In addition, there is less diversification of household income since the zone recorded the lowest percentage of respondents engaged in other non-climate sensitive occupations. Literature on livelihoods (Ellis 2000; Ellis and Mdoe 2003; Ellis and Allison 2004; Scoones 1998) suggests that low levels of

Table 27.5 A summary of measurable socio-economic indicators in the ecological zones

Ecological zones	HH (members)	LL (%)	DCO (%)	DO (%)	ACI (%)	DFR (%)
Forest	5.5	69.0	92.0	41.0	10.3	51.1
Transition	6.3	36.0	100.0	15.4	33.3	46.2
Sudan Savannah	7.4	52.0	94.0	48.1	59.6	48.1
Guinea Savannah	5.6	56.0	100	42.3	44.2	42.5

Household size (*HH*); literacy level (*LL*), dependence on climate sensitive primary occupation (*DCO*); diversification of occupation (*DO*); access to Climate Change Information (*AIC*); dependency on forest resource (*DFR*)

Table 27.6 Socio-economic vulnerability assessment of the four ecological zones

Ecological zones	Level of vulnerability							
	HH	LL	DCO	DO	ACI	DFR	Total score	Vulnerability
Forest	1	1	2	1	3	3	1.8	L
Transition	2	3	3	3	2	2	2.5	H
Sudan Savannah	3	2	2	2	1	3	2.2	M
Guinea Savannah	1	2	3	3	2	1	2	L

L Least vulnerable, *M* Moderately vulnerable, *H* Highly vulnerable

income and dependence on rain-fed agriculture are factors that create vulnerability to environmental stressors.

Rural Communities' Adaptation to Climate Change

Rural Ghana is highly vulnerable to climate change (Gyampoh et al. 2008). However, forest-dependent rural communities have found varied ways of coping with these changes, based on experience and traditional knowledge. The different coping measures described by the communities are presented in Table 27.7.

The most dominant form of adaptation engaged by rural communities is engagement in non-climate sensitive occupation (diversification of household income). The rest are: migration to peri-urban areas (34.6 %), increases in farm size (31.3 %), and crop diversification (30.2 %). Regarding peri-urban migration, Van der Geest and de Jeu (2008) mention environmental reasons for internal migration in north–west Ghana in a 2004 survey report. The situation is likely to get worse as the impact of climate change worsens. Sudan Savannah, Guinea Savannah and upper parts of the Transition zones constitute northern Ghana.

The adaptation strategies adopted by the communities are more reactive rather than anticipatory or planned. Ellis (2000), Smit et al. (2001), Barrett et al. (2001) and most climate change adaptation literature alludes to local-level adaptation as reactive. Furthermore, most of the coping activities are based on experience and observation whilst local knowledge is not explored. Also, some of the local coping

Table 27.7 Coping and adaptation measures in response to climate change effects

Coping measures	Ecological zones				
	Forest (%)	Transition (%)	Sudan Savannah (%)	Guinea Savannah (%)	Total
Irrigation (from dams and dug out wells)	12.8	17.9	34.6	61.5	28.0
Crops diversification	17.9	12.8	32.7	50.0	30.2
Increase fertilizer and manure application	25.6	53.8	23.1	13.5	26.9
Increase farm sizes	38.9	43.6	21.2	26.9	31.3
Alternative jobs engagement	41.0	15	48.1	42.3	37.9
Peri-urban migration	28.2	17.9	53.8	32.7	34.6

strategies adopted in response to observed risks and hazards, relate both to climate and non-climatic factors.

Nonetheless it was observed that the adaptation strategies adopted by rural communities' varied from zone to zone. For instance, the Sudan Savannah zone recorded peri-urban migration as the dominant adaptation strategy while Guinea Savannah recorded irrigation. Such variations in the adoption of climate change adaptation strategies strongly argue against a "one-size-fits-all" approach to developing and recommending adaptation strategies to vulnerable communities. For effective policy intervention, each ecological zone and local communities should be examined on its own merit.

Climate Change and Policy Implication

Policy responses to climate change impacts in Ghana are addressed to some degree in some policy statements and programs, though most are not explicit or specific in the context of climate change. However, it is important that they include direct perspectives on climate change.

Below are some examples of programmes and policies addressing both directly and indirectly the subject of climate change:

- Formulation of National Climate Change policy
- Establishment of National Steering Committee on Climate Change
- Programmes introduced towards the objectives of UNFCCC, CBD, etc.
- National Biodiversity Strategies and Action Plans
- Ghana Poverty Reduction Strategy.

Recommendations

Climate Change Awareness and Communication

Climate change awareness and knowledge was generally low in rural communities in all ecological zones. Climate change education and awareness in rural Ghana is necessary in promoting adaptation to climate change. Local people's difficulty in differentiating effects of climate change from general environmental degradation underscores the need to develop local terminologies for climate change concepts. This will help to effectively explain to rural communities with low levels of formal education the concepts, effects and impact of climate change. A national communication strategy could target schools with a curriculum explaining climate change concepts, risks and options for mitigation and adaptation. The agriculture extension service may serve as agents of climate change and adaptation information dissemination.

Reducing Climate Change Vulnerability

The vulnerability assessment indicated that socio-economic characteristics such as education, climate-sensitive livelihoods, household size, dependence on forest resources, access to climate change information and diversification of household income influence the level of vulnerability. Thus, investment in education systems, creation of non-climate sensitive employment opportunities in rural Ghana may be policy targets for reducing vulnerability.

Climate Change Adaptation

To strengthen rural communities' adaptive capacity, there should be an integrating of climate change in planning and budgeting at all levels of decision-making. Instead of recommending a panacea for all situations, planned adaptation mechanisms should consider local reality, and reflect communities' priority strategies so as to help them adapt to current and future changes. Location-specific adaptation strategies could be included in district development plans and implemented under the guidance of local authorities. More research is needed to determine the continuous non-linear qualities and robustness of rural communities' adaptation strategies.

The varying adaptation strategies engaged by various communities in the four ecological zones should lead policymakers and climate change researchers away from "one-size-fits-all" approach in developing and recommending adaptation strategies to vulnerable communities. For effective policy intervention, each ecological zone and local community should be examined on its own merits.

Conclusion

This study has investigated the impact of climate change at household level in forest-dependent communities as well as adaptation strategies and socio-economic vulnerabilities of such communities in four ecological zones in Ghana.

Reduced crop yield and livelihood capacity are the most strongly felt impacts of climate change. Rural communities in the Transition Zone are the most vulnerable. This zone is characterised by a large, mainly rural population with a lower diversification of income sources, large household size, high illiteracy rate and high dependence on rain-fed agriculture and forest resources. To reduce climate change vulnerability, critical issues such as illiteracy, non-climate sensitive livelihoods, sustainable agricultural practices and sustainable forest resource management should be the focus of climate change resilient policy.

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Author Biographies

William Kwadwo Dumenu is a research scientist currently working with the CSIR-Forestry Research Institute of Ghana. He holds an MSc degree in Forest Ecology and Management. His specialism is forest governance and policy, and climate change.

Elizabeth Asantewaa Obeng holds an MSc degree in Sustainable Resource Management from the Technical University of Munich, Germany. She specialises in environmental and natural resource economics and forest ecosystem management.

Sparkler Brefo Samar is a social research scientist working with the CSIR-Forestry Research Institute of Ghana. He holds an MSc degree in Economics and Rural Development. He specialises in forest products and marketing, and rural development.

Ebenezer Owusu-Sekyere holds a PhD in Agroforestry and currently works with the CSIR-Forestry Research Institute of Ghana. He specialises in agroforestry and forest soil science.

Emmanuel Asiedu-Opoku is forest statistics technician working with the CSIR-Forestry Research Institute of Ghana. He holds a Higher National Diploma certificate in Statistics. He specialises in social forestry research.

Part III
Category 3

Chapter 28
An Outline for Funding Adaptation and Disaster Management Schemes

Dr. Jan Kunnas

Abstract This paper develops further a proposal to split continued climate negotiations into two separate blocks. The first block deals with historical emissions of greenhouse gases, including a mutual debt cancellation: the accumulated carbon debts of developed countries up to a cut-off year would be swapped for conventional monetary debts of developing countries. The second block deals with future emissions and how to finance adaption to climate change. Following the "polluter pays" principle, the funds should be collected in proportion to the responsibility for climate change and redistributed in proportion to the needs for adaption and management of climate-related risks. A system based on separate blocks ensures large flexibility. For example, the system of fund collection after the cut-off point could be taken from Oliver Tickell's "Kyoto2"proposal, which puts forward a system for levying climate funds via fossil-fuel production permits. Peter Illig again provides a reminder of the important concepts of direct access, intended to establish a clearly defined and transparent system for delivering financial resources as close to the targeted impact as possible, and also highlighting the distinction between compensation and development aid. Finally, some incentives to join the proposed scheme are suggested.

Keywords Adaptation · Carbon debt · Climate change · Debt swap · Disaster management · Fairness · International climate negotiations

Dr. J. Kunnas (✉)
Department of Biological and Environmental Science, Sustainable Bioenergy Group, University of Jyvaskyla, Box 35 40014 Jyvaskyla, Finland
e-mail: jan.kunnas@eui.eu

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Introduction

The goal of this paper is to develop an outline for continued climate negotiations that are in accordance with the principle of climate justice, settling the injustice that those who contribute the least to climate change are the ones to suffer the most from its effects. It develops further a proposal to split continued climate negotiations into two separate blocks, and examines how it fits together with other similar proposals (Kunnas 2011). The first block deals with historical emissions of greenhouse gases, including a mutual debt cancellation: the accumulated carbon debts of developed countries up to a cut-off year would be swapped for conventional monetary debts of developing countries. The second block deals with future emissions and how to finance adaption and management of climate change related risks.

Historical Emissions

Developing countries are justifiably complaining that the main reason for climate-warming so far has been the historical greenhouse gas emissions of developed countries. Settling this *carbon debt* takes away the excuse for developing countries not to participate in a climate treaty.

The estimates of the size of this carbon debt vary greatly. Andrew Simms et al. (1999) calculated how much of the G7 countries gross domestic product is produced through the use of fossil fuels in excess of an equitable global per-capita allotment of carbon emissions. According to this calculation, G7 countries were already running up carbon debts of around USD 13 trillion each year in the late 1990s. A more modest estimate is presented by Vinod Raina (2002). Attaching a price tag of between ten and twenty US Dollars for each tonne of excess emissions, he ended up with a yearly carbon debt for the G7 countries of between USD 15 and 30 billion a year, and for all Northern hemisphere industrial countries of between USD 30 and 60 billion. Olivier Ragueneau (2009) again estimated that the carbon debt of industrialised countries accumulated since the beginning of the fossil fuel driven industrial revolution equals the total external debt of developing countries (USD 2,860 billion vs. USD 2,850 billion).

It can of course be argued that developed countries have no moral responsibility for greenhouse gases emitted before climate change was considered a problem (Vanderheiden 2008). However, in this case one stumbles into the question of the appropriate cut-off date. Swedish chemist Svante Arrhenius is often mentioned as the first to have warned about global warming as a consequence of increased atmospheric concentration of carbon dioxide. Arrhenius (1896) calculated that a doubling of CO_2 in the atmosphere increases global surface temperature by an average of five to six degrees Celsius. However, he did not consider this a problem. On the contrary, Arrhenius (1908) looked forward to better climates and abundant crops for the benefit of a rapidly propagating huamn race. So this could hardly be the appropriate cut-off point.

The first to warn that a warming climate could be something to worry about was the Canadian physicist Gilbert Plass (1956a, b). In a series of articles published in 1956, he estimated that if the carbon dioxide content of the atmosphere doubles, the surface temperature will rise by 3.6 °C. Contrary to his predecessors, Plass (1956c) regarded this as a problem, arguing that: "…the temperature from this cause may be so large in several centuries that it will present a serious problem to future generations." The following year, Roger Revelle and Hans E. Suess (1957) hardened the tone of the warning, stating that the present rate of combustion of fossil fuels presents "…a large scale geophysical experiment of a kind that could not have happened in the past nor be reproduced in the future." The first measured evidence for rising levels of carbon dioxide was again the so called "Keeling Curve" in 1960. Thus, one could argue that the turn of 1960s is the appropriate cut-off point.

Another possible cut-off point could be 1979, when the first World Climate Conference appealed to the nations of the world "…to foresee and to prevent potential man-made changes in climate that might be adverse to the well-being of humanity." Yet another could be 1990, when the Intergovernmental Panel on Climate Change stated in its First Assessment Report that the threat of climate change was real, and that a global treaty was needed to deal with it (IPCC 2004). Steve Vanderheiden (2008, p. 190), for example, proposes the latter as the most defensible starting point, arguing that: "By then, most national governments were fully aware of the likely effects of various kinds of human activity on global climate and could have initiated emission abatement programmes…"

But can ignorance be a defensible reason for the lack of moral responsibility? Modifying the "polluter pays" principle, Henry Shue (1999, p. 535) claims: "If whoever makes a mess receives the benefits and does not pay the costs, not only does he have no incentive to avoid making as many messes as he likes, but he is also unfair to whoever does pay the costs."

In a recent working paper Richard Tol (2011), however, argues that: "Most rich and most poor countries benefitted from climate change until 1980, but after that the trend is negative for poor countries and positive for rich countries." But this does not remove moral responsibility for pre-1980 emissions. David Archer (2005) suggests 300 years and a 25 % rate that lasts forever, as the best approximation for the lifetime of fossil-fuel CO_2. Oceans have absorbed about half of total anthropogenic carbon dioxide emissions (Sabine et al. 2004), but not without cost: when carbon dioxide dissolves in seawater, it forms a weak acid called carbonic acid. Because of this chemical process, the average pH of the oceans has decreased by 0.1 unit from pre-industrial levels, and an exponential decrease of nearly 0.8 pH unit is forecasted by 2300. This could have major effects on calcifying marine biota, such as calcareous plankton and coral reef communities (Royal Society 2005; Caldeira and Wickett 2003; Orr et al. 2005). It also means that the buffer for future emissions has been used up. Thus eventual repayments can be considered as payments for using up the buffer.

To avoid taking moral standpoints, one could also consider developed countries' use of fossil fuels in excess of an equitable global per-capita allotment of carbon emissions as a conventional loan that has financed the carbon-led growth of developed countries since the Industrial Revolution. If developed countries default on this loan, why should developing countries have any responsibility for paying their loans either? Alternatively, it can be interpreted as a rent for the buffer for future emissions that has been used up.

This mutual indebtedness—developed countries' carbon debts versus developing countries' conventional monetary debts, or unpaid rents for the buffer—provides an opportunity to settle the scores, and start on a clean slate. Considering this mutual debt, developing countries joining a global climate treaty should get their debt cancelled. As a bonus, cancelling the debts restores the crumbling banking system by cleaning the assets from unserviceable loans.

A Fair Emissions Quota

Mutual debt annulations clean the slate for negotiations on how to cope with future emissions. This block can again be split into two separate blocks. In the first block, a sustainable emissions level and a fair distribution have to be defined; in the second block, what to do with emissions above this level needs to be defined. A sustainable emissions level can be defined as an emissions level that does not cause any further climate warming. The author leaves it to climate scientists to define the exact level, as the purpose of this article is only to provide a suggestion for a general framework for continuing climate negotiations.

Intuitively it sounds clear that the sustainable emissions level has to be divided equally among all groups. Following a Rawlsian approach, it could perhaps be argued that a different division is to the greatest benefit of the least advantaged (Rawls 1971; Kunnas 2009). However, the current situation, whereby developed countries are emitting greenhouse gases on a per-capita level manifoldly greater than those from developing countries, without paying any kind of compensation for this overdraft, can hardly be supported even from a Rawlsian viewpoint.

An overdraft, at least for a transition period, could perhaps be justifiable if countries emitting more than their fair quota were to pay for their excess emissions. By selling emission quotas to countries needing additional quotas, countries emitting greenhouse gases below their quota of the sustainable emissions could raise money to finance vital investments in human capital and infrastructure, such as schooling, healthcare or clean water. Simultaneously, their capacity for disaster management would be strengthened. The possibility for collecting funds, does, however, not take away the need and responsibility for developed countries to pay for future damage caused by of climate change. One way of collecting funds for these repayments is explained below.

Towards a Sustainable Emissions Level

The last block, dealing with emissions above the sustainable level, is started by deciding an emissions path from present emissions levels to the sustainable level. The gentler the slope, the longer it takes to reach the sustainable level and the more additional warming the planet is committed to.

The projected distribution of the economic impacts of climate change is such that the disparity in well-being between developed countries and developing countries is increased, with disparity growing for higher projected temperature increases. The highest human costs will be borne by the poorest of the poor, as they have less capacity to adapt and are more vulnerable to climate change damage (IPCC 2007). Inequities related to climate change impacts and adaption are, however, not exclusive to developing countries (O'Brien and Leichenko 2010). Even in regions with higher adaptive capacity, such as North America, Australia, New Zealand and the Nordic Countries, there are vulnerable communities, including indigenous peoples (Arctic Climate Assessment 2007).

Thus, the design of an emissions path towards sustainable emissions must be accompanied by a system to collect funds for adapting to the adverse impacts of climate change and manageing inevitable climate-related risks. Following the "polluter pays" principle the funds should be collected in proportion to the responsibility forclimate change and redistributed in proportion to the needs for adaption and disaster management. The total amount of funds needed depends on the additional warming and adaption costs the chosen emissions path leads to. The payment for each unit of greenhouse gases emitted can be calculated by dividing the best available estimate of the total adaption and management fund required by the total emissions above the sustainable level under the chosen emissions path since the cut-off point for moral responsibility for greenhouse gas emissions discussed above.

Countries considering their payments to the fund to be too large can then unilaterally strive for a deeper and faster emissions reduction path decreasing both total global emissions and their share of them, and thus also their level of payment.

The effectiveness of the system is enhanced if the funds collected for adaptation and management needs in the long run are invested in the development of climate-friendly energy technology in the short term. By making new energy technology available, emissions goals are made cheaper, lowering the threshold for lower emissions targets.

Development of new technology should be accompanied by technology transfer to developing countries. This transfer should not be only "high-tech". Finland, for example, sustained "energy and carbonless" growth through the nineteenth century thanks to technologies like improved heating and cultivation methods not requiring burning, which can be considered quite primitive from a present-day perspective (Kunnas and Myllyntaus 2009). A broader vision of appropriate technology would also benefit energy security in developing countries. Following the demands of climate justice this means the development of clean, renewable, locally controlled and low-impact energy resources that enhance the right of all people, including the poor, women, rural and indigenous peoples, to have access to affordable and sustainable energy (Bali Principles of Climate Justice 2002). There is no need for confrontations in the development of, for example, improved stoves, carbon-free electricity or improved energy efficiency in industry (Rowlands 2011).

Interchangeable and Additional Building Blocks

An advantage of a scheme like this, based on separate building blocks, is that some parts can be replaced with other blocks. For example, the system of fund collection after the cut-off point could be replaced with Oliver Tickell's (2008) proposal of a system for levying climate funds via fossil-fuel production permits. His proposal starts by applying a global emissions cap—in the proposal presented above, the cap is set only by individual countries' willingness to pay for additional damage. In Tickell's proposal, permits to produce CO_2 or other greenhouse gases are sold up to the cap by global auction, using a Uniform Price Sealed Bid system subject to reserve and ceiling prices. The funds thus raised—projected to be around USD one trillion per year—are, again, invested in solving the problems of climate change with an emphasis on the needs of poor countries, poor people and those most adversely affected. His proposal also includes an emergency relief fund and investments in the development of new energy technology.

Furthermore, a fair system for the distribution of the funds is needed. While designing this system it is important to incorporate the views of the poor who are disproportionately impacted by climate change. Peter Illig (2010) raises two important concepts for this discussion:

- Direct access, intended to establish a clearly defined and transparent system for delivering financial resources as close to the targeted impact as possible;
- Highlighting the distinction between compensation and development aid, meaning that any new funding allocated forresponses to climate change should come "in addition" to existing commitments for normal development aid.

Direct access is an important precondition for vulnerable groups to be able to take full ownership of, and responsibility for, their stock of risk and the consequences of unmanaged risk. Without owning their risks they remain effectively in denial, while experiencing unexpected disasters for which they are unprepared and unable to manage (compare to UNISDR 2011). The engagement of poor and vulnerable groups as active participants and not as victims or clients empowers them to be part of disaster risk reduction, and taps into local knowledge to help lead risk reduction efforts, recovery and reconstruction (Global Platform for Disaster Risk Reduction 2011).

Incentives to Join the Proposed Scheme

For developing countries with a debt overhang the prospect of getting their debt cancelled is a clear incentive to join the scheme. For countries on the paying side, either in the form of cancellation of monetary debts or financing adaptation to climate change, there are no such clear incentives. Although the cancellation of developing countries' debts comes in exchange for the carbon debts of the developed countries, there is, realistically, no way for the developing countries to force repayment.

Besides encouraging them to behave altruistically, can any incentives be found to encourage developed countries to join the scheme? One such incentive has already been mentioned above: cancelling debts restores the crumbling banking system by cleaning assets from unserviceable loans. It also improves the transparency of the banks by cleaning balance sheets of unrealistic and non-recoverable claims. Tying forthcoming bank-bailouts to debt cancellations would minimise free-riding and lower the costs of debt cancellation.

Another incentive is suggested by Dirk T.G. Rübbelke (2011), namely strategic confidence-building through improving fairness: "The basic idea is that industrialised countries' support of adaptation in developing countries might induce developing countries to feel treated more fairly and this in turn might have a positive impact on their willingness to contribute to international mitigation efforts." He distinguishes between:

- Fairness perception based on observations in the course of international environmental negotiations/policy and
- Fairness perception based on past experiences.

The suggested structure for future negotiations presented in this paper would enhance both perceptions of fairness:

- The failure in Copenhagen shows the danger of having a prearranged draft made by just a few powerful people. What is laid out here is therefore only a rough structure for future negotiations. It has separate, though interlinked, building blocks, which can easily be changed to incorporate other suggestions.
- The debt swap outlined at the very beginning can be seen as a correction for perceptions of unfairness in the past, while the adaption and disaster management fund strives for a fair future.

Conclusions

This paper has argued that splitting continued climate negotiations into two separate blocks saves time and makes it easier to agree on an a comprehensive climate treaty. The first block deals with historical emissions, including a mutual debt cancellation, the second with future emissions and how to finance adaption to climate change.

Considering the mutual indebtedness—developed countries' carbon debts versus developing countries' conventional monetary debts—developing countries joining a global climate treaty should get their external debts cancelled. Such debt settlement would be a strong motivation for developing countries to join a climate treaty; it would also take away their strongest excuse for not participating in a climate treaty—their perfectly justified appeal that the main reason for the present climate change is the historical greenhouse gas emissions of developed countries. Such strategic confidence-building through improving fairness would have a positive impact on developing countries' willingness to contribute to international mitigation efforts, and constitute a persuasive reason for developed countries to join the scheme.

Mutual debt annulations clean the slate for negotiations about the fair distribution of a sustainable emission level that would not cause any further warming of the climate. Countries emitting greenhouse gases below this level could sell these savings to gather funds to provide schooling, healthcare and other development aspects.

Finally, we need an agreement on an emissions path from present emissions levels to a sustainable level. The gentler the slope, the more additional warming we commit the planet to. The highest human costs of this will be borne by the poorest poor, as they have less capacity to adapt and are more vulnerable to climate change. Thus, we need a system to collect funds for adaption to the adverse impacts of climate change and management of inevitable climate-related risks. The funds should be collected in proportion to responsibility climate change and redistributed in proportion to need for adaption and disaster management.

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Author Biography

Dr. Jan Kunnas holds a Ph.D. in History and Civilisation from the European University Institute in Florence, Italy. He has done extensive research on Finland's transition from a solar-based energy system to a fossil fuel based one, and the environmental consequences of this transition. As a project researcher for the Sustainable Bioenergy Group at the University of Jyväskylä, he is focusing on the possibilities to reverse this trend.

Chapter 29
How Effective is Small Dam Flood Safety Accountability and Assurance Policy in Vietnam?

Tuyet Thi Dam, Roger L. Burritt and John D. Pisaniello

Abstract This paper examines the effectiveness of small dam safety accountability, responsibility and assurance policy practices in Vietnam. Vietnam is of interest because of the catastrophic consequences of an increasing number of dam failures in recent years associated to floods. Yet the solutions necessary to minimise dam failure in Vietnamese floods remain unexplored. The effectiveness of the Vietnamese small dam safety accountability, responsibility and assurance policy practices was tested in three stages. First, international benchmarks were established based on available literature for comparison with the case study in Vietnam. Second, ten on-site dam surveys were undertaken in Tan Moc commune to explore prevalent dam safety problems. Third, fifteen semi-structured interviews were conducted with five key stakeholder groups to examine perceptions of the effectiveness of the current policy and associated practices. The surveys demonstrated that all ten dams surveyed were rated "High" hazard and were at high risk of failure because of physical and management inadequacies. Interview evidence confirmed floods were the dominant cause of dam safety deficiencies and dam failures. In addition, accountability and responsibility for dam safety was poorly implemented, giving low levels of assurance to communities. The comparison showed that Vietnam not only failed to satisfy international benchmarks but also performed far below the minimum level. This research provides an original contribution towards assessing the status of small dam safety management and assurance policy in developing countries such as Vietnam.

T. T. Dam (✉) · R. L. Burritt · J. D. Pisaniello
University of South Australia, Centre for Accounting, Governance and Sustainability, Way Lee Building, City West Campus, North Terrace, Adelaide 5000, South Australia
e-mail: damtt001@mymail.unisa.edu.au

R. L. Burritt
e-mail: roger.burritt@unisa.edu.au

J. D. Pisaniello
e-mail: john.pisaniello@unisa.edu.au

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Introduction

Flooding following dam failure continues to be a major reason for critiques of dam development. Dam critics and proponents emphasise that every dam has the potential to fail and the resulting floods can cause substantial damages for downstream areas (Clarke 2007; AGD 2009). Dam failures are seen to be potentially as destructive as earthquakes, hurricanes, air crashes, fires and explosions (Smith 1989; DSE 2007) because subsequent devastating floods cause great harm to life and human health as well as adverse social, economic and environmental impacts (WCD 2000; UNEP 2004, 2006; He et al. 2008; WB 2008; AGD 2009).

Many notable dam failures have occurred throughout the world. For example, the Shimantan and Banquia dams failed in 1975 in Henan province in central China because of the cumulative failure of 60 small dams in the upstream catchment area. Around 230,000 people were killed, more than 1 million hectares of land were inundated and over 100 km of the Beijing-Guangzhou railway line damaged in this disastrous cumulative dam failure (Fu and Qing 1998; Fuggle and Smith 2000). In 1993, more than 1,200 lives were lost as the Gouhou dam failed in Qinghai Province (Fuggle and Smith 2000). He et al. (2008) provide an extensive review of failure consequences from 1954 to 2003 in the three highest failure rate countries, namely China, Spain and the US. In general, a wide range of dam failure disasters have occurred and have caused numerous fatalities and considerable economic losses. For example, 3,481 dam failures happened in China over the 50-year period examined; 30,000 people were killed, 5 million houses destroyed and 1 million hectares of farmland inundated (He et al. 2008). Within Europe, the failure of the Maupassant dam in southern France in 1959 claimed over 450 lives (Smith 1989). In addition, the Stava tailings dam failure in Italy in 1985 killed 268 people, destroyed 62 buildings and caused serious environmental damage (Chandler and Tosatti 1995). The safety of dams is of global concern. Hence, there is a need for research into the accountability and assurance policy for dam failure flooding in the context of dam safety management.

This paper focuses on dam failure and safety policy in the developing country of Vietnam. Vietnam is of interest because of the catastrophic consequences of an increasing number of dam failures in recent years associated with floods (Nguyen 2003; Nguyen 2009; Nguyen 2010; ThanhNien-News 2010). In addition, Vietnam has one of the largest dam systems in the world along with China and the US (Dao et al. 2000). The dam network comprises over 750 medium and large dams and thousands of small dams (Silver 1999; Dao et al. 2000; WB 2004). Floods rank highest among catastrophic disasters affecting Vietnam. A large percentage of the Vietnamese population is at high risk from dam failure flooding (Silver 1999).

At present, Vietnam has no national record of either small dams or their problems. There has been no systematic collection of data on dam failures and there have been no specific approaches to determine associated impacts or economic losses from failure (Nguyen 2007). Ad hoc evidence suggests that many dam safety problems and notable dam failures have occurred in various provinces in Vietnam but have often been unreported (Nguyen 2003). These failures have taken hundreds of lives and have caused devastating impacts on property and the environment (Silver 1999; Nguyen 2007). For example, the 2,000 ML reservoir of Nha Tro dam failed in Nghe a province in 1978, causing the death of 27 people, damaging thousands of hectares of rice fields. In 1986, the overtopping failure of Dau Tieng dam damaged 3,452 hectares of mature rice (ready for harvesting), 1,144 hectares of early rice (not ready for harvesting), 1,197 hectares of farming products and 871 hectares of fruit, flooded 3,114 houses and damaged 47 houses. The failure of the 500 ML Buon Bong dam storage killed more than 30 people and caused thousands of dollars of damage. In 2002, Am Chua dam in Khanh Hoa failed but no records of damages and losses were available (Silver 1999; Nguyen 2003, 2007). In 2009, the 250 ML reservoir of Z20 dam failed and about 200 m of railway embankment was destroyed. A number of trains from the North to the Central and the South were cancelled (Nguyen 2010). If systematic evidence can be gathered about the problems associated with small dam safety policy and factors contributing to current dam safety, then deficiencies including dam failures, lives, property and the environment could be better served.

Hence, this paper addresses the primary research question: *How effective are small dam flood safety accountability, responsibility and assurance policy practices in Vietnam?* To address this question, answers to the following four research sub-questions are needed:

1. What benchmarks are available to assess the effectiveness of dam safety management policy in Vietnam?
2. What are the physical problems associated with small dam safety in Vietnam?
3. What are the factors contributing to small dam safety problems identified in Vietnam?
4. How do Vietnamese dam flood safety accountability, responsibility and assurance policy practices compare with available international benchmarks?

It is to these four questions that the paper will now turn, first to describe the research methods used. The paper then reviews available literature on international dam safety assurance benchmarks. Evidence gathered from surveys and interviews is also presented, followed by comparison with identified Vietnamese dam safety practices in relation to established international benchmarks. The paper then concludes with comments and recommendations for future research.

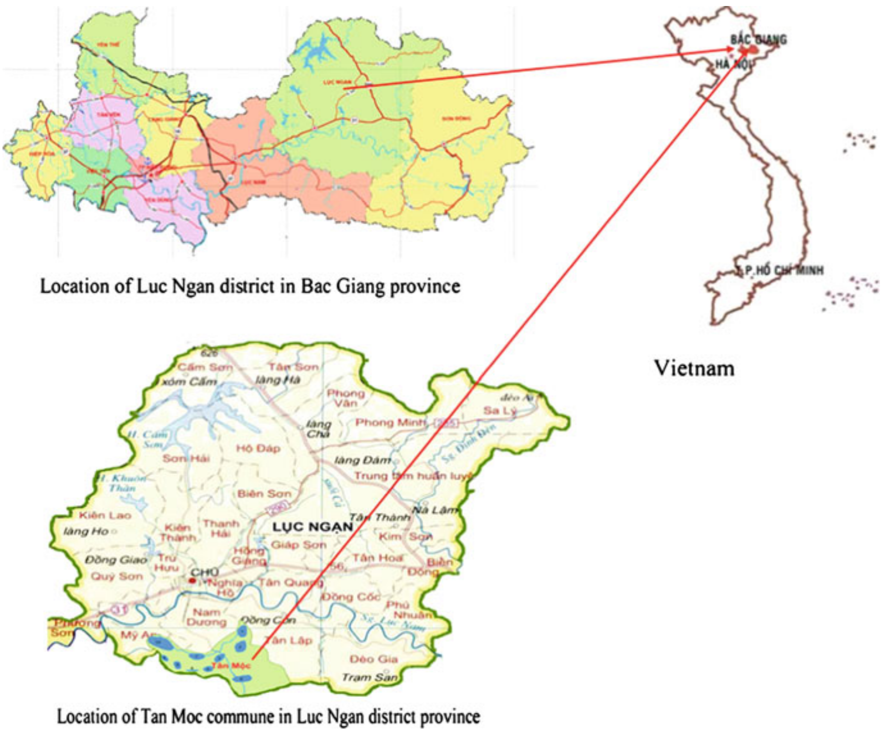

Fig. 29.1 The study sites and their locations in Vietnam

Research Methods

A brief discussion follows of the area in Vietnam chosen for study citing reasons for the choice, and the three-stage method used for triangulation of the results: literature review, on-site surveys, and semi-structured interviews.

Study Area

The study area selected in Vietnam to underpin the research is Luc Ngan district, Bac Giang province about 50 km from the capital city of Vietnam, Hanoi. Luc Ngan district is located between 21° 15′–21° 35′ N and 106° 33′–106° 52′ E in the northeast of Bac Giang province in Vietnam (DWIM, 2006). The district covers an area of 1,012.2 km^2 and its population in 2004 was 196,516 (Fig. 29.1).

The reason for selecting Bac Giang province as an overall indicative case study area for analysis is that Bac Giang is one of the Vietnamese provinces with a large number of, mostly small, dams (DWIM 2006, 2009; MARD 2009). Available data show that dam failures occur every year and have caused severe property and

Table 29.1 Historical dam failures in Luc Ngan district, Bac Giang province, Vietnam

Dam failure	Commune	Year of failure	Cost of dam repair Vietnamese Dong (1000 VND)	Equivalent US dollar[a] (USD)
Non khuat	Hong Giang	2008	5,000,000	312,500
Ran	Tan Moc	2008	400,000	25,000
Ia	Tan Moc	2008	200,000	12,500
Chao	Giap Son	2008	5,000,000	312,500
Da Mai	Giap Son	2008	600,000	37,500
Bau	Giap Son	2008	700,000	43,750
Hoa Quang	Nam Duong	2008	6,000,000	375,000
Deo Gia	Deo Gia	2008	3,000,000	187,500
Bien Dau	Bien Dau	2008	300,000	18,750

[a] *Note* In 2008, I USD = 16,000 VND on average over the entire year

environmental damage in the province (Nguyen et al. 2009; Tran 2009; Nguyen 2010). "Luc Ngan's topography is hilly and steep with an average height ranging from 400–600 m" (DWIM 2006, p. 3). The topography is divided by many hills and rivers thereby creating a number of deep valleys where many reservoirs and dams are located (DARD 2004). This steep topography exacerbates probability and severity of dam failures to the local community who live and are accommodated in immediate downstream areas. Some recent historical dam failures in the research area and their costs of repair are listed in Table 29.1.

Research Design, Data Collection and Analysis Methods

The research was designed in the three following stages:

Stage 1

A literature review was undertaken of international dam safety benchmarking so that benchmarks could be established for comparison with the set of dams examined and associated dam safety accountability, responsibility and assurance policy practices identified in Vietnam from the following two stages.

Stage 2

An embedded case study was conducted containing ten on-site surveys, which were conducted on purposively selected dams in Tan Moc commune, Luc Ngan

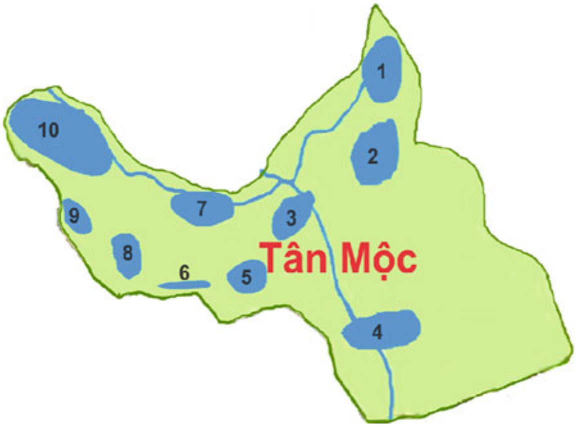

Fig. 29.2 Ten sample dams that were conducted in on-site surveys

district, Bac Giang province—Vietnam (Fig. 29.2). All dams selected for on-site surveys in the fieldwork had to satisfy the following two criteria: (1) dams of less than 15 m in height and with a storage capacity of less than 3000 ML (small dams) (Government of Vietnam 2007); (2) "Significant" or "High" hazard dams based on an initial assessment of the dam size, living activities and economic development in the downstream inundation area (ANCOLD 1994, 2003). The dam surveys were undertaken continuously from 28 September to 2 October 2010.

An extensive set of photos were taken and stored separately for each individual dam. In addition, on-site survey assessment of each dam was written on a dam inspection checklist developed from two publications: (1) "Your dam—your responsibility: A guide to managing the safety of farm dams" by the Victorian Government Department of Sustainability and Environment (DSE 2007); and (2) "Dam safety guidelines: inspection and maintenance of dams" by the Water Management Branch, Ministry of Environment, Lands and Parks, British Columbia (MELP 1998). The two publications are dam safety management guidelines in line with international acceptable practices for small earthen dam review and inspection (Pisaniello and McKay 2006; Pisaniello 2010a, b). All photos taken in the on-site dam surveys were analysed using the photo-interpretation method to assess objects or semiotics (Slater 1998; Demeritt 2001; Rose 2001; Brewer et al. 2005).

Stage 3

Fifteen qualitative semi-structured interviews were conducted within five key stakeholder groups. Stakeholder interviews were conducted face-to-face from 10 September 2010 to 21 October 2010. The stakeholders were asked questions in relation to Research Sub-Questions 2 and 3 above. The interviews involved three stakeholders in each group including:

Group 1: Policy regulators, members of Water Resources Administration, Ministry of Agriculture and Rural Development or members of Vietnamese government's policy and laws Board on dam safety management.
Group 2: Researchers and consultants who specialise in dam safety management.
Group 3: Local authorities, members of Bac Giang province's Water Infrastructure Management Department, Luc Ngan district's Department of Agricultural and Rural Development and Tan Moc commune people's committee.
Group 4: Local dam managers who are managing dams in Tan Moc commune.
Group 5: Members of the local community who are living close to dams and bearing the dam safety threats in Tan Moc commune.

The constant comparative method (Glaser 1965; Tesch 1990; Sivesind 1999; Boeije 2002; Carter 2010; Hammersley 2010) was used for interview data analysis. Comparison of interview data was constantly used as data was coded and analysed. Answers by each interviewee were scrutinised and compared to evaluate consistency as well as conflicts in their conversations. In addition, answers to each question were scrutinised and compared across interview participants to identify similarities and differences among different stakeholders.

Hence, these three stages provided triangulation of data to enhance the validity of conclusions reached in the context of the small number of dams examined and interviews conducted in Vietnam.

Results

Establishing International Dam Safety Policy Benchmarks

Assessment of the effectiveness of policy requires that benchmarks of best practices be established against which to compare practice in Vietnam. Hence, Research Sub-Question 1 asks *"What benchmarks are available to assess the effectiveness of dam safety management policy in Vietnam?"* As indicated below, considerable prior work has been undertaken on the matter of deriving international benchmarks. International dam safety policy benchmarks are established based on comprehensive review and comparative assessment of dam safety management accountability, responsibility and assurance practices in a large number of countries (Pisaniello 1997; Pisaniello and McKay, 2003; Pisaniello and Burritt, 2010; Pisaniello 2010a; Pisaniello et al. 2011; Tingey-Holyoak et al. 2011). Three benchmarking models ranging from 'minimum practice' to 'best practice' have been developed for providing increased dam safety accountability and assurance to the public (see Pisaniello et al. 2011, Tingey-Holyoak et al. 2011 for greater details). The essential elements of each model are presented in Table 29.2.

A particular element common to all three models that is important to consider is classification of dams in relation to the failure risks and hazards which they pose. Such classification at the "micro" dam safety management level implicitly

Table 29.2 International benchmarking models in dam safety management

Type of model	Key elements
'Best practice'	1. Legislative purposiveness 2. Administrative enforcement 3. Registration and classification of dams 4. Surveillance, inspection and safety reviews 5. Community education and preparedness 6. Owner responsibility with information 7. Punitive enforcement 8. Owner education and guidance 9. National/federal involvement
'Average practice'	1. Legislative purposiveness 2. Registration and classification of dams 3. Community education and preparedness 4. Owner education and guidance
'Minimum practice'	1. Registration and classification of dams 2. Community education and preparedness 3. Owner education and guidance

Sources Ada ted from Pisaniello et al. (2011); Tingey-Holyoak et al. (2011)

involves justifying the costs to dam owners/managers of properly constructing and maintaining dams against the risk of dam failure and all the associated potential failure consequences via a risk based approach, e.g. via dam hazard classification or rating (Pisaniello 1997; Pisaniello and McKay 1998; Pisaniello et al. 2011).That is to say, whilst the direct benefits that different classes of dams provide to humans can be significant, for example, community water supply, farming irrigation, flood mitigation, etc. (Pisaniello et al. 2011), these alone may not always justify the high costs to dam owners/managers of constructing and maintaining dams properly to ensure dam safety. But international benchmark practice requires that such costs always be justified against the benefits of minimising failure risk and avoiding all the potentially high cost failure consequences, which includes loss of life, damage to downstream property and environment and the loss of the dam asset itself and its direct benefits. International benchmarks require such dam safety risk based assessment be applied to various elements, such as those shown in Table 29.2. For example, under the best practice model every dam needs to be given a hazard rating (element 3) so that stronger surveillance, reporting, maintenance and safety standards can be imposed upon more hazardous dams under element 4 (Pisaniello 1997; Pisaniello and McKay 1998, 2003). Similarly under the minimum practice model dams need to be hazard rated (element 1) so that stronger community education and preparedness plans (element 2) can be imposed on dams with higher hazard (Pisaniello et al. 2011; Tingey-Holyoak et al. 2011). The process of assigning dam hazard rating requires assessing all the potential consequences and costs of dam failure, which most importantly includes valuing the lives of downstream communities (Pisaniello et al. 2011; Tingey-Holyoak et al. 2011).

In this paper, international benchmarks established are used as criteria for assessing the adequacy and appropriateness of the Vietnamese dam flood safety accountability, responsibility and assurance policy practices identified in the area examined.

Physical Small Dam Safety Problems

Given the development of international benchmarks Research Sub-Question 2 asks "*What are the physical problems associated with small dam safety in Vietnam?"*

Results from the on-site dam surveys demonstrate that all ten dams surveyed in Tan Moc commune, Luc Ngan district in Bac Giang province are seriously degraded and poorly maintained. All of the dams surveyed are highly hazardous and, hence, have the potential to fail with disastrous consequences. The current condition and associated maintenance levels of the sample dams are extremely poor and unacceptable. All ten dams surveyed are in critical need of repair and maintenance (see Tables 29.3 and 29.4 for details of the problems and Figs. 29.3, 29.4, 29.5, 29.6 for typical problems).

From the stakeholder interviews, the most prevalent safety problems of small dams in Vietnam are found to include: erosion, seepage, structural cracking, inability to store design water capacity, vandalism, inappropriate spillways, traffic damage, settlement, sinkholes, animal burrows and excessive vegetation (see Table 29.5 for further details).

Factors Contributing to Small Dam Safety Problems

Given the physical problems of dam safety identified above Research Sub-Question 3 asks "*What are the factors contributing to small dam safety problems identified in Vietnam?"*

According to the stakeholders interviewed most dam failures in the past coincided with the occurrence of extreme weather, especially floods and heavy rains (see Table 29.6). The majority of the participants interviewed (over 80 %) perceived that floods and heavy rains make a considerable contribution to dam failures in many Vietnamese rural provinces. In addition, landslides are seen as another cause of dam failures, particularly in the mountainous Northern provinces such as Tay Bac, Hoa Binh and Ha Giang provinces. The age of dams is confirmed by the surveys and interviews as a major reason behind dam failures. Dams built over 30 years ago during the Vietnam War had, and were perceived to have, large safety problems. The safety of these dams is seen to be compromised because of inadequate design and construction.

Stakeholders interviewed expressed the view that subjective (human) factors are undoubtedly the dominant cause of the current poor dam safety status and dam failures (see Table 29.7). Moreover, the stakeholders perceived that human factors

Table 29.3 Problems that exist with the ten small dams surveyed in Tan Moc commune

Dam No	Height (m)	Storage capacity (ML)	Hazard rating	Main problems associated with dam safety	Acceptable or unacceptable[b]
1	4	600	High[a]	–Excessive vegetation on the upstream face, downstream face and crest of the dam. The crest is uneven –Upstream and downstream faces are substantially eroded –Spillway is concrete and in good condition	Unacceptable
2	6	800	High	–The top crest is damaged by traffic: dip on the crest –Slide on the upstream face –Excessive vegetation on the downstream face –Traffic damage and slide on the downstream –Spillway is in good condition	Unacceptable
3	4	500	High	–The top crest is damaged by traffic: dip on the crest –Slide on both the upstream and downstream faces of the dam –Spillway is in good condition. Excessive vegetation and trees	Unacceptable
4	5	500	High	–The top crest is damaged by traffic –Traffic damage on the downstream face –Slide on both the downstream and upstream faces –The crest is uneven. Low area and a lot of cracking on the top –Two large holes on the top (serious) –Spillway is appropriate	Unacceptable
5	6	2500	High	–Failed in 2008, about 20 houses flooded away –Cracking on the crest. Animal burrows –Slide on both the upstream and downstream faces of the dam –Spillway is in good condition	Unacceptable
6	5	200	High	–Dams No. 5 and 6 caused a cumulative failure in 2008 –Excessive vegetation and trees on both downstream and upstream faces –Cracking. Spillway is built of concrete and appropriate	Unacceptable
7	5	600	High	–Slide and cut on the top. Cracking. The crest is uneven –Small and very old outlet –There are a number of large trees. There is no spillway	Unacceptable

(continued)

Table 29.3 (continued)

Dam No	Height (m)	Storage capacity (ML)	Hazard rating	Main problems associated with dam safety	Acceptable or unacceptable[b]
8	2.5	350	High	–The top is damaged by traffic –The crest is uneven, low areas on the top –Large hole on the crest and slides –Small outlet and very small spillway (under standard) –Spillway is blocked by large trees	Unacceptable
9	2	300	High	–Failed in 2008 and repaired in 2009 –Rice fields were damaged because of the failure in 2008 –Slides. Cracking. The top is damaged by traffic	Unacceptable
10	3	1000	High	–The top is damaged by the traffic –Uneven crest and low areas on the top –Slide on the downstream –Excessive vegetation on both the downstream and upstream –Outlet is broken. Too old and cracking outlet –Spillway is too small and blocked	Unacceptable

Notes [a] Because many dwellings are located downstream of and in close proximity to the dam
[b] Based on a dam inspection checklist developed from Ministry of Environment, Lands and Parks • Water Management Branch, British Columbia (1998) "Inspection and maintenance of dams • dam safety guidelines" and Department of Sustainability and Environment, the Victoria Government (2007) "Your dam • your responsibility: A guide to managing the safety of farm dams"

are as important or as more important for dam safety than the impacts of natural extremes and the age of dams. There are a number of human factors involved (as indicated in Table 29.7).

The first two factors indicate the lack of responsibility and accountability that has a direct and strong influence on the safety of dams. The stakeholders reported that no specific individuals or organisations have taken responsibility for dam failures in the past. In addition, there is a lack of individuals and organisations that actually take responsibility for dam repair, review, surveillance and maintenance as well as the setting of safety standards. Poorly defined and implemented accountability at both the central and local levels leads to the dam safety problems arising in various ways. For example, dam managers are not held accountable by either central government agencies or local authorities to undertake regular and/or periodic dam review, surveillance and maintenance.

The lack of dam safety risk based assessment was the most cited factor (86 %) contributing to the small dam safety problems (Table 29.7). Most participants did not correctly identify dam safety risks and hazards from dam failures. Most of them did not understand basic concepts of dam safety risks and dam hazards. On one hand, the explanation of the participants indicated that a large number of dams are currently at high risk of failure and many dams are potentially hazardous. On

Table 29.4 Current physical safety problems associated with the ten dams surveyed

Dam components	Actual problems	Details of problems	Percentage of dams[a] (%)
Reservoir	Inability to store design water capacity	–Sediment accumulation –Irrigation gate leakage –Spillway leakage	100
Crest	Overtopping	–Inaccurate estimation of hydrographical parameters –Spillway is blocked –Flooding is over the design flood capacity –The top is constructed lower than designed	60
	Settlement on the crest	–Traffic damage –Animal burrowing activities –Instability of the embankment	80
	Transverse cracking	–The dam foundation is depressed –Instability of the embankment –Shrinkage of surface materials –Materials are low quality	20
	Longitudinal cracking	–Water in the reservoir increases or decreases suddenly. This sudden change of water level creates depression on the top –The dam foundation is depressed –Slide occurs on the embankment	40
	Ruts along the crest	–Traffic damage –The movement of foundation	30
Upstream slope	Seepage under the foundation	–The quality of material is low. Hence. water is eroding the material –Rodent activity –Geological assessment is inaccurate	20
	Slide and slump	–The lack or loss of embankment material –Rodent activity –Erosion –Traffic damage –Downstream slope is too steep	80
	Sinkholes	–The movement of foundation create holes –Material is seeped –Animal burrows	20

(continued)

Table 29.4 (continued)

Dam components	Actual problems	Details of problems	Percentage of dams[a] (%)
Downstream slope	Seepage through the embankment	–Rodent activity creates open pathway through embankment –The abutment is not properly designed and constructed	70
	Seepage at the abutment	–The abutment is not properly designed and constructed –Plants/trees are not removed completely in construction	30
	Slide and slump	–The lack of or loss of embankment material –Rodent activity –The downstream slope is too steep	80
Spillway	Eroded spillway	–Erosion –The gradient of the channel is too steep	20
	Blocked spillway	–Soil and stone erosion –Trees and plants –Inaccurate design	50
Outlet	Eroded outlet	–Outlet is too small –Conduit is eroded –Foundation movement	20
	Leaking and breaking	–Valve is broken –Vandalism –Outlet is too old	40

Note [a] On the basis of ten dams

Fig. 29.3 Excessive vegetation and trees on both the upstream and downstream slopes

the other, most of the stakeholders insisted that small dams only constitute low threats.

A majority of the participants (80 %) perceived poor dam safety management at the local level as an influential factor on dam safety problems (Table 29.7). The stakeholders identified that six main problems associated with the key components of dam safety management at the local level cause dam safety deficiencies. They include (1) a lack of adequate operation manuals and management guidelines for dam managers; (2) many stages including dam planning, design and construction;

Fig. 29.4 Severe traffic damage on the crest

operation and review; monitoring and surveillance; and remedial works and maintenance are poorly undertaken; (3) dam managers lack knowledge and qualifications to operate and manage dams; (4) there are insufficient funds for different stages of dam safety management; (5) local authorities and dam managers have insufficient financial and legal powers to handle non-complying and emergency situations; and (6) the local community has little or no influence on other stakeholders, such as policy regulators, local authorities and dam managers, to improve the current dam safety status.

Fig. 29.5 Inability to store design water capacity because of leakage

Poor dam safety management at the central level is also seen by the stakeholders interviewed to contribute to current dam safety problems (Table 29.7). The results from the stakeholder interviews indicate that the existing laws and regulations are neither efficient nor effective. In addition, regulatory agencies at both the central and local levels lack competence in addressing dam safety problems. Moreover, the participants suggested that the absence of dam safety assurance programs and the lack of dam safety standards are also causes of the current problems. The reported shortcomings of dam safety management at the central level represent a low level of involvement of central government agencies that inevitably leads to the present problems.

Fig. 29.6 Piping failure resulting from construction or material defects and inappropriately designed spillway

Unconsciously devaluing lives of the local community was highlighted as being an important reason for dam safety problems (Table 29.7). Participants observed that life is given a low value and consequently the protection of the local community against hazardous dams is given little priority. Some participants pointed out that economic values and political interests are seen as more important than human life and social values.

Overall, the factors perceived to contribute to small dam safety deficiencies in the area examined include physical and human related problems.

Comparison of small dam safety accountability, responsibility and assurance policy practices identified in the case study with international benchmarks.

Table 29.5 Common problems of small dams in Vietnam cited by key stakeholders

ID	Problems of small dams in Vietnam	Number of participants	Percentage of participants[a] (%)
1	Erosion	14	93
2	Seepage	14	93
3	Cracking	11	73
4	Inability to store design water capacity because of silting and/or leakage	10	67
5	Blocked spillway	10	67
6	Inappropriately designed spillway	10	67
7	Vandalism	10	67
8	Damaged by traffic	9	60
9	Outlet leakage	9	60
10	Outlet broken	9	60
11	Settlement	6	40
12	Animal burrowing	5	33
13	Excessive vegetation and/or trees	5	33
14	Sinkhole	3	20
15	Slides and/or slumps	2	13
16	Low area on the crest of dams	2	13

Note [a] On the basis of 15 participants

Table 29.6 Perceived physical factors contributing to current dam safety problems

Factor	Number of participants	Percentage of participants[a] (%)
Flood	15	100
Heavy rain	12	80
Age of dams	12	80
Landslide	11	73

Note [a] On the basis of 15 participants

Table 29.7 Perceived human factors contributing to current dam safety problems

Factors	Number of participants	Percentage of participants (%)
Lack of responsibility	6	40
Lack of accountability	3	20
The absence of dam safety risk based assessment	13	86
Poor dam safety management at the local (micro) level	12	80
Poor dam safety management at the central (macro) level	6	40
Life is given a low value	5	33

Note On the basis of 15 participants

Table 29.8 Comparison of Vietnamese dam flood safety accountability, responsibility and assurance policy practices with the established international benchmarks

Elements of international benchmarks	The quality of Vietnamese dam flood safety accountability, responsibility and assurance policy practices•Satisfactory (S), Unsatisfactory (U) or Not Applicable (N/A)[a]								
	Flood and heavy rain	Age of dams	Land-slide	Responsibility	Accountability	Dam safety risk based assessment	Dam safety management at the local (micro) level	Dam safety management and assurance policy at the central (macro) level	Life of downstream communities
1. Legislative purposiveness	*N/A*	*N/A*	*N/A*	**U**	**U**	*N/A*	*N/A*	**S**	*N/A*
2.Administrative enforcement	*N/A*	*N/A*	*N/A*	**U**	**U**	*N/A*	*N/A*	**U**	*N/A*
3. Registration and classification of dams	*N/A*	*N/A*	*N/A*	**U**	**U**	**U**	**U**	**U**	**U**
4. Surveillance, inspection and safety review	**U**	**U**	**U**	**U**	**U**	**U**	**U**	*N/A*	**U**
5. Community education and preparedness	*N/A*	*N/A*	*N/A*	**U**	**U**	**U**	**U**	*N/A*	**U**
6. Owner responsibility with information	*N/A*	*N/A*	*N/A*	**U**	**U**	*N/A*	**U**	*N/A*	*N/A*
7. Punitive enforcement	*N/A*	*N/A*	*N/A*	**U**	**U**	*N/A*	*N/A*	**U**	*N/A*
8. Owner education and guidance	*N/A*	*N/A*	*N/A*	**U**	**U**	*N/A*	**U**	*N/A*	*N/A*
9.National/federal involvement	*N/A*	*N/A*	*N/A*	**U**	**U**	*N/A*	*N/A*	U	*N/A*

Note [a] Based on the established international benchmarks

Given the problems and factors emerging from the set of dams observed in Tan Moc commune in Vietnam, it is now time to examine the results for Research Sub-Question 4: *"How do Vietnamese dam flood safety accountability, responsibility and assurance policy practices compare with available international benchmarks?"*

In order to determine whether the Vietnamese dam flood safety accountability, responsibility and assurance practices are effective, each of the factors causing the current dam safety problems identified is compared with each element of the established international benchmarks. The comparison is presented in Table 29.8.

The safety of any dam depends significantly on spillway flood capacity, structural integrity and earthquake resistance (Pisaniello 1997; Pisaniello and McKay 2003). These aspects can be properly maintained through element 4 of international benchmarks in Table 29.8. However, it appears that the sample dams surveyed in Vietnam did not have adequate capacity to meet these benchmarks because flood, heavy rain, age of dams and landslide were confirmed by a majority of the stakeholders (over 70 %) to be the main cause of dam safety problems (see Table 29.6). Hence, element 4 of international benchmarks is unsatisfactory.

Responsibility and accountability exists under all elements of available international benchmarks (Pisaniello et al. 2011; Tingey-Holyoak et al. 2011). For example, at the local (micro) level, dam owners are responsible for the safety of dams and liable for consequences of dam failures. Dam owners also take responsibility for dam repair, review, surveillance, and maintenance. At the central (macro) level, regulatory agencies take responsibility for providing specific inputs or enabling dam safety legislation as well as setting dam safety standards. The results from the surveys and interviews show that all the various forms of responsibility and accountability at both the local and central levels of international benchmarks are unsatisfactory in the case study in Vietnam as indicated in Table 29.8.

International benchmarks require dam safety risk-based assessment to be applied to various elements in Table 29.8. For example, every dam needs to be given a hazard rating (element 3) so that stronger surveillance and reporting requirements can be imposed upon higher hazardous dams under element 4 (Pisaniello et al. 2011; Tingey-Holyoak et al. 2011). Similarly, stronger maintenance procedures and safety standards (element 4) and stronger community education and preparedness plans (element 5) can be imposed as the hazard rating of dams increases (Pisaniello 1997; Pisaniello and McKay 1998, 2003). According to the key stakeholders interviewed, the lack of dam safety risk based assessment is a contributing reason for small dam safety problems in Vietnam. Therefore, elements 3, 4 and 5 (Table 29.8) are unsatisfactory in the Vietnamese context.

International standards for dam safety management at the local (micro) level are set under elements 3, 4, 5, 6 and 8 in Table 29.8 (Pisaniello 1997; Pisaniello and McKay 1998, 2003; Pisaniello et al. 2011; Tingey-Holyoak et al. 2011). None of these elements is satisfied by Vietnam because 80 % of the participants perceived poor dam safety management at the local level as being an influential factor for dam safety deficiencies (see Table 29.7). Dam safety management at central (macro) level is internationally benchmarked through elements 1, 2, 3, 7 and 9 in

Table 29.8 (Pisaniello et al. 2011; Tingey-Holyoak et al. 2011). The stakeholder interviews indicate that Vietnam does have legislation and regulations in place with the intent/purpose to provide dam safety assurance (element 1). Hence, element 1 is satisfactory (Table 29.8). However, other elements including proper administration by regulatory agencies (element 2), punitive enforcement (element 7), registration and classification of dams (element 3) and involvement of the central government (element 9) are also unsatisfactory. Therefore, dam safety management at the central level in Vietnam appears to only satisfy one (element 1) of the relevant five Elements of international benchmarks (Table 29.8).

International benchmarks which place value on the lives of downstream communities include elements 3, 4 and 5 (Table 29.8). Essentially, the more lives that are at risk downstream of a dam, the higher its hazard classification will be (element 3), the stronger the required surveillance, reporting and design standards will be (element 4) and the more sophisticated the required community education and emergency preparedness procedures will be (element 5). The case study found that such elements are not achieved in Vietnam (as indicated in Table 29.8). The key stakeholders suggested that lives of the local community are given a low value.

In summary, the Vietnamese dam safety accountability, responsibility and assurance policy practices identified in the area examined are ineffective because they only satisfy one (element 1) of the nine crucial elements of available international benchmarks. The comparison also highlights that even the minimum level benchmark (Table 29.2 and elements 3, 5 and 8 in Table 29.8) is not satisfied by the case in Vietnam.

Conclusions

On-site dam surveys, stakeholder interviews and comparative analysis provide consistent strong evidence that Vietnamese small dam flood safety accountability and assurance policy is ineffective and inefficient in addressing dam safety problems as well as averting dam flooding failures. It is evident that small dams in Tan Moc commune, Luc Ngan district, Bac Giang province in Vietnam constitute destructive threats to the downstream community, property and environment. Floods were confirmed to be the dominant cause of dam safety deficiencies including dam failures. However, human factors are seen by the key stakeholders as the major cause of dam safety problems. The comparison of dam safety assurance policy practices with available international benchmarks suggests that Vietnam not only fails to satisfy international acceptable benchmarks, but also performs far below the minimum level benchmark.

The overall outcomes provided in this paper suggest that there is a need to improve the quality of small dam flood safety accountability, responsibility and assurance policy practices in Vietnam in order to provide increased levels of assurance to communities and satisfy international standards. In order to achieve this need, as a starting point, it is essential for the government of Vietnam to provide "minimum practice" that includes (1) registration and classification of dams via risk-based assessment; (2) community education and preparedness; and (3) dam owner education and guidance including education and training of dam managers. In addition, it is also essential for the central government, policy makers and local authorities to place a higher value on lives of the local community. Moreover, this need can be only obtained if the local community living under the dam safety risks are empowered and involved in local dam safety management and preparedness.

The main limitation of this research is that is has not been possible to generalise the findings to fit broader spectrum of the population. This is because the evidence gathered from 10 on-site dam surveys and 15 stakeholder interviews is from one province in Vietnam. Hence, the findings can only be applied cautiously to other similar areas. Nevertheless, the use of the constant comparative method and triangulation of data enhances the validity of conclusions reached in the context of the small number of dams examined and interviews conducted. The methods of on-site dam surveys, stakeholder interviews and comparative analysis used can be transferred to any jurisdiction, especially those in developing countries for assessing the status of dam safety management practices and the quality of dam safety assurance policy.

Future research can explore the extent of the problems and any other contributing factors over more study areas in Vietnam, and how international benchmark guidelines can be applied to Vietnam in order to achieve appropriate dam flood safety accountability, responsibility and assurance policy.

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Author Biographies

Tuyet Thi Dam has been working on a Master's programme at the Centre for Accounting, Governance and Sustainability in the School of Commerce, University of South Australia, since 2009. Her current research focuses on small dam safety accountability, responsibility and assurance policy and dam safety risk management in Vietnam. Ms Tuyet is an Endeavour scholarship holder funded by the Australian Government for her Master's. She also received a Bachelor degree in Environmental Economics from the National Economics University in Hanoi, Vietnam, in 2006.

Professor Roger L. Burritt is a Professor of Accounting at the School of Commerce. His main research interest is in the relationship between the language of business, as captured by accounting, and its relationship with the environmental and social environments in which business operates. Professor

Burritt is founding director of the Centre for Accounting, Governance and Sustainability in the School of Commerce which encourages the building of research talent across the areas of accounting, finance, education, engineering and law.

Dr John D. Pisaniello has multi-disciplinary interests, with Honours degrees in Civil Engineering and Law. Dr Pisaniello is currently a Senior Research Fellow in the School of Commerce and Leader of the Sustainable Law and Engineering Group within the Centre for Accounting, Governance and Sustainability at the University of South Australia. His research aim is to ensure engineering/policy/law systems are cost-effective and "user-friendly" while remaining in line with current best practice, and promoting equity, sustainability and safety in areas such as water resources and conservation, dam safety and management, planning, development and environmental law, renewable energy, and public health and safety assurance.

Chapter 30
Management of Disaster Risks Derived from Large Fuel Subsidies of Natural Gas in Argentina

Alejandro D. Gvonzález

Abstract Through a system of heavy subsidies, natural gas in Argentina has one of the lowest prices in the world. Residential users get the lowest price per m^3 delivered, but the price for businesses is also very low. In comparison, prices for residential use in 24 countries listed by the International Energy Agency (IEA, 2011a) averages USD 0.79/m^3; while in Argentina the price ranges from 0.02 to USD 0.10/m^3, the lowest for the coldest regions where consumption in buildings is higher. Since 2003 the price per unit of energy of residential gas is 10–20 times lower than diesel, 5–10 times lower than firewood, and 10–20 times lower than electricity. As a consequence, customers have been misled by low bills and have solved the inefficiencies of buildings and appliances by very high consumption, postponing what otherwise would have been much-needed refurbishments. No public awareness exists on this situation. Attempts made by the government in 2009 to raise prices ended in public protests and court demands, and the largest increases had to be withdrawn. There are high risks of social unrest due to a lack of education and options related to fuel consumption. Recent serious social unrest as a result of higher gas tariffs in Punta Arenas, southern Chile, confirmed the behaviour observed in 2009 in Argentina. In both cases, no energy conservation measures have been done. Other risks include reduction or extinction of gas reserves, unsustainable budgets to support subsidies, discouragement of renewable energies, and pressure on native forests for firewood. Education and dedicated energy conservation measures are proposed to manage disaster risks derived from decades of subsidies.

Keywords Climate change · Adaptation · Disaster · Risk · Capacity building

A. D. Gvonzález (✉)
Research Institute on Biodiversity and Environment (INIBIOMA), CONICET and Universidad Nacional del Comahue, Centro Regional Universitario Bariloche, 8400, Bariloche, Argentina
e-mail: gonzalezad@comahue-conicet.gob.ar

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Introduction

Direct household energy consumption in heating, cooling, sanitary water, and appliances is connected both to user behaviour and equipment efficiency. This was widely realised in the 1950s and 1960s in northern European countries, and sooner or later a variety of efficiency policies were set in place (Balaras et al. 2005). For example, heating energy per m^2 has been decreasing steadily since then, to the present average value of around 90–120 kWh/m^2 in Germany or Sweden.

In Argentina, the main residential energy resource is natural gas (NG), which accounts for 64 % of total residential energy, followed by electricity (24 %), bottled gas (9 %) and firewood (3 %) (IEA 2011b). However, NG is provided by a nation-wide network which does not reach all households, but nearly 60 % are connected. The NG network does not cover the warmest north-eastern provinces, the rural areas, or the shanty towns in large cities. Therefore, the sector with NG provision consumes a great share of energy from this resource. For instance, in a warm temperate city like La Plata (province of Buenos Aires, mean annual temperature 15.5 °C), NG accounts for nearly 86 % of energy use in households. Whilst in a city in the cold region of Patagonia (Bariloche, mean temperature 8 °C), households with NG provision draw 95 % of their energy use from this resource (González et al. 2007). Prices per m^3 are different in both regions, and at present tariffs also depend on consumption. In La Plata prices range from USD 0.04 to 0.10/m^3, while in Bariloche residential gas prices are between USD 0.02 and 0.06/m^3. The base price changes along regions but also further subsidies are applied in colder areas (González 2009a). These tariffs are between 10 and 30 times lower than those listed for 24 countries by the International Energy Agency (IEA 2011a).

A consequence of long-term cheap fuels was a building stock which does not have the required technology to be energy conservative. Since 2001, Argentinean norms have included different levels of thermal quality in buildings; however, the norm has only been given as a reference and is not mandatory. The majority of buildings have the lowest level stated by the norm, and this fact has led to a very high consumption of NG (Filippín et al. 2011; González 2009a).

The acquisition of knowledge leading to energy conservation measures (ECMs) is a process which takes decades, and it is encouraged from both needs and policies. Neither of these two conditions has been present in Argentina. Even in higher education, at the different faculties of Architecture and Engineering, the curricula lack the detailed account of measures to make buildings more efficient (De Schiller and Evans 1990/1991).

On the other hand, the residential sector has been granted a non-interrupted supply of energy, even in times of shortages that have largely affected the industry. For example, households' use of NG in winter increases by 8–10 times the summer consumption and in this period industry has to deal with a 30–50 % reduction in their required gas supply (Filippín et al. 2011). In summer, the use of excessive electricity for air conditioning inefficient buildings forces the industry to find alternative means, mostly based on individual diesel generators.

Since 2005 the government has systematically encouraged industry to obtain individual electricity generation capacity based on diesel to have as a backup provision. The policy of giving excessive energy privileges to households makes industry and commerce suffer higher costs derived from cuts, shortages, and individual generation. The shortages are taken by the government and the public as a natural occurrence in cold and warm seasons, but no one stresses the fact that energy cuts for industry could be easily avoided by improving building efficiency. On the other hand, as will be discussed below, the energy privileges have created a sense of entitlement in households that leads to anger and violent protests when energy provisions or costs are touched. The privileges materialised by subsidies have lead to social unrest which blocks essential ways to make energy conservation policies effective. This is a serious matter that cannot be solved by standard proposals based on available technical solutions. Education and dedicated technical advisors on ECMs are proposed as key policy actions to reduce social and environmental disaster risks.

Risks Identified

The main risks of having heavy energy subsidies for over a decade are:

1. Environmental injustice, which has deepened during the last decade.
2. Health risks associated with buildings not reaching comfort temperatures.
3. Total unawareness of the high amount of energy consumed.
4. Not having technical expertise to achieve energy conservation measures.
5. Social unrest in the wake of rising energy prices.
6. Forest degradation following the decrease in gas supplies.

Environmental Injustice During the Last Decade

Low energy prices have been common in Argentina since the 1980s; however, injustice has been deepened in the last decade by extreme benefits in natural gas prices given only to part of the residential sector. The part connected to the gas network accounts for 60 % of households. The majority of this sector has a middle or high income, and the majority of households not connected to cheap gas are low-income households and poorer sectors at social risk (Bravo et al. 2008). Rich neighbourhoods, high-income gated housing projects, and most middle-high income households enjoy subsidies they do not actually need, while poorer neighbours must pay 5–15 times higher prices for the same energy unit based on other fuels (González 2009a).

Electricity is commonly used as a thermal source by households lacking NG provision. The ratio of prices per energy unit of electricity with regard to that of

NG was around ten in the 1990s and has risen to 30 since 2003. During the same comparison period, illegal electricity connections also rose sharply (Bravo et al. 2008). The consumption pattern across groups with or without NG access is very different. For instance, in the city of Bariloche, the average one-family dweller with NG provision uses 500 kWh/m^2 per year, which represents 3.6 tons of CO_2 per person per year. This per capita emission is only the contribution from household energy use without taking transport into account. Note that the mean total emission for the country is around 4 tons of CO_2 per person per year, but this figure averages over a large part of the population having poor or very poor energy access (IEA 2011a).

Health Risks Associated with Buildings not Reaching Comfortable Temperatures

Considering the present construction, even a slight decrease in energy supply can sharply reduce the average temperature of houses in winter. The average actual house has wall U-values of 3–4 W/m^2K, single glass windows, a large infiltration rate, poorly insulated roofs and floors, and low-efficiency appliances. Therefore, without a generous supply of energy, the dwellings' present constructions lead to ambient conditions which are far from comfortable. Winter indoor temperatures in households heated with firewood, bottled gas, and/or electricity are usually between 10 and 15 °C. These households are also the group with the majority of fire-related accidents, derived from either fireplaces or electrical wiring not adapted to high heating consumption.

Total Unawareness of the High Amount of Energy Consumed

In educational workshops and seminars given to the public and to technical professionals, a complete lack of awareness of the magnitude of the energy consumed by household in Argentina has been observed. The perception of both the public and professionals is driven by bill payments and not by real energy units. Not feeling the amount of energy leads to a lack of appropriate technical actions required for energy conservation, and so the lack of awareness contributes to maintaining a vicious circle of energy requirements and the right to have it. As previously mentioned, the average per capita energy and GHG emissions declared by the country do not show high impacts because it averages on a large population of very low and low incomes which account for more than 40 % of households. This sector has none or limited access to natural gas, using instead bottled gas, firewood, charcoal, diesel, and electricity with prices per unit of energy between 10 and 15 times higher than those for natural gas (Bravo et al. 2008).

Nevertheless, Argentinean households with a natural gas provision have an actual energy consumption and emissions rate that surpasses climate-equivalent European consumption by a factor of 3:4 (González 2009a). Unawareness of energy privileges might have been the main reason for social unrest when attempts to raise prices to reasonable levels were made. Since 2010, the government required the energy companies to state the amount of subsidies given in each bill, and has also provided a chart showing how much money a household in other countries pays for the same amount of energy. The results of this information are still unknown. In any case, all information and comparisons given referred to payments but not to the amount of energy consumed, thus it does not solve unawareness of high consumption.

Not having Technical Expertise to Achieve Energy Conservation

Argentina has never achieved effective ECMs, yet there have been energy conservation programmes which started in 2007; however, they focused on the implementation of behaviour and electricity. For a number of different reasons these programmes have not been successful (Smedby 2010). One of the main reasons for the failure was that building and appliance inefficiencies have never been properly addressed in the programmes. For instance, in areas with a colder climate, electricity accounts for less than 5 % of total energy consumed in the average household (González et al. 2007). Moreover, even in a warm temperate climate in the province of Buenos Aires, electricity accounts for only 14 % of energy input in households (Rosenfeld et al. 2003). In spite of this, conservation programmes focused on electricity, failing to take into account the excessive consumption of NG. Clearly, the urgent problem in Argentina is thermal efficiency, and at present, lighting or other non-thermal appliances have no significant mitigation. The programmes for saving on electricity have given both small reductions and increases; being in average rather ineffective. What is saved by more efficient lighting and appliances is wasted in air conditioning or electrical heaters, which can be bought for low prices in the market and used in buildings which are poorly insulated. Thus, the key fact is that the policy and education needed for real improvements in thermal efficiency in Argentina has never been made. Few initiatives from private owners and few academics have proved that the country has been ready for a long time to make use of its human and material resources, in order to achieve an energy conservation program (De Schiller and Evans 1990/1991; Rosenfeld et al. 2003; Filippín et al. 2011). Policy implementation and the education needed to make the suggestions work are long-term processes which involve a complex network of stakeholders (professionals, industry, businesses, government, and private owners, etc.). Not having this network in place implies a high risk for the future, as the country has only 5 years of reserve in oil and around 7 years in natural gas. The cold-weather areas like the one referred to in the present study are at very high risk due to a lack of policies and actions preventing high consumption.

Social Unrest in the Wake of Rising Energy Prices

A proportion of privileged households enjoying subsidies belong to middle-low and middle incomes. Residential buildings are so inefficient that consumption of natural gas per m^2 is 3–5 times higher than it should be with providing even moderate thermal insulation. The result is that small houses (and so middle to low incomes) actually have very large consumption patterns. In 2009, the government tried to enforce gas tariff increases based on consumption, assuming that only high incomes were responsible for high consumption. This hypothesis proved to be wrong. When houses lack thermal insulation it does not hold true that high consumption implies high income (González 2009b). This mistake led to public protests, households refusing to pay bills, and ended in a large portion of the increase being suspended by the court. A similar situation was evident in the beginning of 2011 in the city of Punta Arenas, south of Chile. This area, as well as the area of Patagonia in Argentina, enjoys a particularly low price on fuels used for heating. Recent studies also showed that in the south of Chile housing is not built according to energy conservation for the climate requirements, and so energy consumption is very high and comfort levels are low (Banzhaf 2011). In Chile, the proposed tariff increase, although never applied, was only 13 %, though it has triggered social unrest lasting several weeks including road interruptions and clashes with the police leaving people injured and property damaged. In both attempts to raise low subsidised prices, in Argentina as well as in Chile, there had not been an awareness campaign to educate households and give advice on the possibility of having simultaneously low consumption and a level of thermal comfort. From the events in these two countries we can learn that both government officials and the population are unaware as to how energy efficiency works. Officials would like to see their proposal for tariff increases agreed and paid for by households, and households would like to see their bills reach a reasonable level for the comfort achieved. A lack of education and technical programmes on energy conservation lead to an increased risk of social unrest because neither stakeholder involved understands the basic problem.

Forest Degradation Following the Reduction in Gas Supplies

Colder regions of the country with a high consumption of NG for heating will try to find alternative fuels when the provision of NG is reduced or the price increased. In the area of Patagonia, the preferred fuel for heating was historically firewood, and it is actually used by households not connected to the gas network. For example, the average consumption of heating energy in one-family dwellings using NG is equivalent to the use of 14 tons of firewood per year (González 2009a). Similar houses which actually use firewood consume between 8 and 15 tons of firewood per year (the wide range represents the variety of thermal quality and comfortable conditions). In the Argentinean part of Patagonia there only forests in a narrow area towards the west, close to the Andes. These are mostly native forests inside or surrounding the numerous National Parks present in the area. Few cultivated forests have been established. The present supply of firewood is partially a mix of cultivated and a variety of native woods. The complex situation of having a sharp increase in the population and high demand for energy, substituting the present fuels constitutes a risk for native forests in the area of study. Rainfall in the Argentinean Patagonia has decreased in the last decade as a consequence of climatic change. Thus, even if planned, large production of firewood would not be possible in the future.

Promoting Energy Efficiency to Decrease Risks

Thermal insulation of buildings is a practice that could simultaneously reduce the above risks. This is a simple matter but it takes many steps to be projected and implemented.

Firstly, policy design, along with implementation and monitoring are essential in ensuring the right governmental direction. So far, the attempts already made for energy policy in Argentina have not been followed by the implementation and monitoring stages. This was partially due to limited administrative resources set up for the programmes (Smedby 2010). On the other hand, the official energy conservation programmes have not worked on the technical education and practical implementation to solve thermal losses. Since the 1990s, researchers from architectural and engineering faculties in Argentina have highlighted the problem of high energy consumption in greater detail, and furthermore suggested technical and policy measures through conferences and publications (www.asades.org.ar). However, the administrations of the various governments since then were not sensitive to include this vital information. Natural gas is a key resource in Argentina's energy supply, and the delay in facing the problem increases the aforementioned risks. Natural gas accounts for 52 % of all primary energy used in the country. Electricity is generated with 55 % natural gas, 25 % hydro, 10 % fuel and diesel oil, 7 % nuclear, and 3 % coal and biomass (IEA 2011b). The country was self-sufficient in NG and oil, but imports have increased sharply since 2005. The energy production in the country reached a maximum in 1999, and levelled off until the present time (IEA 2011b).

Research data obtained over the last two decades in various climatic regions of the country showed potential for energy-use reductions between 50 and 70 % as a result of energy conservation measures (ECMs) (Filippín et al. 2011; González

2009a; De Schiller and Evans, 1990). Colder regions would save more in fuels for heating, while temperate areas would also save electricity from a lower usage of air conditioning. For example, in the city of Bariloche, average heating energy produces nearly 8 tons of CO_2/year per household. The ECMs that would provide walls and roofs with U-values of around 0.5 W/m^{2}K (instead of the present 3–4 W/m^{2}K) to a house of 100 m^2, has a current cost of eight medium salaries. In this cold region, the moderate refurbishment would reduce GHG emissions to between 3 and 4 tons CO_2/year per household. In a temperate region like La Pampa (described by Filippín et al. 2011), with a similar refurbishment cost, the combined winter and summer savings would account for 2–3 tons CO_2/year per household. These ECMs could even be done with materials made in Argentina (for instance, glass wool, polystyrene, and a diverse range of envelopes), which are also available in every builders store across the country (see technical details in González 2009a). The cost of these ECMs are the same as 50 years of household heating costs at current gas prices, but less than 3 years if EU gas prices were considered. In winter 2011, around 20 % of the gas provisions were imported from Bolivia by pipeline, or delivered as liquefied natural gas (LNG) by boat from Central America and Qatar. The prices paid were international commodity prices, with extra costs for LNG, and in addition, large special discharging ports had to be made. In spite of these efforts in the provision, high winter demand by households enforced the government to limit gas delivery to industry. Therefore, the overall cost for the country of not having policies promoting ECMs does not lie only in the subsidies but also in losses derived from paralysed industrial capacity when households' demands are high. An allocation of subsidies to ECMs and a gradual rise in tariffs were discussed in a previous paper (González 2009a).

Secondly, technical education and assistance should be given in the places where people need them. A network of technical offices with both purposes, education and support, has been proposed to open in every neighbourhood (González 2009a). These technical offices should be provided by the state, including the skilled professionals who could advise neighbours. The office should organise regular seminars and workshops to explain energy efficiency to people and to make suggestions for change. Besides these educational activities, the office should offer free advice to households on the best way to improve energy use, and the best way to refurbish houses. There is a large group of households that could afford moderate refurbishments leading to a 30–50 % reduction in energy. This sector should be encouraged, and could be used as an example for the sceptical who are in fact numerous at present because of misinformation. On many occasions, companies organise workshops to show and promote their products, but this information is biased by the interest of the different brands to sell their particular product. In some cases, the message has confused the public. For example, people have installed roof insulation of less than 1 cm because there were efforts from the seller to convince people about a material which has good conductivity, but lacks enough thickness. The industry and commerce play a key role in the needed improvements; however, their role should be to provide existing and new materials, and not to press for non-suitable solutions biased by profit. The advice, therefore, should come from technical counsellors looking for the best possible solutions that could be fulfilled with different materials and methods. All households, regardless of income, should get free advice from the government's technical offices.

In Latin America, most buildings actually have the technology and the thermal performance that was found in the 1950s in EU countries (Filippín et al. 2011). At present, with widespread availability of low price air conditioning appliances, a substantial proportion of electricity is wasted in non-insulated buildings. This is also shown in a study on sustainable development in Chile (Karakosta et al. 2009). This research looked for renewable solutions to reduce the risks that Chile gets locked into using coal technologies to meet electricity demand. However, the large use of resources due to low efficiency in heating and cooling was not a concern held by most stakeholders interviewed. Clearly, no sustainable resource can be enough when energy is wasted in buildings which completely lack thermal insulation. Thus, as discussed so far, ECM priorities are valid for both cold and warm climate regions.

Thirdly, to encourage refurbishments and to make the first steps to reach reasonable tariffs in Argentina, an energy price increase based on income should be implemented. This is a measure very different than the one implemented in 2009, when gas tariffs were raised based on consumption, i.e. higher gas consumers got higher percentage increases. With the present inefficient building stock, this measure reached low and middle income sectors, and thus deepened inequalities and triggered anger and protests. A tariff increase based on income is likely to have two desirable outputs: (a) it would encourage owners with economical capacity to make thermal improvements to bring their bills down; (b) it would balance the subsidies that temporarily should be kept to improve the dwellings of lower-income households. The low and low-middle income households could also be eligible for government subsidies to improve their houses, with the condition that the larger the improvements made, the larger the tariff that they will pay. In the long term, tariffs should be set at regular levels compared to other household's expenses, and plain for all income sectors.

Fourthly, resource conservation technologies and ecological consequences should be a study subject from primary school curricula. In secondary and tertiary levels the matter should be included in all natural and exact sciences accordingly. Physics, chemistry, and ecology give clear opportunities, but the basic matter should also be taught in humanities and other social sciences, in which a discussion on environmental justice and equal energy opportunities should be included in curricula. The government could also promote the making of films and technical programs, including interviews with academics, films showing technical advice and detail of works done, and this information should be aired frequently in different attractive formats.

Conclusions

Risks of disaster in the residential sector of Argentina caused by heavily subsidised low energy tariffs have been studied in this paper. A number of risks were identified: the scarcity of fossil fuels, firewood production affected by climate change, the environmental impact on forests and emissions, health issues, sustainability of settlements in a cold region, and unawareness leading to social unrest. A decade of deepening the already low subsidised tariffs led to a total lack of interest in conservation techniques in constructions. The consumption of energy in buildings, in both winter and summer, surpasses many times over the consumption in similar climates found in Europe. This fact is caused by the use of cheap energy to compensate for not having proper thermal insulation in buildings. A number of policy measures designed to lower risks were proposed here: creating technical offices in each neighbourhood to educate and advise; raise energy tariffs in a manner proportional to income; education in schools and getting the public to increase participation in the improvement programmes, and lowering the risks of social unrest. In the areas with the highest gas consumption levels, moderate energy conservation measures that can be afforded by a large proportion of households could reduce GHG emissions by between 2 and 4 tons of CO_2/year per household. Subsidies for fuels can be directed to improve the energy efficiency rating of poorer households. Given the present energy consumption of buildings in Argentina, and the fact that reserves of oil and natural gas are rapidly decreasing, the risks discussed here should urgently be taken into consideration. Otherwise, the sustainability of settlements in Patagonia is at high risk, and social unrest caused by energy tariffs and shortages are likely to occur in the next 5 years.

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Author Biography

Alejandro González is a senior researcher at the National Research Council of Argentina (CONICET). He has a PhD and investigates energy use and the contribution to climate change from the residential sector. He has investigated the reasons for excessive energy use in heating in Argentina, the results of which have been published in the journal "*Energy Policy, Energies, and Energy & Buildings*" and on contributions of consumption to climate change (Food Policy); in particular he has shown GHG emissions in food production as a function of protein and calorific content.

Chapter 31
Preventing Climate Disasters: Legal and Economic Aspects of the Implementation of the National Fund on Climate Change in Brazil

Patricia Borba Villar Guimarães and Anderson Lanzillo

Abstract The scientific and technological development over the course of the 20th century has changed the conditions of human life substantially by creating new ways of social, communicational, and economic interaction around the world. However, this new way of life has altered the environment and generated the unwelcome phenomenon of climate change. Several environmental disasters are occurring around the world because of climate change. In Brazil, climate change has caused environmental disasters such as droughts and floods. Before this situation, many countries have enforced new legal norms at national and international level in order to face this challenge. According to this trend, Brazil is committed to enforce new environmental legal norms and has created the National Fund on Climate Change. Thus, the objective of this paper is to study the legal and economic aspects related to the National Fund on Climate Change taking into account Brazilian national policies and economic data available at the International Energy Agency and at the Brazilian Energy Balance.

Keywords Development · Climate change · Brazil · National Fund on Climate Change

P. B. V. Guimarães (✉) · A. Lanzillo
Departamento de Direito Público—DPU, Universidade Federal do Rio Grande do Norte—UFRN, Avenida Senador Salgado Filho, 3000-Lagoa Nova, Natal-RN 59078-970, Brazil
e-mail: patriciaborba@ig.com.br

A. Lanzillo
e-mail: adv.anderson@gmail.com

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Introduction

Modern economic and social development has brought many consequences to the way of thinking and life of modern man. However, among all the perceived changes, climate change has attracted the interest of both the scientific and the global community because of the potential impact on the future of mankind. Previously climate change had been discussed without tangible evidence, but now it is seen more clearly because of environmental disasters that happen around the world.

Environmental disasters caused by climate change are affecting many natural and social systems. The extinction of species of flora and fauna may not move the economic and political debate enough, but social and economic losses have come to show that measures tp combat global warming and climate change are required. In Brazil, social and economic losses due to climate change are happening, especially because of droughts and floods.

In this context, the global community is building a set of legal instruments to combat the effects of climate change (United Nations Framework Convention on Climate Change and Kyoto Protocol) and, following the global trend, Brazil has created the National Fund on Climate Change according to the general provisions of the National Policy on Climate Change. The creation of the environmental fund is presented with the clear purpose of promoting actions that seek to mitigate/adapt existing social conditions to the effects of climate change. However, its implementation depends on the analysis of the economic environment and public policy. In this study we have taken into account the Brazilian public policies related to the topic, as well as economic data from the Brazilian Energy Balance and the International Energy Agency.

Features of the National Fund on Climate Change

Public policies and actions by private agents are required in the current scenario to deal with climate change. Although there is a discussion as to whether this phenomenon has its origin in human actions or even if it happens at all, the environmental disasters caused by profound changes to the climate leave no doubt that measures must be taken at the global level to increase regulation (Figueres and Maria 2005, p 233).

In Brazil, the National Fund on Climate Change (Law No. 12.114/2009 and Decree 7.343/2010) is a kind of environmental fund arising from the context of the National Policy on Climate Change (Law No. 12.187/2009). The National Policy on Climate Change recognises the existence of climate change as a result of human actions, be they direct or indirect, and as causing adverse effects on natural and socioeconomic systems, as well as on human health (Articles 2 and 8, Law No. 12.187/2009). Beyond this recognition, the National Policy on Climate Change shows that the actions related to climate change (especially the incentive to reduce emissions) must combine social and economic development and protect the climate system (Article 4, Law No. 12.187/2009). Brazil has assumed a voluntary commitment to reduce projected emissions between 36.1 and 38.9 % by 2020 (Article 12, Law No. 12.187/2009).

Thus, in order to achieve these objectives, the National Fund on Climate Change has been created to acquire and distribute funds focused on projects, studies and ventures aimed at mitigating climate change or adapting the human life to its effects (Article 2, Law No. 12.114/2009). The fund is administered by the Steering Committee, under the Ministry of the Environment, whose mission it is to manage the investments from the financial recourses in the fund and to approve projects according to the plan approved by the Ministry (Article 4, Law No. 12.114/2009 and Article 9, Decree No. 7.343/2010).

The financial recourses from the National Climate Change come from a diverse base: (a) special government participation on the production by large or highly profitable oil reservoirs; (b) the Union's budgetary resources; (c) financial resources from agreements between the federal state and municipal governments; (d) donations; (e) loans from financial institutions; (f) reversal of the annual balances not used, and (g) resources of interest and amortisation of financing (Article 3, Law No. 12.114/2009).

There are two lines of financing that are covered with the resources of the fund: (a) financial support in the form of repayable loans, and (b) non-refundable financial support for projects aimed at mitigating climate change or adapting to its effects. In addition, the fund's resources can be used to implement various activities related to environmental education, studies on climate change, climate science and emission reduction of greenhouse gases (Article 5, Law No. 12.114/2009).

Since the creation of the National Fund on Climate Change is fairly recent, there is no comprehensive data on its application. However, the fund is in operation, at least in terms of the level set in the budget. In 2011, the National Fund on Climate Change was provided with a budget of BRL 233,727,463.00 (more or less USD 149,000,000.00) (Ministry of the Environment, 2011).

Legal Aspects of the Implementation of the National Fund on Climate Change

It is known that developing countries are often less prepared to develop actions to address climate change because of their economic weaknesses (Figueres and Maria 2005, p 239–240), but Brazil is living a special moment in the economic area and attracts more and more resources that can be applied to projects related to climate change. However, there are two challenges that must be addressed in order for this fund to produce practical results: (a) a lack of national experience in dealing with the effects of climate change and the disasters it has caused, and (b) the Brazilian energy policy.

As stated above, the creation of the National Fund on Climate Change is still recent and before it there was no legislation or measures to prevent environmental disasters in Brazil. The common idea until recently for the Brazilian people and government was that Brazil was a country without serious environmental problems caused by climate change. However, recent tragedies show otherwise.

A report says that in January 2011 there were landslides due to large volume of rainfall and flooding of rivers in the mountainous region of Rio de Janeiro. There were 550 dead. At the same time there was flooding in Australia that killed 27 people. The large number of deaths in the Brazilian case was due to lack of preventive measures in the affected cities (Nova Friburgo and Petrópolis Teresópolis), although in the capital (Rio de Janeiro) the same problems did not occur due to prior investment and other measures taken (COELHO 2011).

From a legal standpoint, two main issues contribute to the problem of managing climate disasters such as those reported above. The first is that Brazil is a Federation. A Federation is a kind of state where there is more than one level of government. In Brazil we have Federal government, state government and municipal government.

Although there is a Federal law on the existence of the fund and the actions needed to address climate change and disasters, the situation is not the same with respect to state and municipal governments, which need to pass their own legislation in order for the National Fund to be applied effectively.

According to Parente and Romeiro (2011), there is no uniformity in the legislative measures taken by state and local governments.

In Brazil there are 26 states, but only 15 have some kind of policy on climate change with mandatory targets (Amazonas, Amapá, Tocantins, Goiás, Santa Catarina, Para, Sao Paulo, Rio de Janeiro, Pernambuco, Espirito Santo, Bahia, Mato Grosso, Minas Gerais, Parana, Rio Grande do Sul) (Parente and Romeiro 2011, p 48).

On the other hand, there are about 5,560 municipalities in Brazil, but only two have policies on climate change with mandatory targets (Rio de Janeiro and Sao Paulo) (Parente and Romeiro 2011, p 48).

Thus, because of this political organisation, we found that both the cities that are prepared for climate change are those who have no political guidelines. The reason for the lack of such political guidelines comes down to the way in which issues surrounding climate change are traditionally viewed in Brazil, which has consequently seen a lack of legislation and practical measures implemented in order to combat the effects of climate change.

The second is that the Brazilian Constitution of 1988 (Article 23) foresees a law to coordinate the actions of federation members. However this law is no longer in existence which has led to significant differences in policies to prevent climate change in Brazil, which have been listen above. The passage of this law is necessary, especially as the fund could have the desired effect, and help combat the effect of climate change in Brazil.

Economic Aspects of the Implementation of the National Fund on Climate Change

Several aspects of Brazilian economic development present challenges to the implementation of the National Fund on Climate Change.

According to Avzaradel (2011 , p 81), there was an increase of 65.2 % in emissions of carbon dioxide between the years 1990 and 2005. The main reason for this increase was activity in the land and forest, principally deforestation, especially in the Amazon (Avzaradel 2011, p 86).

Another point is the energy policy in Brazil. The energy sector is in second place for emissions of carbon dioxide in Brazil (Avzaradel 2011, p 82).

At first glance energy policy should not be a barrier to deployment of the fund, since there are several renewable energy sources in Brazil. According to Calou (2011, p 144–145), Brazil expanded the supply of energy through investments in renewable energy.

To complement this good prospect, data from the Brazilian Energy Balance 2010 show that Brazil has an energy matrix predominantly from renewable energy sources, with 76.9 % of hydro power and biomass at 5.4 % (Energy Research Company 2010, p 12). However, this view may well be impeded by conflicting signals in Brazilian energy policy.

Despite the large presence of renewable energy, Brazil still lacks an overall regulatory framework on renewable energy. Brazil has only one incentive programme ("Incentive Programme for Alternative Sources of Energy—Proinfa", established by Law No. 10.438/2002) and sparse regulations on biofuels.

On the other hand, there is extensive legislation that encourages the exploration of oil and gas in Brazil (Law No. 9.478/1997 and Law No. 11.909/2009). After the discovery of oil and gas in pre-salt layer, Brazil has strengthened further this policy to get more oil in ultra-deep water, creating a law to increase state presence in the activity (Law No. 12.351/2010) and spending more resources for an energy resource that is increasingly recognised as a main cause of CO_2 emissions (Moomaw et al. 2011, p 03). From a financial standpoint it is understandable that this policy has been taken; today oil-related activities are responsible for much of the collection of taxes, and contribute significantly to the gross national product of Brazil. Petrobras, a stated-owned company, is counted among the major national companies.

What is the greatest threat? According to data from Word Energy Outlook 2010, fossil fuels will still be accounting for 50 % of energy demand by 2035. Moreover, countries that are not members of the OECD will account for 93 % of the increase in energy demand, especially China (International Energy Agency 2010). Looking at this data, fossil fuels remain the main fuel around the world. Before this demand, Brazil could direct the production of oil, especially one from the pre-salt layer, to supply the global market. Exporting oil to the global market establishes a paradox; while Brazil has favourable conditions to reduce its own emissions within the country itself, this same country contributes to the "exportation" of emissions, meaning that other countries will also continue to produce CO_2 emissions.

Thus, although the National Fund on Climate Change indirectly establishes a "compensatory policy", since part of the income from oil and gas finances it, this is not enough for the fund to meet their goals. As it is increasingly recognised, renewable energy resources contribute to a mitigation of the effects of climate change (Moomaw 2011, p 03). Brazil needs to recognise this fact in a more readily, and must seek the approval of a comprehensive regulatory framework for renewable energy. This is a basic condition so that the resources of the fund can be approved in projects that contribute nationally and globally to projects aimed at helping the Earth cope with the issue of climate change.

Conclusions

Dealing with climate disasters in Brazil has only recently become an issue for public policy. Traditionally, the Brazilian government is committed to reducing carbon emissions, but it has thought that natural disasters were not something that required a stronger domestic policy, with regard both to legislative actions and to social and economic actions.

We perceive that that Brazil has a vehicle for combating these disasters, namely the National Fund on Climate Change, which strives to follow international guidelines and is quoted as a case study in the quoted in the UNDP document (Flynn 2011, p 58).

However, there are legal and economic challenges to the National Fund that it must overcome in order to fulfil its role, which requires an act of political coordination between the various levels of government in Brazil (Federal, state and municipal governments). Social and economic actions are also required in order to reduce the negative impact of activities that cause harmful environmental effects from the use of natural resources, and to reduce the effects of polluting energy sources.

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Author Biographies

Patrícia Borba Vilar Guimarães in Law and Natural Resources. Professor at Universidade Federal do Rio Grande do Norte, Natal, Brazil. Experience in law, focusing on, institutions and sustainable development.

Anderson Souza da Silva Lanzillo Master's degree in Law and Energy. Professor at Universidade Federal do Rio Grande do Norte, Natal, Brazil. Experience in Law, focusing energy regulation.

Chapter 32
The Economics of Climate Change, Urbanisation, and Long-Term Flood Protection

David Corderi Novoa

Abstract Heavily urbanised areas located in the low-lying deltas of Asia have been identified as being especially vulnerable to climate-related impacts (IPCC 2007). It has been predicted that coastal cities in East and South Asia will face an increase in the exposure of population and assets to flooding (Nicholls et al. 2008). Climate change projections suggest the possibility of an increase in the frequency and intensity of floods in these areas. At the same time, urban growth will increase the value of potential flood damages and vulnerability in the region. Given these changing disaster risks, coastal cities will need to revisit their long-term disaster risk management strategies with special consideration to flood protection investments and urban development plans. A balance will need to be found between the potential increases in flood damages and the economic benefits from growth in areas vulnerable to floods over the next decades. This paper presents an economic analysis of investments in flood protection infrastructure to mitigate increased disaster risk due to climate change and urbanisation based on hydrologic, engineering, and socio-economic considerations. The analysis is applied in the Ho Chi Minh City province of Vietnam, an area that is growing rapidly and is also subject to flooding. Probabilistic cost-benefit analysis is used to study the economic viability of alternative infrastructure designs for flood protection. The analysis improves upon traditional disaster risk planning by taking into account future changes in flood frequencies due to climate change and changes urban development due to economic growth. The framework presented illustrates the potential to incorporate economic methods in the evaluation of investments for disaster risk reduction and climate change adaptation.

D. C. Novoa (✉)
Department of Agricultural and Resource Economics, University of California, Davis, One Shields Avenue, Davis, CA 95616, USA
e-mail: davidcornov@yahoo.com; dcorderi@primal.ucdavis.edu

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Introduction

Heavily urbanised areas located in the low-lying deltas of Asia have been identified as being especially vulnerable to climate-related impacts (IPCC 2007). It has been predicted that coastal cities in East and South Asia will face an increase in the exposure of population and assets to flooding (Nicholls et al. 2008). Climate change projections suggest the possibility of an increase in the frequency and intensity of floods in these areas. At the same time, urban growth will increase potential flooding damages and vulnerability. Given these additional risks, coastal cities will need to revisit their flood protection investments and urban development plans. A balance will need to be found between the potential increases in flood damages and the economic benefits from growth in areas vulnerable to floods over the next decades.

A recent study by the Asian Development Bank has emphasised the vulnerability of the Ho Chi Minh City (HCMC) province to risks related to climate change and variability. The province is the main economic centre of South Vietnam and has a population of around 7–8 million people. HCMC accounted for over 23 % of the country's GDP in 2006 (ADB 2010) and has been growing rapidly −11.3 % annually between 2000 and 2007, attracting a lot of migrants from other areas of the region. According to government plans, economic growth in the province is expected to be 8.7 % between 2011 and 2025, and 8 % between 2026 and 2050 (ADB 2010). This rapid growth will entail an expansion in the urban areas to accommodate new industries and services. Urban development will however be constrained by hydro-climatic conditions. HCMC is a tropical coastal city located on the estuary of the Saigon–Dong Nai River basin of Vietnam. Much of the province is located in low-lying lands that are prone to frequent flooding associated with heavy monsoon rainfall, storm surges or even just high tides. Currently more than 12 % of the HCMC population is being affected by regular flooding (ADB 2010). Climate change can worsen flooding problems in HCMC province through potential sea level rises and increased frequency and intensity of extreme rainfall.

Long term disaster risk management strategies will need to incorporate climate change into the regional development plans of the area. There is currently a flood infrastructure investment master plan which amounts to almost USD 1 billion between now and 2050. The plan mainly covers the costs of building and upgrading more than 300 km of river and sea dikes to protect the districts in the province, and encompasses heightening the existing dikes by 1–3.6 m. The proposed investment plans constitute a first attempt at estimating future needs for disaster risk reduction. These plans use traditional frameworks of analysis where hydrology and engineering alone are used to determine flood infrastructure needs. However, the current plans have not taken full consideration of economic aspects such as the trade-offs between the benefits and costs of increased dike heights.

Additional economic analysis on flood infrastructure investments can shed light on the economic desirability of such infrastructure design choices. This paper proposes the use of probabilistic cost-benefit analysis and optimisation techniques to identify the trade-offs between the additional costs associated with increasing dike heights and the benefits of greater protection in the future. The objective of the analysis is to obtain the economically desirable future dike height level that takes into account two factors; the increase in the frequency of floods due to climate change and the increased value of economic activity at risk of floods due to urbanisation and growth. This economic analysis is expected to provide a framework for evaluating the net economic returns of long-term flood infrastructure investments.

The paper is organised as follows: "Existing economic approaches for analysing flood protection investments" reviews the existing approaches to analysing flood protection investments before "Hydro-economic analysis of flood protection investments" presents a summary of the study area, the methodological approach to follow and results. "Conclusion" concludes on the insights obtained through the analysis, the potential to replicate the analysis in other areas, and possible extensions.

Existing Economic Approaches for Analysing Flood Protection Investments

Traditional analysis of flood protection investments has been concentrated on determining the levels of risk for a particular intervention without taking into account the cost associated with it. The economic approach to flood investment planning follows cost-benefit analysis principles, measuring the trade-offs associated with increased costs and benefits of flood risk reduction investments. Normally, the costs of protection tend to rise at an increasing rate for additional flood protection. Measuring the benefits of flood protection investments includes a probabilistic element, reflecting the uncertainty of flood events (Young 2005). Expected annual damages represent the potential benefit attributed to a certain flood control project being in place. Moser (1997) provides a good overview of the different steps involved in estimating the benefits of flood protection for risk-based optimisation. These steps require a combination of assessment on the hydrologic, hydraulic, engineering and economic fronts. We will be following this approach in our analysis.

This economic framework for planning flood defences also emerged in the Netherlands in the late 1950s (Hillen et al. 2010). Van Dantzig (1956) pioneered this work by formulating the problem of optimal height of dikes as an economic-decision problem where the lower risks created by enhanced protection must be balanced against the increased costs associated with such protection. This methodology was developed after the flood disaster in 1953 in the south-western part of the Netherlands, which called for a reassessment of flood protection. Based on this approach it is possible to establish an optimal exceedance frequency of the design water level based on risk of flooding and cost of protection, which is also associated with the optimal dike height. Recently, Jonkman et al. (2004) applied this concept to flood protection investments in the Netherlands. Brouwer and Kind (2005) also elaborated a cost-benefit analysis of flood control policy in the Netherlands. Voortman (2003) and Voortman and Vrijling (2004) studied the implications of climate change for the design of flood defence systems. The authors extend Van Dantzig's model by considering uncertainty and the possibility of changes in flood frequencies in the design of flood protection investments. Jonkman et al. (2009) applied the same approach to analyse flood protection investments in New Orleans.

Van Dantzig's framework envisions a onetime investment decision which can be regarded as static. His formula assumes a fixed loss exceedance probability after each investment. However, expected yearly loss by flooding may be increasing over time due to continued economic growth in the flood plain. Eijgenraam (2006) extended the framework to consider periodic improvements in flood defences in response to ongoing economic development and changes in flood probability. When the potential damage increases by economic growth, the flooding safety level has to decline over time in order to keep the expected loss within a boundary of economically viable protection levels. This dynamic approach has been applied by Kind (2008) to all major dike rings in the Netherlands taking into account local economic factors (e.g. investment costs, growth rate) and damage level, a study which is more relevant for regional planning.

Long-term disaster risk management in California has also been studied given that the current flood protection system is under pressure from both climate change and land development. Researchers in California have developed risk-based optimisation frameworks to study long term flood protection strategies. Logan (1990) studied the economic implications of alternative flood control policies for the Sacramento-San Joaquin Delta, which is comprised of 46 islands protected by levees. The author's model ranks alternative policies using an economic model that simulates future climate scenarios and incorporates uncertainty in flood damages and construction costs. The model results suggest that it is not economically optimal to upgrade the levees in all islands given the costs and expected benefits of investment under a range of climate scenarios.

Lund et al. (2010) and Suddeth et al. (2010) extend the levee analysis in the San Joaquin delta and construct a model to evaluate a number of possibilities for levee improvement beyond a certain flood control plan. Their model tries to answer how the state of California should optimally prioritise levee upgrade efforts in the delta. At the same time, their model is able to evaluate the economic desirability of repairing the levee of an island once it has failed. The authors find that it is not economically viable to upgrade all levees in the system, and for some islands they also find that levee repairs are costly relative to the low economic productivity of the islands, as reflected in land and asset values. Their model is able to provide region-specific optimal decisions on levee upgrade and repair.

Zhu et al. (2007) study the flood protection investment implications of urbanisation and the intensification floods in the Sacramento River in California. The authors study the economic implications of different configurations of levee setbacks and levee heights under different climate change and urbanisation scenarios using an economic-engineering approach. The model integrates a probabilistic assessment and a hydraulic model of the river to analyse changes in flood frequency due to climate change and the subsequent probability of levee failure. The authors study the economic trade-off of increasing levee setback for additional protection and decreasing the annual land value benefits due to land reclamation.

This paper presents an economic analysis of flood protection investments to mitigate increased disaster risk due to climate change and urbanisation. The analysis is based on the principles suggested by Young (2005) and Moser (1997), following the framework proposed by Van Dantzig (1956). Given the quality of hydrologic and economic data, several assumptions will be made to be able to implement the economic optimisation model. Our economic framework evaluates the costs and benefits of alternative dike heights given future projections in 2050. This approach can potentially be extended to consider the temporal aspects of dike construction over the planning period as in Kind (2008) and Eijgenraam (2006).

Hydro-Economic Analysis of Flood Protection Investments

The Study Area: Ho Chi Minh Province

Hydrologic Conditions

HCMC province is located in the lower Dong Nai basin, a vast flat and low-lying area with an elevation of between 0 and 1 m above sea level. The river system in this area is a complex branched and looped river network connecting the Dong Nai, Sai Gon rivers via many canals and small rivers. The main large rivers have sections of narrow width and are meandering, which has certainly reduced the rivers' capacity to release floods, and the canals are strongly affected by tidal intrusion. In the rainy season, this lower part suffers inundation due to the high flows from the upstream part, tidal intrusion from the East Sea, and local rainfall within the lower basin itself. There are two man-made reservoirs, Dau Tieng and Tri An, located upstream, which regulate the freshwater flows into the lower basin.

The HCMC province is located in a tropical monsoon zone with high temperature and two clearly distinct rainfall seasons. Rainfall in the rainy season accounts for approximately 87–93 % of the annual total while the rainfall in the dry season is only 7–13 %. Annually, the rainy season begins in May and ends in

Table 32.1 Average monthly rainfall in the HCMC Province (in mm)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5.7	4.3	17.3	42.7	164.5	185.8	211.8	220.8	254.3	219.4	104.3	38.8

October, lasting approximately 6 months. As shown in Table 32.1, precipitation is highest in the months from May to November. Flow in the lower Dong Nai River basin is dominated mainly by rainfall regime, and therefore it varies accordingly in terms of time. The flood season, which occurs from June to November, begins approximately one to two months after the rainy season, and constitutes 80 % of the total annual flow.

According to past studies, the Dong Nai river basin experienced serious flooding problems in the year 1932, 1952, 1964, and 1978 (Doc Du Dung 2009). The flood in 1952 is considered as the largest recorded and the 1978 flood as the biggest in recent years. The 1952 flood is reported as a high flood with a return period of about 80–100 years. The flood was caused by typhoon with long-lasting heavy rainfall over a wide area. Maximum daily rainfalls recorded at major rain gauge stations in the basin ranged from 113 mm at Tan Son Nhat (Ho Chi Minh City) to 422 mm in the upper area (at Di Linh station). The 1978 flood took place during the period from the end of August to the beginning of September 1978. The return period of the flood was estimated to be about 10 years. The flood was caused by the heavy rain over the basin. Flood water levels are summarised in Table 32.2.

The Regional Economy and Flood Damage

HCMC province is the economic centre of southern Vietnam and has a population of around 7–8 million. HCMC accounted for over 23 % of the country's GDP in 2006 (ADB 2010) and has been growing rapidly −11.3 % annually between 2000 and 2007, attracting a lot of migrants from other areas of the region. According to government plans, economic growth in the province is expected to be 8.7 % between 2011 and 2025, and 8 % between 2026 and 2050 (ADB 2010). This rapid growth will entail an expansion in the urban areas to accommodate new industries and services. Table 32.3 presents disaggregated data on district population, past and projected, land value, area and production based on ADB (2010).

Urban development has been and will continue to be constrained by hydro-climatic conditions. Currently more than 12 % of the HCMC province's population is being affected by regular flooding (ADB 2010). Table 32.4 presents a summary of damages caused by floods in the lower Dong Nai basin based on Doc Du Dung (2009).

Table 32.2 Water levels during the 1952 flood and the 1978 flood along the main Dong Nai River

Location	1952 flood water level (m)	1978 flood water level (m)	Distance from Tri An (km)	Remarks
Tri An	NA	49.07	0	
Tan Dinh	11.04	7.37	28	Right bank
BinhThanh	7.80	NA	45	Right bank
PhuocThanh	5.68	NA	50	Left bank
Tan Hanh	5.60	NA	53	Left bank
Bien Hoa city	4.80	2.07	60	Right bank
HiepHoa	4.13	NA	62	Left bank
Long Binh	3.43	NA	70	Left bank
Long Dai	2.35	NA	73	Left bank
Thanh My Loi	1.50	NA	90	Left bank
Cat Lai	NA	1.48	90	
Nha Be	NA	1.48	102	Left bank

Flood Infrastructure Plans

The current flood infrastructure investment master plan amounts to almost USD 1 billion between now and 2050. The main investment costs are for covering the costs of building and upgrading more than 300 km of river and sea dikes to protect the districts in the province. This plan encompasses heightening the existing dikes by 1–3.6 m. Table 32.5 presents more details on the dike construction components of the proposed infrastructure plan based on Doc Du Dung (2009). Additional investments are geared towards constructing sluice gates, and improving canals in the area. The proposed investment plans constitute a first attempt to estimate future needs and use their own framework of analysis. Figure 32.1 contains a map with the location of the dike construction plans.

Economic Approach: Assumptions, Results and Limitations

Our economic optimisation model of flood infrastructure investment contains the following elements: (1) an estimated function of damages due to different levels of flooding; (2) an estimated relationship between increased dike height (i.e. different system configurations) and changes in the probability of flooding, and (3) the investment costs associated with improving the dike, i.e. a function that relates costs and the level of dike height increases. Further below, the assumptions and input information for these elements are summarised.

We use the economic model to analyse two areas that have plans to improve flood protection. One area is outside of the main city centre and is more rural (Nha Be District) and the other area is closer to the city and is more industrialised (Districts 2, 9 and Thu Duc: see Fig. 32.1). While the data used in the model is

Table 32.3 District level population, area, land value and Gross Domestic Product

District	Population 2007 (thousands)	Projected population 2050 (thousands)	Area (hectares)	Land value 2007 (1,000 VND/m^2)	GDP 2007 (million USD)
District 1	201	232	762	22,410	462.30
District 2	130	1,492	5,072	1,556	299.00
District 3	199	148	471	17,407	457.70
District 4	190	125	408	7,369	437.00
District 5	191	128	432	12,946	439.30
District 6	249	216	713	8,508	572.70
District 7	176	1,071	3,554	4,070	404.80
District 8	373	575	1,969	4,318	857.90
District 9	214	3,420	11,357	1,621	492.20
District 10	239	172	584	10,759	549.70
District 11	227	154	508	7,245	522.10
District 12	307	1,583	5,463	2,043	706.10
Go Vap	497	592	2,010	4,072	1,143.10
Tan Binh	388	671	2,226	4,934	892.40
Tan Phu	377	482	2,094	4,796	867.10
BinhThanh	450	623	468	10,127	1,035.00
PhuNhuan	176	146	4,692	9,234	404.80
Thu Duc	356	1,433	43,246	3,995	818.80
Binh Tan	447	1,557	10,838	1,932	1,028.10
Cu Chi	310	1,804	25,422	717	713.00
Hoc Mon	255	1,483	10,005	1,237	586.50
BinhChanh	331	1,926	61,284	3,217	761.30
Nha Be	75	437	1,575	1,778	172.50
Can Gio	67	393	5,192	423	154.10
Total	6,425	20,863	200,345		14,777.50

loosely based on these areas, it should be noted that a number of analytic simplifications and data imputations have been made. Therefore our results should not be seen as identifying a recommended course of action for either area. Instead, our analysis is meant to evaluate the relative merits of alternative flood infrastructure design strategies for dealing with urban growth and climate change.

Flood damage estimation is based on the study by ADB (2010) and previous studies by the Southern Institute of Water Resources Planning (Doc Du Dung 2009). These studies develop projections of population, land use and GDP growth based on government plans, and are used later on to perform hydrological analysis under future climate change conditions. Hydrodynamic models are used to determine the area, depth, and duration of flooding as well as estimating damage costs. In this analysis, it is assumed that flooding could only occur due to overtopping of the flood defences.

Following the methodology applied in Vietnam by Van Mai (2010), we construct a probabilistic flood damage curve using a log-normal distribution in each

Table 32.4 Damages by floods in recent years in the river system

		1997	1998	1999	2000	2001
Total Damage	billion VND	41.1	58.5	229.8	873.5	125.9
Damages in terms of agriculture	billion VND	35.0	53.9	167.6	433.8	60.3
1. Cultivation						
a. Total area		37,054.0	30,075.0	38,069.0	104,683.0	22,731.0
–Yearly crops	ha	36,884.0	29,245.0	35,285.0	95,229.0	21,744.0
–Perennial crops	ha	170.0	830.0	2,784.0	9,454.0	987.0
b. Damaged area	ha	7,623.0	8,157.0	21,103.0	45,563.0	5,784.0
–Rice	ha	5,459.0	7,222.0	18,112.0	31,956.0	4,459.0
–Crops, short industrial plants	ha	2,164.0	810.0	2,376.0	12,900.0	1,035.0
–Perennial crops	ha		125.0	615.0	707.0	290.0
2. Livestock	billion VND					
a. Cattle, poultry that are dead	animal	–	–	4,535.0	180,902.0	494.0
b. Areas of aquaculture that are flooded	ha	331.0	35.0	875.0	1,072.0	296.0
Other damages	billion VND	6.1	4.6	62.2	313.8	65.6
1. Fatality	person	2.0	9.0	17.0	48.0	28.0
2. Houses	house					
a. Flooded	house	2,632.0	839.0	18,428.0	102,063.0	24,161.0
b. Swept way, broken	house	438.0	5.0	2,321.0	9,595.0	490.0
3. Transportation						
a. Bridges damaged	bridge	7.0	143.0	441.0	592.0	96.0
b. Roads flooded, eroded	km	90.0	123.0	819.0	1,431.0	609.0
4. Irrigation works						
a. Sewers, dams damaged	item	37.0	26.0	88.0	69.0	4.0
b. Dykes, channels eroded	km	21.0	27.0	103.0	1,931.0	1,371.0

Table 32.5 Proposed flood protection investments in the lower Dong Nai basin system

Region	Description	Investment cost 2050 (bil. VND)	Length of dikes (km)
I	Area between Sai Gon river and East Vam Co river	11,451	172.25
II	Areas in the left banks of Sai Gon River	363	41.09
III	Areas between East Vam Co and West Vam Co	1,340	151.67
IV	Areas in the left bank of Dong Nai river	629	71.26
V	Areas in the left bank of Dong Nai river	2,058	19.5
	Total	15,841	455.77

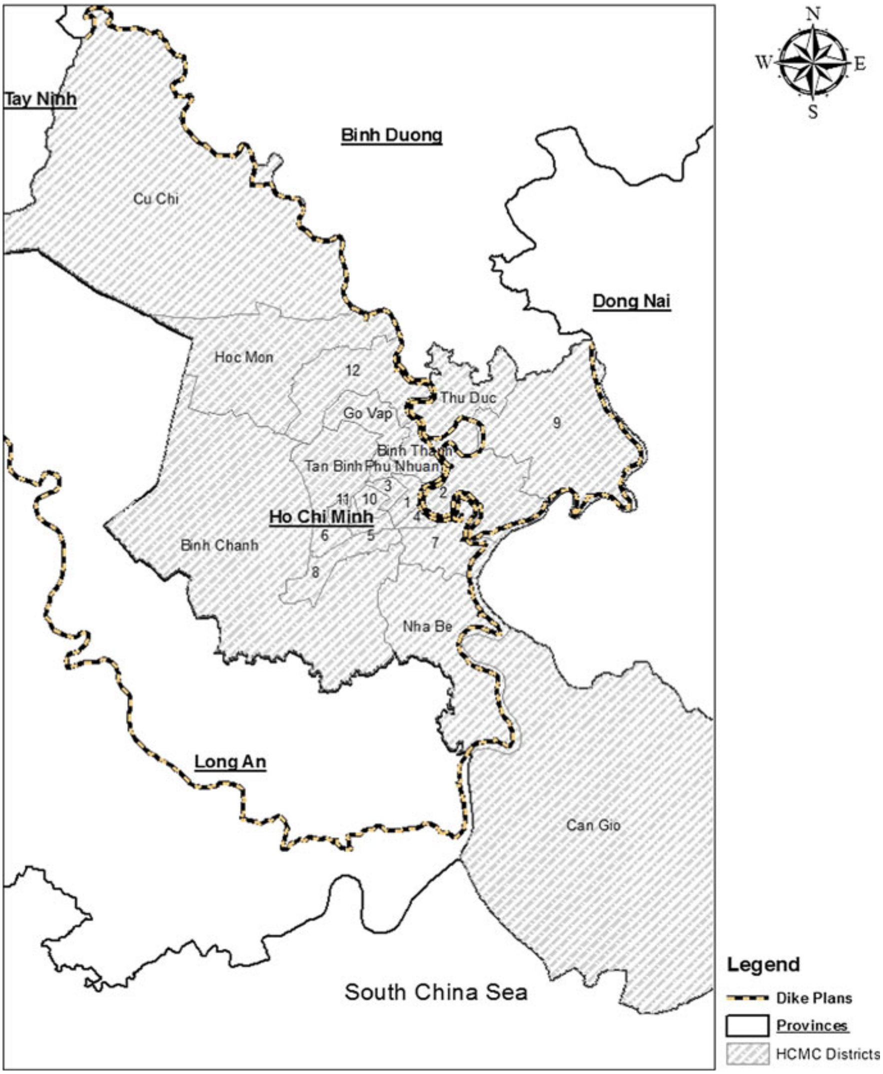

Fig. 32.1 Dike investment plans

area. Various water levels associated with probabilities of different return periods are used to approximate the needed dike height. The cost of dike heightening is based on Van Mai (2010) and Doc Du Dung (2009).

The economic optimisation model aims at minimising total expected cost in the area to be protected and can be formally written as:

$$Min\, ETC\left(H, P_f\right) = P_f(H) * D + C(H)$$

Table 32.6 Characteristics of the urban and rural areas for flood protection

Type	District	Population 2050 (thousands)	Area (ha)	Planned dikes (km)	Flooded area in ha (average duration in days)	Estimated cost of floods 2050 (billion VND)
	District 2	1,492	5,072		3,036 (127)	5,719
	District 9	3,420	11,357		5,877 (140)	14,014
	Thu Duc	1,433	43,246		1,593 (95)	4,312
Urban	Total	6,345	59,675	72	10,506 (-)	24,045
Rural	Nha Be	437	15,750	20	7,948 (95)	9,572

where
ETC(.) = expected total cost
H = designed dike height
P_f = overtopping probability with dike height at H
D = flood damage
C(.) = cost of building a levee at height H

The objective of the model is to minimise expected total cost by choosing the height of the dike to be constructed in the area to be protected. Our model formulation implicitly incorporates the fact that higher dike heights correspond to a smaller probability of flooding and, therefore, lower expected damage, the first term in the total cost equation. By summing the costs and the expected damage or risk, the total costs are obtained as a function of dike height which can also be thought of as a safety level.

Table 32.6 presents some of the characteristics of the flood protection areas to be considered in the study. Flooded area and estimated flood damages have been taken from ADB (2010) to provide a reference for the readers. As can be seen in the table, the more urbanised district has a greater value at risk of flooding and has also a greater flood investment protection scheme, with 70 km of dikes. The rural area has developed at a slower pace (see Table 32.3 for comparison) and therefore has a lower value at risk. Both areas face slightly different flooding conditions due to their location; however, the cost of increasing dike heights is the same for both regions.

Results of the economic optimisation for each of the areas suggest that the optimal dike height for rural and urban areas differs, see Figs. 32.2 and 32.3. The economically viable height increase in rural areas is around two meters, whereas for heavily urbanised areas it is around three meters. These results suggest that the safety standards for the various dikes depend on the economic value of the area and the characteristics of flooding. Areas where population and urbanisation occurs faster will need to have a higher level of protection from an economic point of view. Peri-urban areas that base their development in rural activities will be

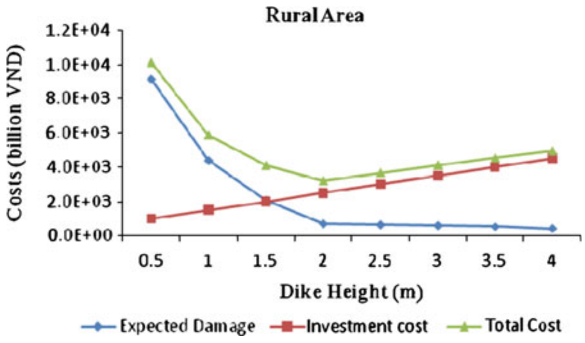

Fig. 32.2 Results of economics optimisation for rural area district

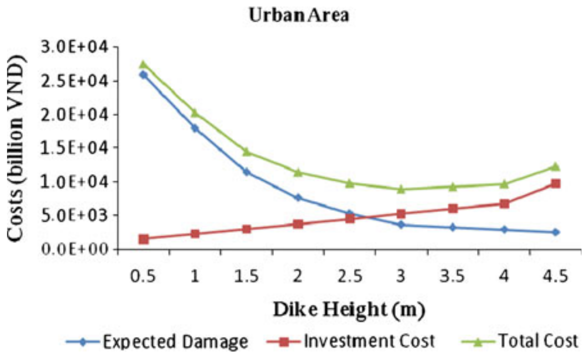

Fig. 32.3 Results of economics optimisation for urban area district

subject to lower levels of protection. This implies that other disaster risk management actions that have a lower cost than infrastructure investments will need to be considered in rural areas. Ultimately, relocating current settlements towards other areas where greater protection is economically justified constitutes another alternative.

The analysis presented in this paper has a number of limitations that are worth mentioning. The future flood damage costs have been estimated based on rough indicators. There is thus considerable uncertainty associated with these estimates. Different changes in population, economic activity and spatial development could lead to alternative damage estimation. In addition to this, cost estimation does not take into account the value of critical assets such as infrastructure, water supply or even wildlife habitat. Life costs and other indirect damages are also not taken into account. A more thorough cost and valuation study for HCMC province will greatly enhance the resolution of the model.

Flood protection has only been analysed through investments in dike infrastructure; however, there are other options available that can reduce flood damages and disaster risks such as improving drainage and pumping or even emergency responses. Our analysis does not take into account the sources of funding for dike upgrade and repair, an important element in decision-making.

The economic optimisation proposed here could also be extended in several directions. The assumption of risk neutrality in the optimisation can potentially be reconsidered and therefore include a penalty against larger flood damages, i.e. risk aversion. Equity considerations can also be included in the optimisation model so that protecting rural areas has a greater societal benefit. Finally, the optimisation model can be extended to consider the temporal aspects of infrastructure investment planning.

Conclusion

This paper has presented an economic analysis of investments in flood protection infrastructure to mitigate increased disaster risks considering hydrologic, engineering and socio-economic aspects. The analysis is applied in the Ho Chi Minh City province of Vietnam, an area that is growing rapidly and is also subject to flooding. Probabilistic cost-benefit analysis is used to study the economic viability of alternative infrastructure designs to reduce future disaster risks taking into account future changes in flood frequencies and urban development. Preliminary results suggest the level of risk reduction depends on the economic value of the area and the characteristics of flooding. It is economically more efficient to provide greater protection in areas where population and urbanisation growth is higher, whereas lower levels of protection are more desirable for areas that are not growing as fast. Regardless of limitations, an important and inescapable conclusion of this analysis is that maintaining the same level of flood safety in all HCMC is unlikely to be economical from a regional perspective. Consequently, alternative long-term disaster risk management interventions will need to be factored into the planning process.

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Author Biography

David Corderi Novoa is an economist specialising in planning, regulation, and policy analysis in the fields of water resources, energy, agriculture, and climate change. He has worked with governmental institutions and private companies while serving as a consultant at international organisations such as the World Bank, the Asian Development Bank, and the United Nations Development Programme. His regional experience spans countries in Latin America, Asia, Africa and Europe. David has a Master's degree in International and Development Economics from Yale University and a PhD in Agricultural and Resource Economics from the University of California at Davis.

Part IV
Category 4

Chapter 33
Adapting to Climate Change in a High Mountain Environment: Developing a Monitoring Expert System for Hazardous Rock Walls

Ingo Hartmeyer, Markus Keuschnig, Jan-Christoph Otto and Lothar Schrott

Abstract The research project MOREXPERT ("Monitoring Expert System for Hazardous Rock Walls") investigates short and medium term responses of slope stability to climatic changes in high alpine rock walls. The study contributes to the question how man and infrastructure are potentially affected by these responses. Based on a combination of geophysical, geotechnical and borehole measurements, surface and subsurface conditions are monitored within the study area at the Kitzsteinhorn (3.203 m), Hohe Tauern, Austria. Factors controlling slope stability in steep bedrock, most notably freeze/thaw and permafrost dynamics, are identified and analysed with respect to changing climatic conditions. The fundamental goal of this research project is the development of a general decision support system for slope stability assessment in steep bedrock. Due to its flexible structure the decision support system is intended to be adaptable for application to rock walls of other regions.

Keywords Permafrost · Rockfall · Slope stability · Rock mechanics · Monitoring · Climate change adaptation · Natural hazards

I. Hartmeyer (✉) · M. Keuschnig · J.-C. Otto · L. Schrott
alpS Centre for Climate Change Adaptation Technologies,
Grabenweg 68, 6020 Innsbruck, Austria
e-mail: hartmeyer@alps-gmbh.com

M. Keuschnig
e-mail: keuschnig@alps-gmbh.com

J.-C. Otto
e-mail: jan-christoph.otto@sbg.ac.at

L. Schrott
e-mail: lothar.schrott@sbg.ac.at

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Introduction

In the context of climate change the stability of rock walls in high mountain areas is an important risk factor for local population, tourism and infrastructure (Harris et al. 2001a). An answer to the question of how climate change alters slope stability in steep bedrock is particularly critical for rock faces underlain by permafrost (Gruber et al. 2004; Gruber and Haeberli 2007). Permafrost-affected bedrock is known to react especially sensitively to climatic warming, and at the same time constitutes large proportions of high-alpine rock faces in Austria (Otto et al. 2010). MOREXPERT therefore holds a strong focus on the investigation of bedrock permafrost, its thermal state and potential future changes.

In permafrost-affected bedrock it is generally accepted that changes of rock and ice temperature affect the stability of a rock wall as the propensity for failure along a discontinuity (e.g. joint plane, fracture) is prone to sub-zero temperature changes. Reasons for this are that alterations of rock mechanical properties and ice mechanical properties that occur during warming (Mellor 1973; Davies et al. 2000; Krautblatter et al. 2010).

A large number of field observations emphasise the importance of the relationship between warming and destabilisation. Numerous rockfall events in steep permafrost-affected rock point to an increasing occurrence of mass movements in the European Alps due to changing climatic conditions. During the hot summers of 2003 and 2005 a large number of rockfall events were triggered from steep bedrock areas underlain by permafrost without preceding precipitation or earthquake (Gruber and Haeberli 2007). In several cases massive ice was visible in the exposed detachment zones (Bommer et al. 2009). Permafrost warming and thaw are therefore considered to be decisive mechanisms through which climate influences the occurrence of natural hazards.

The causal relationship between warming and destabilisation clearly demonstrates the need for the investigation of thermal changes occurring in high-alpine rock walls. MOREXPERT addresses this need as numerous techniques are applied to assess the thermal state of rock faces within the study area and its implications for slope stability.

Mountain permafrost research is a relatively new scientific discipline that emerged in the early 1970 s (Haeberli et al. 2010). Long-term data series on permafrost conditions are limited but essential for the understanding of permafrost dynamics and related processes. As a consequence the projects Permafrost and Climate in Europe (PACE) (Harris et al. 2001b), the Swiss Permafrost Network (PERMOS 2010) and the Permafrost Long-term Monitoring Network (PERMANET 2011) initiated long-term permafrost monitoring in the Alps. Particularly high mountain peaks in the western Alps (e.g. Schilthorn [CH], Matterhorn [CH], Aiguille du Midi [F]) have been equipped for continuous monitoring of permafrost (PERMOS 2010; Ravanel et al. 2011). In Austria, extensive monitoring (e.g. with deep boreholes and geophysics) of permafrost is limited to very few sites (e.g. Hoher Sonnblick).

MOREXPERT initiates a new long-term monitoring site focusing on the relationship between permafrost and mass movements at the Kitzsteinhorn, Austria. The project is embedded within the frame of the alpS Centre for Climate Change Adaptation Technologies in Innsbruck, Austria. MOREXPERT started in September 2010 and will run for at least four years. This article should therefore be understood as a progress report with lots of further results to follow at a later date.

Objectives

Within MOREXPERT a number of challenges on theoretical, technical and application-oriented levels are encountered. The objectives can be grouped into three thematic categories respectively:

- On a theoretical level an improvement of the understanding of processes operating in high alpine rock faces is targeted. Based on data from our monitoring system the authors attempt to identify and analyse causing and triggering factors of potentially hazardous rockfall events with respect to climatic changes. The improvement of our knowledge regarding the relationship of warming and destabilisation is crucial for the development of efficient climate change adaptation strategies (Gruber and Haeberli 2007).
- On a technical level, the objective is the establishment and maintenance of a sophisticated monitoring system in a rugged high-mountain environment targeted. Technical challenges include, for instance, the installation of measuring instruments in steep and inaccessible terrain and the robust design of measuring instruments to resist low temperatures and natural hazards (e.g. avalanches, rockfall) (Bommer et al. 2009).
- On an application-oriented level a general decision-support system (DSS) for slope stability assessment in steep bedrock is developed. The DSS will be designed utilising information gained from the monitoring system, its application, however, should not be limited to the project's study area. It is considered by the authors as a transferable best-practice guide that can be applied to potentially hazardous rock faces in other mountain environments. Amongst other things, the decision-support will offer recommendations for the efficient and targeted application of several state-of-the-art methods to detect/monitor potentially hazardous processes.

Study Area

The study area is located at the Kitzsteinhorn (3.203 m), situated in the Hohe Tauern, Austria's highest mountain range (Fig. 33.1). It consists of rocks of the Glocknerdecke, primarily of limestone-micaschists. The study area is comparatively small,

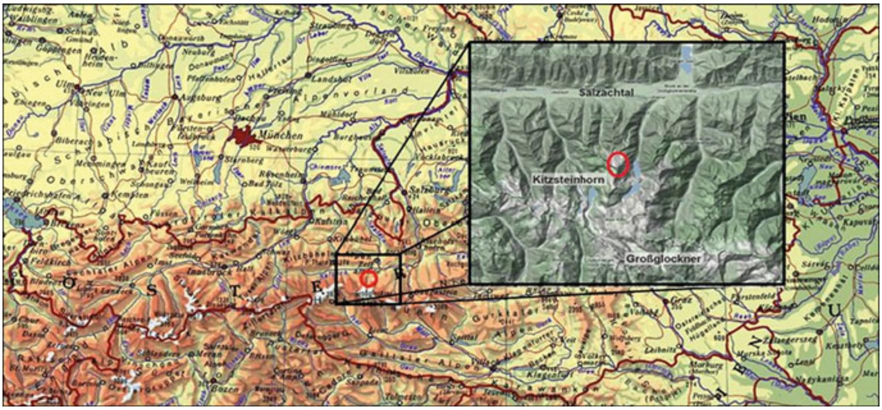

Fig. 33.1 Location of the study area (Kitzsteinhorn)

encompassing the summit pyramid and covering approximately 35,000 m^2. It extends from the top of the Schmiedingerkees glacier (2.950 m) to the summit of the Kitzsteinhorn.

Numerous reasons support the selection of the Kitzsteinhorn as our study area. The intense glacier retreat in recent decades has led to a very dynamic glacier-permafrost interaction at the Kitzsteinhorn. Particularly the melting of ice faces led to an increased occurrence of rockfall events. Due to the ongoing retreat of the Schmiedingerkees glacier some rock faces have lost their natural bearings, thereby creating overly steep cirque walls. The generally high rockfall susceptibility makes the Kitzsteinhorn an ideal study area for the investigation of slope stability issues.

The tourism infrastructure existing within the study area (cable car, ski lifts, ski slopes, etc.) is directly affected by alterations of rock stability. The cable car station in the study area accounts for an excellent logistic situation that enables convenient transportation of heavy measuring equipment. The western ridge of the Kitzsteinhorn is crossed by a gallery (tunnel) 400 m in length. The existence of a gallery of these dimensions allows the acquisition of (thermal) information from great depths which represents another major advantage of the Kitzsteinhorn study area.

Finally, the study area has a very long tradition of high mountain research. An abundance of historical data on glaciology and meteorology allow the compilation of long time series to estimate the consequences of climatic changes over the last century (e.g. Tollner 1951).

Monitoring Concept

A sophisticated slope stability monitoring system is currently established in the study area. The monitoring system comprises various state-of-the-art methods that allow the complementary acquisition of surface and subsurface information

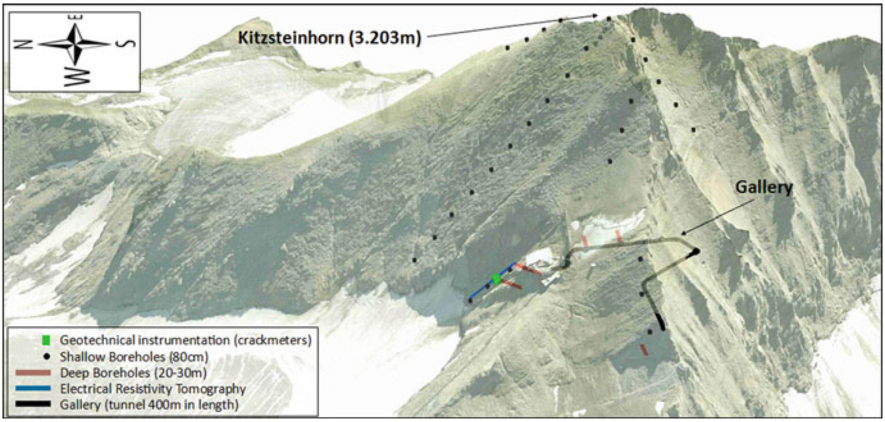

Fig. 33.2 Overview of permanently installed instrumentation

(Fig. 33.2, Table 33.1). As a consequence, data on changes occurring at the surface (e.g. rockfall events) can be directly related to potential subsurface (thermal) changes (e.g. deepening of active layer). The relationship between surface and subsurface processes is central to the project and represents a major distinctive feature to numerous other (monitoring) projects that frequently focus on the investigation of one geomorphic process set.

Furthermore the authors want to emphasise that the application of all methods and techniques (listed below) is limited to the comparatively small mountaintop area of the Kitzsteinhorn. The application of a large number of different methods in a relatively small area is another important characteristic of the MOREXPERT project as other research projects frequently investigate entire mountain ranges or climate zones (e.g. Allen et al. 2009).

The temporal scale of investigation within the monitoring concept depends on the observed process. It ranges from permanent monitoring for very dynamic processes (e.g. frost weathering) to time-section monitoring on a seasonal or annual basis for less dynamic processes (e.g. reaction of rock temperatures in great depths).

Geophysical Methods

In high mountain and polar studies geophysical methods can be applied to investigate, for instance, the thickness and occurrence of ground ice or the physical characteristics of permanently frozen ground (Hauck and Kneisel 2008). To gain information on subsurface properties and processes that take place a few meters below the surface two geophysical methods will be applied: (i) ERT (Electrical Resistivity Tomography) and (ii) GPR (Ground Penetrating Radar).

Table 33.1 Methods applied within the MOREXPERT project

Applied methods	Permanent monitoring	Periodical monitoring
Geophysical methods		
Electrical Resistivity Tomography (ERT)	✔	✔
Ground Penetrating (GPR)	X	✔
Geotechnical methods		
Crackmeter	✔	X
Laserscanning		
Terrestrial laserscanning	X	✔
Airborne laserscanning	X	✔
Borehole temperature data		
Deep boreholes (20–30 m)	✔	X
Shallow boreholes (80 cm)	✔	X
Climate data		
Meteorological station	✔	X
Mapping techniques		
Geomorphological mapping	X	✔
Geotechnical/Geological mapping	X	✔

Electrical Resistivity Tomography (ERT)

ERT represents the tomographic variant of the direct-current (DC) resistivity method. It is the most commonly applied method for permafrost-related investigations. ERT measurements are conducted by feeding a direct electrical current into the ground using two electrodes. The resulting voltage difference is recorded at two potential electrodes (Hauck and Kneisel 2008). This four-electrode-array is repeated several times with varying distances between the electrodes along a profile line. As a consequence the resistivity distribution of the recorded subsurface area can be reconstructed.

ERT is very well suited to distinguish between frozen and unfrozen subsurface regions as a marked increase of electrical resistivity occurs at the freezing point (Krautblatter et al. 2010). Within the MOREXPERT project two permanent ERT arrays will be installed in a north-facing rock slope directly underneath the cable car summit station. These arrays will allow continuous monitoring of resistivity changes at different scale levels at an hourly basis. As electrical resistivity strongly depends on temperature, permanently installed ERT arrays represent a valuable method to gain information on occurring subsurface thermal changes.

In addition to these permanently installed arrays ERT measurements will be conducted at several sites within the study area, including the gallery. To monitor occurring changes these measurements will be repeated with different time intervals (seasonally, annually) creating time-sections of the monitored area. Thus, insights into important causing/triggering factors of rockfall such as frost weathering and active layer deepening can be achieved.

Ground-Penetrating Radar (GPR)

During GPR measurements an electromagnetic pulse is transmitted into the ground from an antenna. As the electromagnetic wave propagates into the ground it is partially reflected by subsurface boundaries of materials with different electromagnetic properties. Subsequently the reflected energy is recorded by a receiver antenna. Depending on the frequency of the transmitted wave a very high vertical resolution can be achieved. The time interval between transmission and reception can be translated into depth if the travel velocity of the subsurface layers is known (Hauck and Kneisel 2008).

Large contrasts between electromagnetic properties of rock and ice make GPR a very well-suited method to measure ice thickness (Hauck and Kneisel 2008). Within the MOREXPERT project GPR measurements are applied to record the decreasing ice thickness of the Schmiedingerkees glacier and to gather information on sub-glacial topography. Knowledge of the morphology of rock faces currently covered by glaciers is crucial as these areas might become ice-free in the near future. Newly exposed rock surfaces are subject to greater temperature amplitudes and in particular to freeze–thaw cycles in summer, and therefore frequently represent overly steep zones that are particularly susceptible to rockfall.

Geotechnical Methods

Joints and fractures in bedrock represent pathways of potentially intensified heat propagation and therefore play an important role in the thermal development of a permafrost body. Within the MOREXPERT project joint apertures will be continuously monitored in two localities using wire-extensometers that are connected to data loggers. Changes to the joint aperture combined observed with geophysical and thermal monitoring can give valuable information on freezing dynamics, which, in turn, are an important triggering factor of rockfall incidents.

Terrestrial Laser Scanning (TLS)

TLS creates highly accurate, three-dimensional images of the scanned area. By sweeping a laser beam over a defined scene, a laser scanner is able to record millions of data points. TLS allows an accurate quantification of changes in geometry and volume in steep terrain over distances of several hundreds of metres (Ravanel and Deline 2010; Kenner et al. 2011). A spatial and temporal analysis of erosive processes occurring in the Kitzsteinhorn study area will be conducted using TLS. Information gained from the TLS campaign should yield “hot spots” of rockfall activity. By combining TLS data on changes occurring at the surface with subsurface geophysical and thermal data the authors hope to contribute towards an improved process understanding of rockfall triggering mechanisms.

Borehole Temperature Data

Mountain permafrost temperatures in the Alps are generally only a few degrees below zero (Vonder Muehll et al. 1998). A slight shift in energy flux at the ground surface could therefore lead to significant permafrost degradation. Long-term ground temperature monitoring in boreholes represents the most important research tool for detecting potentially hazardous thermal anomalies and warming trends.

Deep Boreholes

To investigate the subsurface thermal and geological situation, five boreholes with depths between 20 and 30 m were drilled in selected sites of the Kitzsteinhorn study area. The boreholes were created by rotary drilling (90 mm diameter) using air flush to avoid contamination of frozen ground with water. To prevent the intrusion of melt water into the borehole a PVC casing will be inserted into the boreholes. The space between the PVC tube and the bedrock will be filled with concrete to allow good thermal connection to the surrounding rock. Each borehole will then be equipped with 10–15 temperature loggers (thermistors) allowing precise measurement of ground temperatures. Downhole geophysical logging will offer valuable information on the lithological situation, as well as on the existence and characteristics of joint sets.

Thickening (deepening) of the active layer in steep bedrock potentially causes large and therefore extremely hazardous rockfall events with deep-seated detachment surfaces. For instance, high rockfall activity during the extremely hot summers of 2003 and 2005 is widely considered as a consequence of active layer thickening. Continuous monitoring of active layer thickness by means of borehole temperature data represents one of the most important tasks of slope stability risk assessment within our project. Temperature data from boreholes will furthermore be utilised to verify and calibrate electrical resistivity values from ERT measurements.

Shallow Boreholes

Aside from five deep boreholes about 30 rock temperature loggers in depths of up to 80 cm will be installed to gather information on near-surface bedrock temperatures. The temperature loggers will be evenly distributed covering different elevation, slope and aspect. Temperature logging will be conducted by simply deploying iButtons® (Model DS1922L) will be used. iButtons are coin-sized devices that integrate storage, real-time clock, temperature sensor and battery in a single package. The objective of these temperature recordings is to obtain a spatially-distributed dataset on near-surface ground temperatures. Furthermore, information on the relevance of various influencing factors such as air temperature, topography, exposition to solar radiation and ground properties can be gained.

Climate Data

Climatic factors control ground surface temperatures. Ground surface temperature in turn is one of the most important factors influencing the ground thermal regime. Therefore knowledge of meteorological components such as air temperature, solar radiation or snow cover is crucial for the understanding of the thermal state of permafrost-affected bedrock and its future development. Within the MOREXPERT project atmospheric conditions will be monitored with a weather station located on the Schmiedingerkees glacier allowing automated observation of air temperature, wind speed, humidity, snow depth, etc.

First Results

In this chapter investigations that were conducted to set up and prepare an efficient monitoring system at the Kitzsteinhorn will be discussed. Again the authors want to emphasise that the monitoring project still is in the early stages, currently being in the first of at least four years. The results outlined in this chapter should therefore be interpreted as first findings that served as a basis for the definition of the monitoring concept discussed above. Within these first investigations the authors focused on a preliminary assessment/evaluation of the thermal state of the rock faces within the study area. This is considered to be of particular importance as rock temperatures have a major influence on slope stability in steep bedrock.

Geotechnical Survey

Preliminary investigations included geotechnical mapping of large parts of the study area. Valuable data on joint orientations and characteristics as well as on block size and shape were obtained. Rockfall, rock slide and rock topple emerged as the major mechanisms of slope failure. The geotechnical mapping campaign demonstrated an abundance of well-developed joint sets with large joint apertures. A detailed survey of their orientation and configuration showed that the

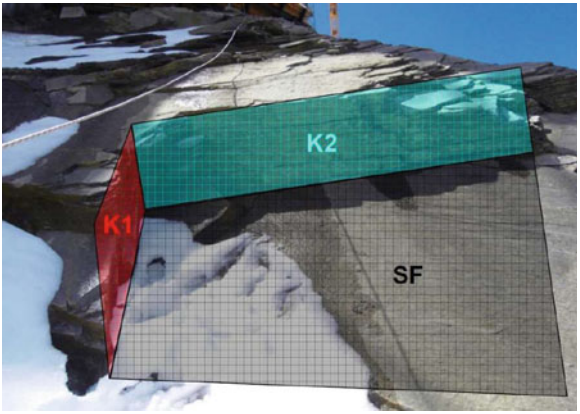

Fig. 33.3 Major joint sets (K1, K2) and schistosity (SF) yield cubic joint-bordered rock bodies

intersection of the major joint sets yields cubic joint-bordered rock bodies, frequently of considerable size (Fig. 33.3).

The geotechnical survey proved that the occurrence of mass movements is primarily controlled by the configuration of joint sets. This has very important implications for the investigation of potential triggering factors, because these joints and fractures represent zones of potentially intensified heat propagation that react sensitively to thermal changes—which yet again underlines the importance of having precise information on the thermal state of rock faces.

Permafrost Modelling

Rock faces affected by permafrost are considered to react particularly sensitively to future climatic changes. Knowledge of the permafrost distribution is therefore critical for slope stability considerations. Permafrost distribution was calculated using the PERMAKART 3.0 model developed by Felix Keller (Academia Engiadina, Switzerland). This model is an empirical-statistical model based on a topo-climatic key which analyses the relation between altitude, slope, and aspect (with foot-slope positions being taken into account as well). The modelling shows that particularly the northwest and to a lesser degree the north-eastern face of the Kitzsteinhorn are underlain by permafrost (Fig. 33.4).

Electrical Resistivity Tomography

A high-resolution Electrical Resistivity Tomography (ERT) inside the subterranean gallery (tunnel) that crosses the Kitzsteinhorn west ridge was performed. The ERT-array was installed in the eastern side wall of the gallery yielding a horizontal (eastbound) direction of investigation. The maximum depth of investigation was

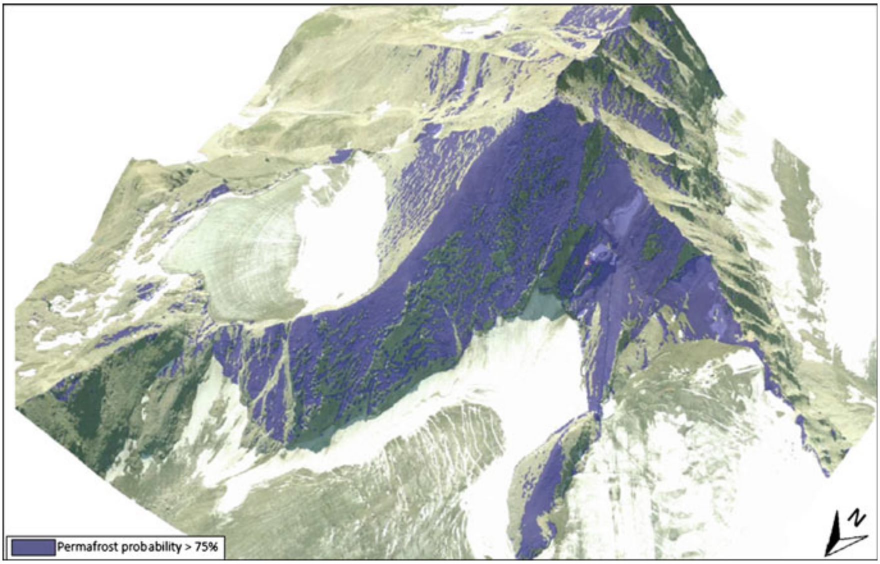

Fig. 33.4 Modelled distribution of permafrost distribution at the Kitzsteinhorn

21 m. The vertical bedrock overburden of the gallery ranges from approximately 20 m to 70 m (Fig. 33.4).

To gain thermal information from the data acquired in the gallery, electrical resistivity was measured as a function of temperature using a 40 × 20 × 20 cm limestone-micaschist sample taken from the study site. The water-saturated rock sample was frozen and thawed several times in a freezing chamber. During these freeze–thaw cycles a four-point Wenner array configuration was employed which confirmed the bilinear temperature-resistivity relationship postulated by Krautblatter et al. (2010).

Final interpretation of acquired ERT data cannot be performed until petro-physical parameters have been analysed and an ERT data error characterisation has been conducted. Preliminary interpretation of ERT data suggests the existence of permafrost-affected rock in the northern part of the tomography as resistivity values measured in this area correlate with temperatures well below the freezing point. The central part of the tomography represents unfrozen rock. Resistivity values in this area correlate with temperatures above the freezing point. The south (right) section of the tomography is influenced by its vicinity to the Kitzsteinhorn south wall. Seasonal frost (cold spell, June 2010) presumably penetrated through open joint systems yielding sub-zero temperatures (high resistivities) in this area (Fig. 33.5). This assumption emphasises the importance of joint systems as zones of intensified heat propagation that react sensitively to thermal changes.

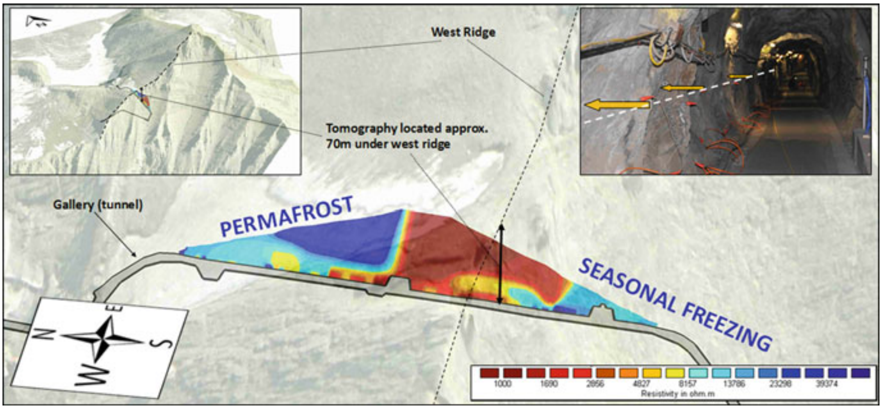

Fig. 33.5 Location, orientation and tomography of ERT conducted inside the Kitzsteinhorn gallery

Conclusions and Outlook

Permafrost ground thermal regimes generally react with considerable lag times to climatic changes. MOREXPERT therefore has been designed as a *long-term* monitoring scheme to investigate these time lags and, additionally, to estimate consequences of climate change.

Within the MOREXPERT project the Kitzsteinhorn monitoring site shall be established as one of Austria's most important reference test sites for permafrost and mass movement research in a high mountain environment. Geotechnical investigations seem to represent the most important step in this early stage of the project. In particular, quantitative analysis of the rock mass, for example by TLS investigations, or from laboratory tests, is necessary and will be intensified to improve slope stability analysis and rockfall modelling.

Permafrost has been modelled and detected within the north–west and north–east face of the Kitzsteinhorn peak. First laboratory analysis delivered a calibration of ERT values and rock temperature. By Spring 2012, five deep boreholes (20 to 30 m) and 60 near-surface boreholes will be equipped with temperature sensors. In addition, two permanent ERT arrays will be installed directly below the summit station.

The implementation of the presented monitoring concept will provide valuable insights into thermal changes occurring in high-mountain rock faces affected by permafrost. The combined monitoring of surface and subsurface processes has the potential to bring forth new findings on the coupling between climate change (warming) and destabilisation (mass movements)—a link that is non-trivial as it is frequently governed by non-linear processes/response-times.

In addition to these objectives directed towards a better understanding of processes operating in high alpine rock walls, the authors intend to derive new combinations of geophysical/geotechnical methods to efficiently monitor potential causing/triggering factors of rockfall. Application of gained information is not intended to be limited to project's study area and will be available as a best-practice guide for slope stability assessment.

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Author Biographies

Ingo Hartmeyer was born July 28 1983 in Vienna, Austria. He graduated from the University of Vienna in 2008 with an academic degree in Geography (Geomorphology). He is currently a PhD student at the University of Salzburg, within the Department of Geography and Geology research group, "Geomorphology and Environmental Systems".

Markus Keuschnig was born February 26 1978 in Schwarzach/St.Veit, Austria. He graduated from the University of Salzburg in 2010 with an academic degree in Applied Geoinformatics. He is currently a PhD student at the University of Salzburg, investigating rock permafrost distribution and dynamics.

Jan-Christoph Otto holds a post-doctoral position at the University of Salzburg (Department of Geography and Geology). His research interests lie in geomorphological processes and landscape dynamics, with special focus on sediment budgets and landform change as a reaction to environmental change, especially in mountain areas (European Alps, Andes).

Prof. Lothar Schrott is the head of the research group "Geomorphology and Environmental Systems" at the University of Salzburg. His research activities focus mainly on geomorphic processes in mountainous areas (European Alps, Rocky Mountains, Andes). Current research projects are related to sediment budgets, mass movements and high mountain permafrost.

Chapter 34
Addressing Adaptation to Support Disaster Risk Reduction: A Framework for Supply Chain Inclusive Adaptation to Climate Change

Andreas Benedikter, Peter Läderach, Anton Eitzinger, Simon Cook and Michele Bruni

Abstract Global climate change (GCC) presents serious challenges to agricultural systems as they strive to meet increasing demand over the coming decades. Within these systems, food value chains are increasingly recognised as being vital for development, yet relatively little is known about the vulnerability of such chains to GCC, or their capacity to adapt. This paper provides a framework to examine how food value chains are affected by the uncertain impacts posed by GCC and what this implies for adaptation. While intervention models mostly deal with measures for producers, the authors hypothesise that adaptation strategies must include the entire chain to achieve the scale needed to tackle GCC. The authors propose that comprehensive situation assessment is necessary to examine both behaviour and assets—two key attributes for adaptive capacities. This framework examines three sets of attributes: (1) The general setup and nature of the supply chain; (2) rural livelihoods' and food supply systems' vulnerability to GCC, including downscaled crop suitability modelling to assess precise impacts of GCC, and (3) the behaviour of people and entities involved in value creation and the institutions mediating them. The framework provides decision-makers with a scale, crop and site

A. Benedikter (✉) · P. Läderach · A. Eitzinger · S. Cook · M. Bruni
International Centre for Tropical Agriculture (CIAT), San Juan de los Robles,
Del Restaurante La Marseillaise 2 cuadras al lago, Casa 303 Managua, Nicaragua
e-mail: a.benedikter@gmail.com; p.laderach@cgiar.org

P. Läderach
e-mail: p.laderach@cgiar.org

A. Eitzinger
e-mail: a.eitzinger@cgiar.org

S. Cook
e-mail: simonernest@gmail.com

M. Bruni
e-mail: MBruni@oxfam.org.uk

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independent road map to design and evaluate adaptation strategies to changing climate conditions. The authors test the framework in three case studies with differing supply chain characteristics and geographical contexts.

Keywords Framework · Climate change · Adaptation · Food supply chains · Vulnerability

Introduction

Climate change is expected to increase the frequency, intensity, duration and magnitude of many types of extreme events, including floods, droughts, tropical cyclones and wildfires (Milly et al. 2008; Solomon et al. 2007). While disaster risk reduction mainly aims at tackling these current, abruptly occurring climate variabilities, climate change adaptation seeks to address future adverse effects owing to progressively increasing temperature and shifting precipitation patterns. Both approaches overlap in the context of climate risk management (Mitchell and van Aalst 2008) having similar aims and mutual benefits (Venton and La Trobe 2008). Although researchers having identified several challenges and gaps that exist with respect to effectively linking disaster risk reduction and adaptation to progressive climate change (Birkmann and Teichman 2010) it is increasingly recognised that preparation and response actions to climate variability and long-term climate change may often correlate positively (Adger et al. 2003). Since both increased disaster risk and adverse progressive climate changes will elevate the vulnerability of many, but especially of the rural poor, intervention strategies to decrease vulnerability will be key in reducing the negative impacts of climate change (Heltberg et al. 2009; O' Brien et al. 2008). In this paper the authors address vulnerability to GCC in a food supply chain context and present a framework for comprehensive adaptation strategies. This is to say that the paper delivers a methodology to decrease impacts on, and enhance adaptive capacities of, stakeholders in food supply chains towards climate change impacts. Many of the adaptive capacities the framework identifies are recognised as being able to offset vulnerabilities posed by both progressive climate change and disaster risk (Davies et al. 2009).

Crops rely on a specific natural environment allowing them to thrive. Despite the uncertainty of models predicting the impacts of GCC on specific sites, it is widely recognised that the progressive variation in climate conditions exposes these vital ecologic systems to indefinite challenges (IPCC 2007; Stern 2007). Along with escalating food consumption and shifting diet patterns worldwide, climate change adds another hurdle for food supply chains. Small farmers form the base of many of these food production systems, they are highly dependent on income and nutrition provided by agricultural products, but are unlikely to possess sufficient assets and capacities to respond to GCC related impacts threatening their livelihoods (Gregory et al. 2005; Marsden et al. 2000). Hence, farmers' vulnerability to GCC permeates into the lives and businesses of private and public institutions, which eventually translates to the consumer (Fischer et al. 2002) and adversely affects supply chains' resilience to external stresses (Peck 2005). Furthermore, food chains are composed of people, entities and processes from distinct contexts, each pursuing individual objectives, facing particular problems, and exploiting diverse resources, signifying that there is no single solution (Adger et al., 2008; Grothmann and Patt 2005; Hodgson 2006; Vermeulen et al. 2008)? Considering the scale and complexity of this issue, assessment and adaptation to such a widespread problem is likely to require an extensive conceptual approach providing comprehensive insight (Howden et al. 2007; Winkler et al. 2010). Although many scientific investigations have provided valuable insights into individual parts of this problem (Adger et al. 2005; Hinkel 2011; Smit and Skinner 2002), little work has been done to comprehensively address the role of food supply chain characteristics, vulnerability of rural livelihoods, and sociological patterns in the context of adaptation to the impacts of GCC.

The objective of this chapter is to help create climate-proof agricultural production. The authors therefore propose a framework as a scale-, crop- and location-independent tool to address the complexity of adaptation along food supply chains. The outputs from this research highlight resilience gaps in the impacts of GCC on different people and entities, as well as juxtaposing them with identified behavioural and asset-related adaptive capacities.

The Global Climate Change Adaptation Framework

This framework has three key components: (1) food supply chain analysis as the affected system; (2) vulnerability assessment of crops, livelihoods, and the supply chain, and (3) behavioural patterns and their implications for the impediment or obstruction of adaptation.

Supply Chain Analysis

Supply chains are important for development as they facilitate market access and amplify income options for the rural poor (Gregory et al. 2005; Marsden et al. 2000). As the primary addressee of chain-inclusive, adaptation resilience of food supply chains therefore becomes a key issue. The principal objective and core of any supply chain are streams of values from early production stages to meet the needs of a consumer. These value streams require assets and structures which in turn are managed through organisational networks of people and entities (Peck 2005). However, GCC puts the natural environment, in which these three layers are embedded, at risk. Therefore it can be stated that assets and organisational structures need to absorb the negative effects of GCC on the vital value streams. For this reason it will be of upmost importance to define the supply chain as a system and to characterise it.

Vulnerability Assessment

The main consideration to explore ways of adaptation to GCC threats is the vulnerability of food supply chains to the uncertain conditions that they are likely to face. Vulnerability can be defined as *"the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes"* (McCarthy et al. 2001). The primary component of vulnerability to GCC along food supply chains is the exposure of crops to changing climate conditions. This is expressed as the change in suitability from current to future precipitation and temperature patterns. Sensitivity and adaptive capacity form the other factors of vulnerability. The former is an indicator to assess secondary impacts of GCC on livelihoods; the latter comprises a population's means to adapt to the impacts to be faced. Therefore, the a vulnerability approach can be a proper means to characterise the direct impacts of GCC on crops, the secondary impacts on people and livelihoods and their capacities to adapt.

While vulnerability assessment is a common instrument used to analyse rural livelihoods the authors enhanced this approach to cover impacts and adaptive capacities throughout the entire supply chain.

Behavioural Patterns

Adaptive behaviour is a key attribute of adaptive capacities. Behaviour is a complex construct based on institutions which mediate people's actions through incentives (Woodhill 2008). To decrease this complexity it can be assumed that adaptation strategies must, above all, address key people, i.e. stakeholders, who need, want and/or facilitate change. Additionally, decision-makers must firstly focus on adaptation-relevant types of behaviour. These are:

1. Positive, adaptation-enabling behaviour which is available or institutionalised in a system;
2. Negative, adaptation-obstructing behaviour which is available or institutionalised in a system;
3. Adaptive behaviour required in a system.

The three outlined components weave in and out of one another, forming a multidimensional framework within which adaptation strategies are thought to operate (Fig. 34.1). When a globally changing climate adversely affects crops, people depending on them are also likely to feel these impacts in a direct or indirect way. Within a food supply system, people are stakeholders and as such are vertically and horizontally linked with others and the value-adding processes they own. As patterns of action, processes will finally be reflected in behaviours carried by institutions. These actions in turn require certain resources in the form of hard or soft assets. However, while climate change impacts hit the natural environment of agricultural systems, embedded assets will also suffer. At the same time these

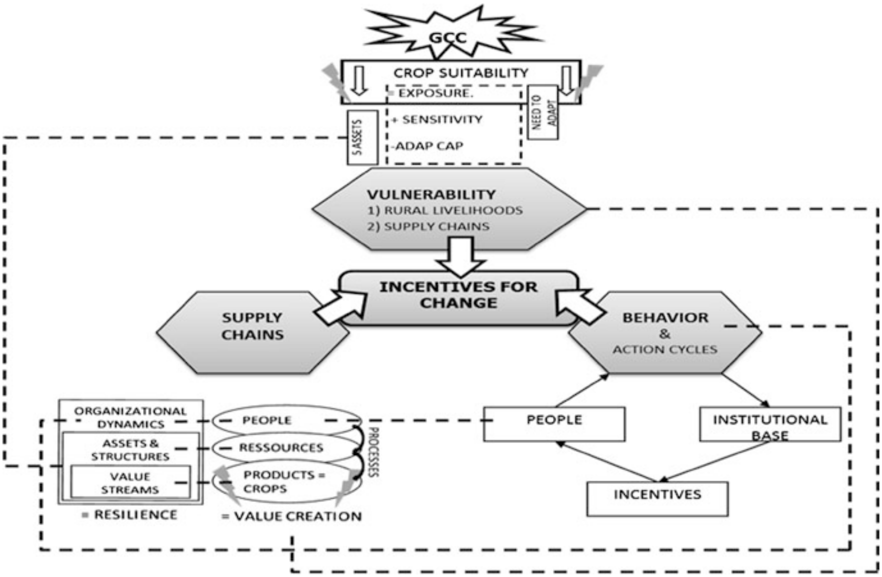

Fig. 34.1 Interdependence of the three framework components

capitals have the duty to support adaptation measures and maintain resilience of value creation by providing process owners with vital inputs.

Although some stakeholders really need to adapt, this, of course, does not automatically materialise in engagement for change. On the one hand, this is because stakeholders have differing adaptation needs. On the other hand, although GCC indicates a necessity to change, people often require additional incentives to drop out of their habitual patterns. It therefore can be stated that adaptation strategies must be aimed at incentives which are based on comprehensive situation assessment. These incentives must be tailored to situations and the people affected by it.

The outlined framework facilitates outlining of incentives as the central objectives of adaptation strategies. This is because the aforementioned comprehensive analyses are responsive to the people, assets and processes as the principal addressees of adaptation measures.

Methodology

This research is tested on three distinct case studies in Guatemala, Colombia and Jamaica. In the Guatemalan departments Sololá and Chimaltenango a food supply chain exporting frozen vegetables to the US market was analysed. The Colombian case highlights small farmers' importance in maintaining Bogotá′s food security. In Jamaica, the farmers' role in supplying fresh vegetables to the local hotel industry was examined.

Supply Chain Analysis

In order to gain insights in the characteristics and to assess chain-inclusive adaptive capacities of the above outlined supply chains, the research team conducted a total of eleven semi-structured interviews with experts of each supply system. These include exporters, sourcing managers, representatives of NGOs and public institutions, tradesmen, wholesalers and public relation officers. The interviews aimed at gaining insights into the structures and dynamics of the supply chains, power and relationships of stakeholders and resilience patterns along the system. An additional 24 focal workshops (eight in each study site) with stakeholders, as well as observations during fieldwork, complemented these topics.

Vulnerability Assessment

According to the Intergovernmental Panel on Climate Change, vulnerability of livelihoods is defined as the degree of susceptibility and incapability of a system to confront adverse effects of climate change (McCarthy et al. 2001) and is composed by three components:

1. Exposure: the degree to which a system is exposed to significant variation in climate;
2. Sensitivity: the degree to which a system is positively or negatively affected by climate related stimulus;
3. Adaptive capacity: the ability of a system to adapt to climate change.

Vulnerability patterns have been assessed at two different levels: (1) farm level, and (2) overall supply chain level, where Vulnerability = Exposure + Sensitivity—Adaptive capacity.

Vulnerability at the Farm Level

As for exposure, the change in suitability from current to future (2030, 2050) climate conditions was determined for local key crops. The research team used historical climate data from the www.worldclim.org database (Hijmans et al. 2005). Future climate predictions are based on the greenhouse gas emission scenario "business as usual" and 19 global circulation models (GCM) and have been downscaled to increase the accuracy of the predictions for the years 2030 and 2050. Publicly available databases provided the crop related to bioclimatic variables to feed into a mechanistic model based on the Ecocrop database (FAO 2011) to finally produce the required crop prediction models. National bodies and institutions helped select the local key crops to be investigated according to their socio-economic importance for the people in the region.

Sensitivity and adaptive capacity of small-holders were subject to on-field assessment of five livelihood capitals available to the rural population. Physical, natural, human, social, and financial assets have been assessed through specially designed questionnaires with farmers in the three sites. The questionnaires included personal information about the interviewed family, questions about their perception for climate change impacts, and most importantly a structured assessment process about which livelihood assets will be affected in the case of changing climate and which can be used as a means to adapt.

The answers have eventually been brought to a 1–3 scale, with 3 meaning a positive value, and 1 a negative value for sensitivity and adaptive capacity respectively. In the next step, the authors assessed the mode of the answers for each asset per supply chain to obtain the results which are displayed in the results section. The sample size of 120 interviews for each case study guarantees their validity in relation to the entire population.

Vulnerability at the Supply Chain Level

Vulnerability assessment at supply chain stage is based upon vulnerability results at farm level. While food chains are complex systems, however, the authors enhanced the assessment methods to evaluate sensitivity and adaptive capacities throughout the entire value creation system. The authors argue that a food supply system has a high sensitivity to GCC impacts when producers are affected and when other stakeholders depend on the producers to supply inputs such as foodstuffs. Estimations about stakeholders' dependence on farmers were mostly achieved through structured notations and a compilation of fieldwork observations.

Adaptive capacity, in turn, comprises by definition a system′s ability to respond to a hazard. Hence, any adaptation supporting means could potentially be included. Considering the supply chain after farm level, results for adaptive capacity are based on robust estimations about adaptive assets available throughout the system, crop diversification, and tangible institutional capacities. These were evaluated through aforementioned expert interviews and complemented by fieldwork observations.

Behavioural Patterns

The authors assessed behavioural patterns together with the supply chain analyses in semi-structured interviews. On the one hand, the aforementioned key stakeholders were asked to provide information about the supply chains' organisational setups and relationships between key actors. These questions included identification of key actors, their mutual power dependencies, strength and nature of their relationships and process ownership along the chain, amongst other things. On the other hand, interviewees were asked to provide an insight into typical action cycles in value creation processes and institutionalised behavioural patterns. Interviewees identified precisely which behaviours and relationships are important for value creation, which can foster or inhibit adaptation in the face of external risks like GCC and how they are made use of, or, alternatively, how they should be changed. Fieldwork observations confirmed or undermined these insights.

Results

Changing climate conditions positively or negatively affect the suitability of crops to their environment. This is where vulnerability of food supply chains originates.

As an example shows ginger having a very high suitability to current climate conditions in Jamaica. However, elevated temperatures and less precipitation are likely to significantly decrease the suitability of ginger to future (2050) climate conditions. This forces the crop to migrate into environmental niches at higher altitudes. As an effect, potential areas of cultivation shrink drastically, inherently affecting the farmers' yield and also the quality of the product. (Fig. 34.2).

While this example highlights crop exposure as the primary biophysical impacts of GCC, it also foretells that adverse effects on crops potentially have negative consequences for the food supply chains of which they form the base. Therefore, changes in crop suitability signify the primary motivation to address adaptation to GCC on a chain-wide level.

In order to do so, it will be vital to understand the projected impacts along the system and hence its need to adapt.

Climate Change

The three cases show the following projected results for changes in temperature and precipitation:

According to the models applied, the temperature in Guatemala is likely to increase 2.2 °C on average until 2050. Conversely, annual precipitation shows a 25 mm decline on average over the period until 2050, with rain patterns shifting from early to late winter months.

Considering future climate patterns in Colombia, Fig. 34.3 indicates a 2.4 °C increase in temperature on average until 2050. At the same time, annual precipitation suggests an 81 mm increase on average in the period until 2050, mainly distributed over the usually dryer months from December to March (Fig. 34.3).

Results predicting Jamaica's future climate conditions indicate annual temperature is set to rise 1.7 °C on average until the year 2050. The island's annual precipitation is reported to decrease 65 mm, distributed over eight of the twelve months of the year (Fig. 34.3).

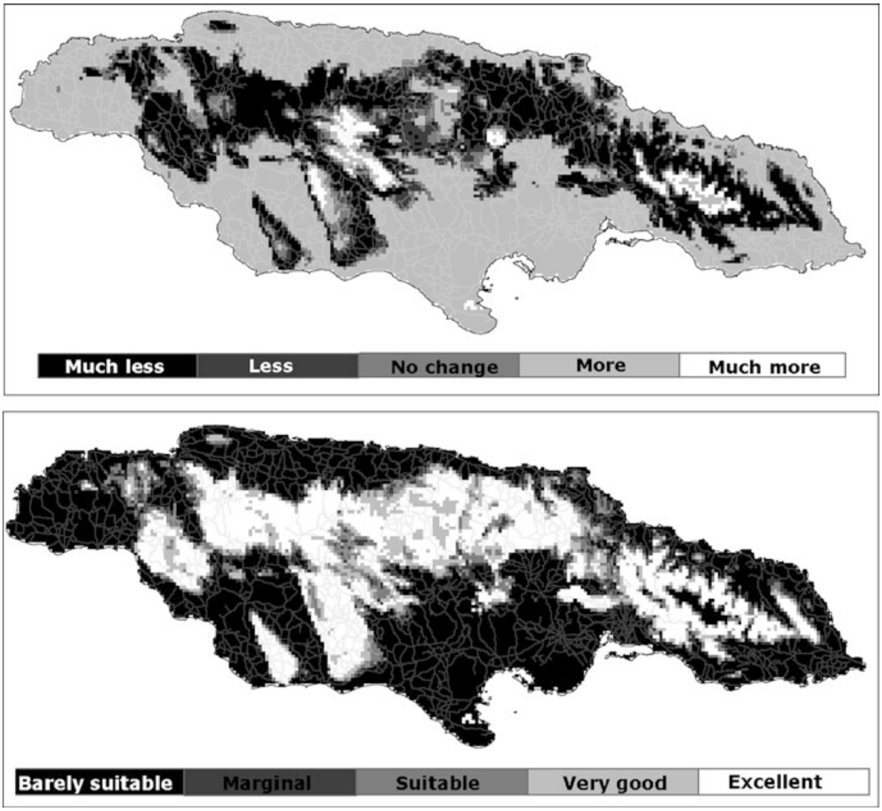

Fig. 34.2 Current suitability for ginger production in Jamaica (*top*) and predicted suitability change for the year 2050 (*bottom*)

Investigated Supply Chains

To facilitate more detailed analyses, the examined case studies have been subdivided into six supply chains according to their marketing channels.

Two main supply chain networks have been identified in Guatemala. One, small-holders serving export markets in a hierarchically strong system of buyers and intermediaries (GTM 2); the other, a similar system, however with the added feature of small producers collaborating with local NGOs (GTM 1) at an early stage of value creation. Three supply chains were identified in Colombia: people selling directly to the consumer on a farmers market (COL 1), selling to any intermediary in an open market system (COL 2) or mixed (COL 3).

The structure of Jamaica′s supply chain can hardly be observed. The interviewed experts agreed that the loosely coupled actors in the chain barely have (formal) long-term agreements amongst each other. Small-holders sell to local markets, intermediaries, the hotel industry or for exportation, with the latter two

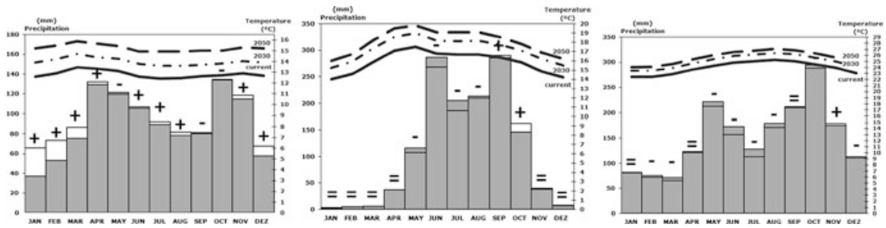

Fig. 34.3 Temperature (current, 2030, 2050) and precipitation (current, 2050) patterns for Guatemala (*left*), Colombia (*centre*) and Jamaica (*right*)

being recognised as major forces in Jamaica's economy. For these reasons, Jamaica′s food supply system was not subdivided into further supply chains.

The following section lists the reported results of these supply chains by country:

Guatemala

Biophysical Impacts: Suitability Change

Predictions of temperature and precipitation led to the following suitability changes for Guatemalan key crops: (Table 34.1).

Sweet pea, cauliflower, potato, broad bean, carrot and beetroot are likely losers, tomato a potential winner of suitability to future climate conditions. Maize, common bean, broccoli and onion will likely maintain their suitability levels. However, high standard deviations of e.g. maize and tomato indicate the heterogeneity of the computed single suitability change values around their mean.

Socio-Economic Impact: Farm Level

Figure 34.4 shows high sensitivity in terms of physical and financial capital at farm level for GTM 1. This is due to poor housing and road infrastructure, as well as inappropriate types of loans which are mainly dealt in kind and in the short term. Natural, human and social capital accounts for low sensitivity. Adaptive capacity scores high for all assets apart from physical capital, which reports an intermediate level. The positive results are attributed to the relatively high participation in organisations providing assistance, less distance to water for farming and the quality of technical training. GTM 2 reports much higher sensitivity than GTM 1. While financial and physical capital are affected for the same reasons, social and human assets also score high sensitivity, mainly because of the scarcity of organisational structures and lack of training on marketing. In comparison to

Table 34.1 Average current suitability, suitability change and standard deviation values in % for main crops in 2030 and 2050, Guatemala

Crop	Carrot	Cauli-flower	Horse bean	Sweet pea	Onion	Broc-coli	Beet root	Potato	Bean	Tomato	Maize
Current	91.81	90.42	90.14	87.29	86.09	86.07	84.97	82.20	74.99	61.25	60.82
SuitChg 2030	−13.38	−17.62	−15.56	−21.20	−2.59	−2.42	−12.75	−16.51	2.14	11.77	2.38
STD 2030	23.39	21.50	24.35	24.34	16.83	24.57	29.85	23.40	25.32	26.63	43.40
SuitChg 2050	−21.98	−30.28	−29.16	−29.85	−4.16	−5.17	−22.47	−29.73	1.74	18.44	1.00
STD 2050	33.00	31.55	35.85	34.07	26.67	38.04	43.27	36.04	36.67	44.27	58.47

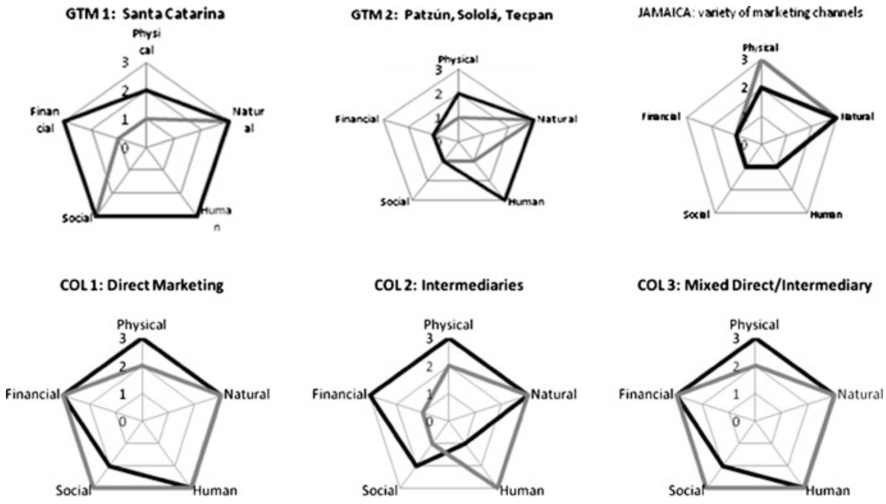

Fig. 34.4 Sensitivity (*grey*) and adaptive capacity (*black*) results for small farmers in the six supply chains

GTM1, GTM 2 reports low values for financial and social capital in terms of adaptive capacities. Poor access to credits, lack of (knowledge of) product certification and little involvement with organisations, as well as low provisions provided by the latter are responsible for this score.

Socio-Economic Impact: Non-Farm Level

At non-farm level the sensitivity of GTM 1 is lowered by the fact that intermediaries and buyers do not necessarily depend on small farmer suppliers. However, low product diversification (mainly broccoli, sweet pea, cauliflower) adversely affects sensitivity and adaptive capacity to some extent, since direct impacts concentrate on the few products which limit adaptation alternatives. Nevertheless, the wide array of assets along the chain and institutional capacities provided by NGO support can potentially enhance these adaptive capacities. GTM 2 shows similar patterns, however lacks these institutional capacities, which slightly lowers its adaptive capacity.

Resilience Factors and Behaviours

The barely formalised, yet well-arranged relationships, between the supply chain actors are a key resilience-supporting factor in Guatemala. Additionally, the supply base in GTM 1 makes better use of the structures available and counts with better organisation of asset employment than GTM 2. The latter lacks social mediators leaving suppliers′ productivity exclusively reliant on capacities provided by and agreements made with intermediaries.

The hierarchically clear defined action cycles along GTM 1 strongly determine the limits of adaptive behaviour. However, within its borders, the supply chain is open for adaptation, with the local NGO giving incentives to engage in concrete measures. GTM 2 lacks these incentives, reducing adaptive behaviours to the institutionalised dependence on inputs via intermediaries.

Colombia

Biophysical Impacts: Suitability Change

Based on the prospective changes in temperature and precipitation, the following suitability change values of local key crops were calculated: (Table 34.2).

Of the 19 investigated crops, papaya, guava, orange, mango, plantain and maize in particular will face drops in suitability to a future climate. Blackberry and cassava will be moderately less suitable to climate in 2030 and 2050, while the remaining crops will be able to maintain their current average suitability. The predominantly high standard deviation values stem from the diversity of nearby zones, which result in heterogeneous values around the mean.

Socio-Economic Impact: Farm Level

Farmers selling directly to the consumer, i.e. COL 1, generally report a low sensitivity to GCC impacts (Fig. 34.3). Social capital is the only asset to only score an intermediate level rating. Similarly, the capital stock of COL 1 provides proper capacities to adapt, except physical capital which only reaches intermediate level. In COL 3 where farmers supply their products directly to the consumer as well as via intermediaries the situation is the same. The intervention by the NGO in combination with optional direct marketing therefore positively influences the farmers' capital stock. In supply chain COL 2 where farmers are exclusively selling through intermediaries the conditions of livelihood assets are different. In comparison to COL 1 and COL 3 sensitivity of human capital increases to a high level in COL 2 due to a lack of technical assistance. At the same time, adaptive capacity in terms of social and financial capital also drops to low levels, mainly owing to a lack of credit access and little participation in organisations.

Table 34.2 Average current suitability, suitability change and standard deviation values in % for main crops in 2030 and 2050, Bogotá area

Crop	Cassava	Plan-tain	Rice	Guava	Potato	Banana	Papaya	Sugar-cane	Tomato	Mango
Current	88.43	87.76	86.55	85.58	83.90	83.26	82.32	77.89	77.62	77.15
SuitChg 2030	−4.15	−13.45	3.52	−13.79	−1.78	2.09	−25.23	−6.22	−2.01	−18.30
STD 2030	16.60	26.17	6.28	26.04	12.72	15.20	31.39	14.71	8.17	27.36
SuitChg 2050	−14.93	−28.64	5.86	−35.92	−3.25	−2.19	−46.81	−13.29	−3.81	−33.87
STD 2050	34.61	49.50	9.74	50.47	24.33	29.02	51.61	24.50	16.16	47.24
Crop	Sweet pea	Bean	Onion	String bean	Black-berry	Maize	Orange	Tree tom	Cafe	
Current	70.77	70.47	68.70	68.55	67.37	67.05	65.64	63.35	62.35	
SuitChg 2030	1.44	−1.02	1.30	2.61	−5.56	−12.74	−24.35	1.30	2.15	
STD 2030	25.50	20.69	28.07	28.97	28.48	26.63	26.86	29.28	30.49	
SuitChg 2050	0.52	−2.91	0.63	0.58	−12.47	−19.30	−35.20	0.40	0.74	
STD 2050	45.57	38.46	49.58	52.14	50.90	40.29	44.69	54.31	53.81	

Socio-Economic Impact: Non-Farm Level

Bogotá sources 70 % of its demanded food items from small farmers around the city. This dependence likely causes the three identified supply chains to be sensitive to GCC impacts. However, the production systems report divergent adaptive capacities. COL 1 is entirely reliant on a single marketing channel and constructed around NGO support to provide important assets like transportation and market booth. For these reasons, its adaptive capacity decreases as a supply chain. On the contrary, the numerous intermediaries along COL 2 and COL 3 dispose of important assets which could be used for adaptation measures. However, these resources are unlikely to be liberated for chain-inclusive adaptation, since they remain concentrated at the entities with the highest market power. Nevertheless, a high degree of crop diversification enhances the crop-related adaptation options along all three chains.

Resilience Factors and Behaviours

Interviews and workshops reported that the resilience of supply chain COL 1 to external stresses is built upon the organisational intervention by local NGOs which provide and manage key assets like transport facilities. Strong but balanced associations on community level can additionally support endurance of this system. Resilience along supply chain COL 2 is mainly based on informal relationships and the mere meeting of supply and demand. GCC can however be sufficiently hazardous to annul this advantage. Prediction of market demand by intermediate organisations can improve further resilience to external stress. System COL 3 potentially benefits from any of the aforementioned resilience-supporting factors.

In terms of behaviours, in COL 1 it is also the NGOs who gave incentives to the farmers to drop out of the institutionalised, intermediary-saturated free market system. This includes the legalisation of the farmer′s market and facilitation of marketing among others, and also feeds into the farmers' motivation to change their often miserable situation. For supply chain COL 2 the research shows that intermediaries hardly recognise small farmers as business partners. This pattern is potentially based on low professionalism at farm level, with growers accepting their role at the bottom of the pyramid. Traders and wholesalers take advantage of their institutionalised power towards communal organisations which, in turn, creates negative effects for adaptive behaviour. In COL 3 the farmers' will to change their situation combines with the cleverness to be open for various marketing channels. In this manner incomes can be stabilised fairly well, while people can build capacities and strengthen local organisations.

Jamaica

Biophysical Impacts: Suitability Change

Climate predictions for Jamaica imply following changes in suitability for the country's key crops: (Table 34.3).

Ginger, highland sweet potato and tomato (Sw Pot 2, Tomato 2), cabbage, carrot and lettuce are likely to lose out, whereas lowland sweet potato and tomato (Sw Pot 1, Tomato 1), cucumber, banana and courgette will likely gain suitability to climate in the future.

Socio-Economic Impact: Farm Level

Concerning sensitivity, social, financial and human capital each report a high level of sensitivity to GCC (Fig. 34.3). Almost non-existent organisational support, difficult access to loans, bad training about markets and absence of book-keeping are identified as its main causes. Physical assets score an intermediate level of sensitivity to GCC, caused by weak road infrastructure, mainly. Similarly, social, financial, and human capital accounts for low adaptive capacity. Responsible for this result are missing provisions by organisations, marketing via intermediaries and little agronomic training in areas such as pest control.

Socio-Economic Impact: Non-Farm Level

At non-farm supply chain level, sensitivity even increases when the socio-economic important hotel industry is considered to strongly depend on national vegetable supply. Adaptive capacity decreases, as important assets and institutional capacities are missing or not efficiently distributed along the entire chain. The high degree of crop variety can only partly absorb these negative effects.

Resilience Factors and Behaviours

A supply chain is considered resilient by the interviewed experts as long as natural capital can provide the amount and quality of products demanded, and also as long as individual actors can supply them on time to market. The intermediaries partly hold the position of key actors in the chain. However, while other actors are to some extent substitutable, federal government is widely recognised as the most powerful participant. Inbound logistics of the hotel industry and federal import/

Table 34.3 Average current suitability, suitability change and standard deviation values in % for main crops in 2030 and 2050, Jamaica

CROP	Lettuce	Cabbage	Sw Pot 2	Tomato 2	Carrot	Irish Pot	Ginger
Current	91.64	91.43	91.39	88.40	87.94	81.58	80.68
Suit Chg 2030	−16.06	−18.90	−19.18	−14.05	−21.59	−12.75	−27.29
STD 2030	18.46	17.40	18.30	20.46	18.71	12.54	24.70
Suit Chg 2050	−27.51	−34.86	−35.60	−24.62	−34.65	−22.38	−46.66
STD 2050	26.98	25.22	26.22	30.27	24.93	18.52	30.23
CROP	Courgette	Cucumber	Sw Pot 1	Banana	Tomato 1	Mango	Orange
Current	76,.59	73.56	69.94	68.78	67.51	62.61	58.54
Suit Chg 2030	13.05	12.86	14.75	12.97	16.00	6.55	2.47
STD 2030	20.89	20.90	22.11	18.06	20.61	31.69	37.46
Suit Chg 2050	18.00	19.35	21.61	18.40	23.48	−0.65	−5.38
STD 2050	29.26	29.88	31.64	28.48	31.02	52.72	55.23

export policy are institutionalised patterns determining Jamaica's balance of payments, and therefore also vast parts of its available income.

In this context, the non-recognition of local farmers as competitive suppliers by the hotel industry on the one hand, and the short-term focused mind-set at farm level on the other, are two examples of important institutionalised traits inhibiting adaptation strategies in Jamaica. Short-termism is based on opportunistic seller-buyer relationships. Additionally, governmental agencies constantly supply small-holders with inputs like fertilisers, which in turn is reflected in farmers' negative attitude towards sustainable practices.

Discussion

This research shows that climate change poses varying types of severe threats to the exemplary supply chains in Guatemala, Colombia and Jamaica. The variation of these threats arises from the distinctive features of various factors, such as exposure, sensitivity, adaptive capacity, supply chain characteristics and behaviours which we included in this framework. As these factors highlight the complexity of the issue, it is not surprising that most farmers are unaware about the threat climate change and even less certain about the types of impacts to be expected. Although the models which have been applied throughout this framework are seemingly abstract, the authors state that the outlined assessment process including the analyses of supply chain, adaptive behaviours and especially vulnerability can be an adequate method to help raising small-holders' awareness to the future threats of GCC and facilitating timely action-taking in adaptation practices. This is, because regionally downscaled crop modelling clearly identifies the undisputable threat which puts small-holders' products and thus their income sources at risk. More so, since assessment of livelihood assets can be ascribed to precise indicators, farmers get insight into how their lives will be affected and what means they have to tackle these impacts. Together with the identified characteristics of supply chains and behaviours, the methods introduced in this framework helped detect several highly concerning situations but also important adaptive capacities in the investigated supply chains.

The Jamaican case, for example, reports many of its key crops as being severely exposed to the effects of GCC and farmers' livelihoods are set to be sizably affected. Together with catastrophic adaptive capacities, low supply chain coherence and an institutionalised arm's length principle to lock smallholders into disadvantageous action cycles, Jamaica's supply chain qualifies for compulsory adaptation. Farmers in supply chain GTM 2 report a very high need to adapt owing to a high exposure of their crops and an alarming rate of sensitivity. However, the research presented showed that strong hierarchies in well-established supply systems can increase the adaptability and resilience of a supply chain, when power dependencies are not misused. This can be ascribed to better control over how assets are used and by whom. While their situation at farm level is less drastic, Colombian supply chains revealed that in open market systems the sensitive producers are easily dominated by other powerful players in the market. In such case the feeble organisational capacities at farm level additionally fortify the institutionalised power of tradesmen and wholesalers, which is likely to hamper chain-wide adaptation measures.

Conclusions

While results vary across the case studies, the research presented in this paper identified alarming characteristics in all of the six investigated supply chains in Jamaica, Guatemala and Colombia, which makes a chain-wide engagement in adaptation to GCC effects very interesting. In this context, the outlined framework proved to enable stakeholders to eliminate many potentially confounding factors from discussion to a manageable number of important aspects to be considered in the context of adaptation to climate change. Firstly, the framework helps identify GCC-imposed problems at various scales and stages of the supply chain. Secondly, the comparison of resources with the needs of a certain situation indicates which incentives to give priority for adaptation. Since incentives are required to enable change, the authors state that these incentives must be the objective of strategies to facilitate chain-inclusive adaptation processes.

In recognition of the apparent links between adaptation to progressive climate change and disaster risk reduction, this framework not only helps to make supply chains more resilient to long-term climate change but also strengthens agricultural systems' preparation and response options to increased disaster risk.

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As part of the ongoing learning and development agenda of the Oxfam Sustainable Livelihoods Learning Network and the Oxfam global strategic priority of reducing the negative impacts of climate change on smallholder farmers through supporting adaptive processes, this project has served as a demonstration of the importance of both forward-thinking and historical-technical (quantitative) and community-based (qualitative) approaches to climate change research and adaptation methodology.

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Author Biographies

Andreas Benedikter is a research fellow on climate change impacts on food value chains in CIAT's Policy Analysis and Climate Change Programme.

Peter Läderach is a senior researcher on climate change and high-value goods in CIAT's Policy Analysis and Climate Change Programme.

Anton Eitzinger is a researcher and GIS specialist in CIAT's Policy Analysis and Climate Change Programme.

Simon Cook is an independent consultant to CIAT and the Basin Focal Project at CGIAR Challenge Programme for Water & Food.

Michele Bruni is the OXFAM GB Sustainable Livelihoods head for Latin America and the Caribbean.

Chapter 35
An Analysis of the Connection Between Climate Change, Technological Solutions and Potential Disaster Management: The Contribution of Geoengineering Research

Tina Sikka

Abstract In this article, the author uses a critical political economy approach to provide a basic topology of the current state of geoengineering research, funding and testing. The central argument is that the material *and discursive* monopolisation of geoengineering research and discussion by elite groups—political, economic and scientific-technological—has led to the marginalisation of the public from this debate and has presented a distorted view of its (geoengineering's) need. Its connection to the main theme of this conference is located in the very clear nexus between climate change, the potentially disastrous outcomes of increased global warming and an examination of the potentially equally dangerous consequences of technologically intensive solutions (like geoengineering) that do not address but disregard the core problem: overconsumption based a resource-extractive and energy-intensive economic system. This piece begins with a brief introduction to geoengineering technologies. I then outline the critical political economy approach which is, at its core, a historically and socially reflexive method that focuses on unpacking the "production and reproduction of…structures" (Mosco 1996, 29) of privilege, followed by a brief justification of why it is pertinent in this context. Following this, the author delivers a critical snapshot of some of the most striking, and simultaneously troubling, geoengineering research currently taking place worldwide. The paper ends with a call for the public to get aggressively involved in learning about geoengineering and engaging in critically informed geoengineering activism, both online and offline.

Keywords Political economy · Geoengineering · Climate change · Critical analysis · Public

T. Sikka (✉)
School of Communication, Simon Fraser University, K9671-8888 University Drive, Burnaby, BC V5A 1S6, Canada
e-mail: tina.sikka@gmail.comtsikka@sfu.ca

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Introduction

> "Intervention in atmospheric and climatic matters… will unfold on a scale difficult to imagine at present…this will merge each nation's affairs with those of every other, more thoroughly than the threat of a nuclear or any other war would have done."—J. von Neumann

In this article, the author uses a critical political economy approach to provide a basic topology of the current state of geoengineering research, funding and testing. This piece opens with a brief introduction and explanation of geoengineering technologies themselves. The author then outlines the critical political economy approach which is, at its core, a historically and socially reflexive method that focuses on unpacking the "production and reproduction of…structures" (Mosco 1996, 29) of privilege, followed by a brief justification of why it is pertinent in this context. Following this, a critical snapshot of some of the most striking, and simultaneously troubling, geoengineering research currently taking place worldwide is given. The paper ends with a call for the public to get aggressively involved in learning about geoengineering and engaging in critically informed geoengineering activism, both online and offline.

The central argument in this paper is that the material *and discursive* monopolisation of geoengineering research and discussion by elite groups—political, economic and scientific-technological—has led to the marginalisation of the public from this debate and has presented a distorted view of its (geoengineering's) need. It is claimed that these powerful groups have been successful, thus far, in reproducing a scientific, political and ideological configuration or constellation, related to our conceptions of technology, nature and the environment that privileges technological intervention and profit-driven growth enormously. By drawing on the political economy approach, what is revealed is how the presentation of corporate-driven technological development, which is often government subsidised, is implicated in an ongoing process of the commodification of nature and framing of technology in a way that makes geoengineering technologies appear apolitical, objective and our only option. Its connection to the main theme of this conference is located in the very clear nexus between climate change, the potentially disastrous outcomes of increased global warming and an examination of the potentially equally dangerous consequences of technologically intensive solutions (like geoengineering) that do not address but disregard the core problem: overconsumption based a resource-extractive and energy-intensive economic system.

It must be made clear, however, that this paper does not by any means constitute an exhaustive overview of all geoengineering research; rather it merely represents a first step. The areas of research chosen have been carefully selected based on *their lack of serious examination* in mainstream media. As such, it is left for others to take up and pursue a dialogue on the findings of the Royal Society, the US Government Accountability Office (GAO) and the US House of Representatives' Committee on Science and Technology. The findings of these bodies, who have all examined the feasibility of geoengineering, have had some mainstream media coverage.

As such, and following the brief introductions to geoengineering and critical political economy, we delve into the core substance of this paper which is constituted by a critical examination of geoengineering research and testing by actors in the following areas: firstly, university affiliated scientists and groups; secondly, individual scientists, scholars and actors; thirdly, governments and government-funded research bodies; fourthly, think tanks; and finally, individual corporate actors. Again, these particular bodies and players have been chosen because of the lack of focused discussion about them—particularly in the media.

Geoengineering

Geoengineering can be defined, at its most basic level, as the deliberate technological intervention into the earth's climate processes in an attempt to reduce anthropogenic climate change. While it often can include climate management and remediation, this paper focuses on carbon emissions specifically. Specific methods fall into one of two primary categories: solar radiation management (SRM) and carbon dioxide removal (CDR). SRM methods tend to focus on the injection of aerosol sulphates into the atmosphere or the setting up of mirrors in space in an attempt to reflect the sun's rays away from the earth. They also include various methods to whiten clouds over the ocean and similar attempts aimed at "increasing the reflectivity of the earth's surface through activities such as painting building roofs white, planting more reflective crops or biomass, or covering desert surfaces with reflective material" (GAO 2010, 2).

CDR techniques, on the other hand, consider ways to actually remove carbon dioxide from the atmosphere through the use of, for example, carbon sinks or carbon sequestration. The most infamous CDR technology is the fertilisation of oceans with iron in an attempt to increase the number of carbon absorbing algae blooms. Another similar method, involving oceans, involves "physically altering ocean circulation patterns to transfer atmospheric carbon to the deep sea, or adding chemically reactive minerals to increase ocean alkalinity" (GAO 2010, 3). Others include afforestation and land-based enhanced weathering.

According to the Royal Society's 2009 report, "Geoengineering the Climate: Science, Governance and Uncertainty", basic geoengineering can be traced back to the 1960s and 1970s. However, more recent proposals, of the sort mentioned above, are distinguished by, their popularity amongst some scientists and policymakers, as well as its actual technical feasibility—i.e. we now have the technological means to carry it out. There are, however, several clear and potentially dangerous drawbacks and other such unintended consequences worth noting which tend not to be clearly thematised by most advocates. For example, according to The Royal Society report, most SRM techniques

> "…would carry with it the termination problem, and would not address ocean acidification or other CO_2 effects…[Moreover] The impact of SRM methods on climate is dependent on where in the atmosphere they are targeted, and their geographical location, and it should therefore not be assumed that a zero net global average radiative forcing means that there are no regional climate effects" (Royal Society 2009, 36).

Overall, it appears that most scientific research and policy bodies that support geoengineering, including the US Government Accountability Office (GAO), are pushing for, as a first step, further modelling, research, testing and discussions. The fact that such a powerful consensus is emerging, without a lot of public involvement, is cause for concern.

Critical Political Economy

This paper, as mentioned, draws on a critical political economy perspective to examine current geoengineering research. As such, political economy is deployed in two distinct ways. Firstly, as a method that addresses the relationship between how geoengineering is discursively taken up and discussed by influential politicians, scientists, research institutes and private corporations and secondly, as Robert W. McChesney asserts, the former's connection to and influence on the broader social structures of society. Put another way, critical political economy

> "…examines how media and communication systems and content reinforce, challenge or influence existing class and social relations. It does this with a particular interest in how economic factors influence politics and social relations. Second, the political economy of communication looks specifically at how ownership, support mechanisms (e.g. advertising) and government policies influence media behaviour and content. This line of inquiry emphasizes structural factors and the labour process in the production, distribution and consumption of communication" (McChesney 2000, 109).

When applied to geoengineering, this approach seeks to ascertain how advocates of geoengineering, most of whom happen to inhabit positions of economic, political and discursive power, have used their positions to push for its testing and eventual adoption as a solution to climate change.

As well, the basic ontological assumptions that form the basis of this paper, and which support the preceding argument, fit with critical political economy's understanding of how wealth, power and influence can be used by those who hold it to unfairly influence public policy and, in this particular case, shape how we choose to deal with climate change (and evaluate the various technologies open to us in this respect). Proponents of critical political economy approaches explain that this occurs because, as Lipschutz argues,

> "…in rich societies, corporations and elites can use their economy and "social" capital to induce or pressure executives, legislatures, agencies and others to pass particular laws and to behave in particular ways that redound to their advantage and to do so in ways that appear to serve the general welfare and interest" (Lipschutz 2010, 4).

Of note with respect to the key source material, it must be stated that much of the information gathered comes from investigative journalists, independent bloggers, civil society groups, concerned academics/scientists and others who keep track of the status geoengineering literature, conferences, media coverage and experimentation. It is, therefore, a daunting undertaking. The amount of information, research, debate and conjecture currently taking place amongst those in the scientific, policy and ethical circles is immense. As such, this article offers only a partial representation of current research and activities.

We now turn to the core subject matter of this piece, which, to reiterate, aims to unearth and track current geoengineering research and testing and examine these endeavours through the lens of critical political economy. Overall, what connects advocates of geoengineering to one another is their joint operating assumption that these technologies *must* place a key role in any attempt, whether global, national or regional, to deal with the potentially catastrophic consequences of climate change despite the very dangerous and much discussed outcomes that may result out of their very deployment.

University Affiliated Scientists and Groups

An interesting fact uncovered during the course of this research had to do with how much of this kind of research, including field experimentation, is currently taking place in the United Kingdom. The most prominent and widely publicised research was undertaken by the influential Royal Society who, in 2009, published its findings of a comprehensive study of geoengineering in a document titled "Geoengineering the Climate: Science, Governance and Uncertainty." It was chaired by Professor John Shepherd, a Professor in Earth System Science in the School of Ocean and Earth Science at the University of Southampton UK, and, over the course of a year, studied the various scientific, economic, legal, political and social dimensions of geoengineering. However, as noted above I do not discuss this report in detail, due to the surfeit of existing commentary on it. Nevertheless, because of its influence, it does bear mentioning.

In the UK there are two SRM experiments currently close to taking place that fit within the defined parameters of geoengineering. Most notably, they are both government funded. The first key actor involved in this testing is a group called the Integrated Assessment of Geoengineering Proposals (IAGP). The IAGP is currently funded by the Engineering and Physical Sciences Research Council (EPSRC) and the Natural Environmental Research Council (NERC)—both of which function as government supported funding and research development agencies. The IAGP is constituted by six UK universities and the UK Met Office. Its stated objective is to work "on this multi-disciplinary project to address some of the major concerns regarding the effectiveness and potential side effects of geoengineering proposals" (IAGP 2011). The NERC and ESPRC are also funding the Stratospheric Particle for Climate Engineering (SPICE) project which was formed, with the participation of four UK universities, to identify existing gaps in knowledge and consider the potential side-effects of geoengineering.

Currently, The IAGP and SPICE are working on two projects: one which focuses on small scale experimentation to discover if and how the properties of particles might be able to block the sun's rays, and hence lead to some global cooling, and the other which examines whether it is possible, and what is the best way, to pump droplets of water one km into the air (this aims to test the feasibility of delivery systems). The overall objective, to reiterate, is to see if these strategies could lead to global cooling by reducing how much sunlight enters the earth's atmosphere.

Turning to the US, some of the most fervent and influential support of geoengineering have come from professional groups of academics and scientists. Political actors frequently cite the opinions of these groups as they make the case for geoengineering in the public realm. The American Geophysical Union (AGU), for example, is a prominent non-profit organisation with worldwide membership dedicated to the furtherance of geophysical sciences. Recently, it has come out in favour of further research into geoengineering methods and technologies. Specifically, their website calls for:

1. Enhanced research on the scientific and technological potential for geoengineering the climate system, including research on intended and unintended environmental responses;
2. Coordinated study of historical, ethical, legal, and social implications of geoengineering that integrates international, interdisciplinary, and intergenerational issues and perspectives, and includes lessons from past efforts to modify weather and climate;
3. Development and analysis of policy options to promote transparency and international cooperation in exploring geoengineering options along with restrictions on reckless efforts to manipulate the climate system (AGU 2011).

Furthermore, in 2009 the American Meteorological Society (AMS) adopted a policy statement on climate change which combines mitigation and adaptation with further research into geoengineering. Although they urge extreme caution—particularly with respect to unintended consequences—the AMS asserts similar recommendations as the AGU with respect to the need for enhanced scientific, social and policy research. They conclude that while,

> "Geoengineering will not substitute for either aggressive mitigation or proactive adaptation…it could contribute to a comprehensive risk management strategy to slow climate change and alleviate some of its negative impacts. The potential to help society cope with climate change and the risks of adverse consequences imply a need for adequate research, appropriate regulation, and transparent deliberation" (American Meteorological Association 2009).

Finally, the American National Academy of Sciences (ANAS), in their 2010 "America's Climate Choices" report, conclude that some kinds of solar radiation management will most likely be needed in the future. As such, they call for enhanced modelling, further research (including social science research) and other necessary steps to ensure that we

> "…better understand the physical science of the impacts and feasibility of SRM as well as issues related to governance, ethics, social acceptability, and political feasibility of planetary-scale, intentional manipulation of the climate system" (Kintisch 2010b).

Cumulatively, the role such research endeavours as those contained in the UK's SPICE and the IAGP, along with the active support of such professional organisations like the ANAS and AMA, play in creating an environment of acceptance, support and inevitability with respect to geoengineering technologies cannot be overstated. Their ability to absorb and funnel all discussions of climate change into a debate about the best way to achieve an instrumentalisation of nature occurs in a manner consistent with a social ontology that "rests firmly and increasingly upon the logic of generalized commodity production" (Garnham 2009, 226). This is particularly the case since it aims to spare us, particularly in the West, from making painful concessions with respect to how we live our lives.

In the next section, the role influential scientists, scholars and actors have played in shoring up a constellation of institutional, discursive and corporate support for geoengineering research is to be discussed.

Individual Scientists/Scholars/Actors

It is important to consider the role (officially) politically unaffiliated and non-corporate actors have played with respect to shaping the often rarefied debate surrounding geoengineering—particularly in light of the prominent and powerful position they hold as so-called experts. In what follows, we consider some of these actors and critically unpack both their political influence and economic power.

Jason J. Blackstock, to begin with, is one such prominent scholar who fits the description of a powerful scientific actor as articulated above. He is currently the CIGI Senior Fellow and Visiting Research Scholar at the International Institute for Applied Systems Analysis in Vienna, Austria, and prominent proponent of geoengineering. His academic work, while somewhat oriented to examining the technical feasibility of geoengineering—as evidenced by his participation in the Novim Group's study "Climate Engineering Reponses to Climate Emergencies" (Novim Group 2009), which aims to evaluate all available information on geoengineering (which they conclude will be needed to deal with a potential climate emergency), is also interested in laying the groundwork for the potential governance structure of geoengineering.

In an article in the *Geoengineering Quarterly*, co-authored with Pablo Suarez and Maarten van Aalst and entitled "Towards a People-Centered Framework for Geoengineering Governance: A Human-Centered Approach," Blackstock makes the argument that it is the most vulnerable peoples who will be affected by both climate change and the unintended consequences of ungoverned geoengineering.

As such, he asserts that a framework for geoengineering governance must be generated to protect vulnerable populations. Blackstock and his colleagues argue that “such a framework must place the protection of human subjects—particularly those populations most vulnerable to climate alterations of any kind—at its core” (Blackstock et al. 2010). This support of governance initiatives adds another more nuanced layer to geoengineering advocacy since it moves beyond technical issues and leaps into the realm of politics and law. In doing so, it also deftly and a priori presupposes its eventual adoption.

Significantly, there are strands of the critical political economy perspective that aim to move beyond pure economics and contend with the generation of precisely these kinds of ideological elements. According to this line of analysis, it is the system of representation, based on and supported by a capitalist system of economic production, of most concern. Dallas Smythe explains this process, whereby the public made to “feel it necessary to cooperate with the monopoly-capitalist system in a variety of ways” (Smythe 2009, 246), including by supporting geoengineering. The public is also, in this sense, manipulated by a changing focus on governance, which sidesteps considered debate on geoengineering itself.

Another non-Western individual of note is the Russian scientist Yuri A. Izrael, known worldwide as an infamous climate change sceptic, opponent of the Kyoto Protocol and leading scientific advisor to Prime Minister Vladimir Putin. Izrael recently published an article entitled “Field Experiment on Studying Solar Radiation Passing Through Aerosol Layers” in the (Izrael et al. 2009a) in which he communicates the results of an actual geoengineering field trial. In this particular trial, scientists blasted aerosol particulates (sulphates) from the ground into the atmosphere. This was done in an attempt to test whether these sulphates would encourage climate cooling, much like volcanic ash does following an eruption. The results, interestingly, were reported as largely effective.

Izrael and his team, in an accompanying article, make the case that stratospheric sulphate aerosols and forestation are *the only* geoengineering methods with the highest chance of success, overall lowest monetary cost and least possibility of negative ecological consequences (including irreversibility). Their operating assumption is that:

> “The inevitability of climate changes [has] generated a set of assumptions about the epoch of irreversible catastrophic implications for the mankind. This makes us studying the possibilities to use more effective, operational and cheaper measures for climate stabilization than the Kyoto Protocol measures, using different climate-forming factors considered in detail by the IPCC” (Izrael et al. 2009b, 335).

Again, it is important to emphasise how significant it is that these leaders and scientists, who all carry an inordinate amount of ideological and sometimes economic power, are most often seen by the public as unbiased and objective actors whose positions on geoengineering can be trusted. In line with the political economy perspective, it is fair to argue that a closer look at their motivations, funding and interests are indeed needed.

Governments and the Military

As noted, much of the most research on geoengineering currently taking place in government circles is through direct or arms-length funding of various research bodies and think tanks. Another area worth discussing, however, is what the research wings of various governmental defence departments. In the United States, according to *ScienceInsider*, in 2009 the Defence Advanced Research Projects Agency (DARPA), under the aegis of the Defence Sciences Research Council, convened a classified meeting to discuss geoengineering at Stanford University. While most of its conclusions are classified, it is interesting that several prominent scientists and supporters of geoengineering, like Carnegie scientist and geoengineering enthusiast Keith Caldeira argue, took the position that adding this military dimension to geoengineering research is not only unnecessary, but also dangerous—particularly since DARPA's primary objective is the development of weapons. Others however, like Michael MacCraken of the Climate Institute, argued that it "could be good for the field" (ScienceInsider 2009).

It appears that the US military has taken an interesting in geoengineering in light of China's recent efforts this area. In this context, a longer historical and geopolitical view has to be taken in which geoengineering is seen as another step in a long line of weather manipulation efforts in tandem with weapons starting over fifty years ago. During the Vietnam War, for example, the US military is said to have seeded clouds with silver iodide to encourage rainfall and curtail opposition activities. Prior to this, research into weather modification, as it was known during the 1950s and 1960s in the United States, increased due to similar Soviet efforts during this time. During the 1970s, discussions of geoengineering tended to revolve more around agricultural concerns until the 1980s when there was little mention of such efforts. It was not until the turn of this century that previously moribund research proposals, and an overall interest in climate engineering, increased exponentially. Now several powerful countries, organisations and individuals have become involved.

An interesting case study of an experiment involving a specific geoengineering technique with state participants is the LOHAFEX research experiment. This experiment was carried out by a research team of 48 scientists from a variety of countries and, most significantly, was directly supported by both the Indian and German governments. The trial involved the fertilisation of a contained eddy of 300 km^2 in the Southern Ocean (which circles Antarctica) with iron ore, which should lead to the growth of carbon absorbing phytoplankton blooms that will absorb CO_2 and take it with it as it sinks to the ocean floor—thereby having a cooling effect on the climate. One of the primary concerns emerging from this experiment, however, are indications that it has raised the ocean pH, thereby rendering coral reefs vulnerable to erosion.

In a similar 2002 Southern Ocean Fertilisation Experiment, funded by the National Science Foundation (NSF), it was widely publicised that the experiment was successful in decreasing carbon and increasing chlorophyll production over the course of its 39 day trial. However, it was also discovered that,

> "The algal bloom also encouraged a diatom called pseudo-nitzschia, which releases a potentially dangerous neurotoxin called domoic acid. Domoic acid has been blamed for sudden marine mammal and seabird die-offs (one such poisoning of seabirds inspired the film, *The Birds*). Although this data has not yet been published… [it has been reported that] 2002 experiment increased the domoic acid level locally by 100,000–1,000,000 times" (Vance, 2010).

Overall, the downside to experiments like LOHAFEX and Southern Ocean Fertilisation Experiment stems from the inability to accurately anticipate unintended consequences. What we tend to hear from these groups publicly is a general emphasis on what worked and why further research is scientifically justified in light of this. By monopolising the material capabilities, institutions and ideas that surround geoengineering, state and even military supported proponents can assert a kind of hegemony that solidifies "the capacity of [this] class to engage in and dominate institutional developments and, when necessary, control the form of mediated compromise" (Comor 1994, 6).

Think Tanks

There are several prominent think tanks, mostly inhabiting the right of the political spectrum, actively involved in geoengineering activities. Primarily the work of these groups revolves around pressing for further research and lobbying for political support. The Climate Response Fund (CRF) is one such organisation. The CRF is a not-for-profit think tank formed in 2009. Its objective is, in an "unbiased" manner, to explore all options in managing the effects of global climate change. Specifically, they make it clear that their primary purpose is to play a major role in developing the research and political parameters that might govern future climate interventions. The CRF's mission, according to their website is to:

Foster safe and responsible research on climate intervention by:

1. Providing a neutral forum where norms and guidelines for climate intervention research can be discussed and developed;
2. Working with national and international partners to encourage appropriate organisations to incorporate the suggested norms and guidelines into their deliberations on climate intervention research;
3. Working with national and international partners to communicate information about climate intervention research to interested groups and the general public (Climate Response Fund, 2010).

They are very clear, however, that none of their work involved funding field experiments.

One of the key resources critical political economy gives its users is the tools to study how corporate control over such research can skew information, privilege corporate interests and make efficiency the overriding objective. Ben Bagdikian calls this "the endless chain" which he defines as a "system of interlocking financial obligations, in the form of ownership equity and debt, which are maintained and reinforced institutionally through interlocking institutional control in the form of cross-corporate directorships" (Bagdikian 2005, 181). In what follows, we use this basic political economy technique to unpack some of the interlocking political and economic relationships in these think tanks.

To begin with, the CRF is led by founder and CEO Dr Margaret Leinen who has an impressive history in the sciences (as a noted oceanographer), in academia and in policy circles. In the past, she served as the Assistant Director for Geosciences for the National Science Foundation (NSF) and the vice-chair for the US Climate Change Science Programme. Significantly, before forming the CRF, Dr Leinen was the Chief Science Officer of Climos, Inc.—another geoengineering think tank.

The CRF's board of directors consists of variety of individuals including Seth Perlman, a prominent lawyer whose work focuses on non-profit law, and Kim Cranston, the current chairman of the Global Security Initiative, a nuclear non-proliferation body.

The CFR also has a number of 'scientific advisors' who include individuals that have served on various committees for the NSF and their global equivalents, many of whom are academics and a few, like Dr Tom E. Lovejoy, who has been active in biodiversity circles. Lovejoy, for example, is the former Executive Vice President of the World Wildlife Fund.

One of the most significant ways in which the CRF, along with the Climate Institute, has supported further work on climate intervention or geoengineering is through the Asilomar Conference on Climate Intervention Technologies, held in March of last year (2010) in Pacific Grove, California. The attendees of this conference, with their multiple interests in the private sector, academia and political circles, recognise how powerful and potentially lucrative the control over geoengineering information, research and money can be.

The Asilomar Conference's guiding assumption is that the current pace of global climate change necessitates that climate intervention techniques be seriously considered. Its stated objectives are to:

1. Identify the potential risks associated with climate intervention experiments;
2. Formulate a structure and approach for assessing experiments for their potential categorical risks and suggest precautions necessary for the experiments;
3. Develop and propose norms and guidelines for use by the international science community and those that provide funding for research. The risk assessment and management guidelines for climate intervention experiments to be developed are intended to serve as an initial element of the governance mechanisms that will be essential before proceeding to climate engineering experimentation (The Climate Response Fund 2010a).

It has to be recognised, in light of these objectives, that the conference began with the shared supposition that geoengineering stands as a possible risk-reducing response to climate change, along with mitigation and adaptation.

The conference's final report however, consistent with a clear support for geoengineering, concluded with the following statement:

1. The core rationale for pursuit of climate engineering research is to advance the collective well-being of society and the environment;
2. Climate engineering research is internationally planned and coordinated;
3. Appropriately scoped governmental oversight, public involvement, and decision-making takes place during consideration and conduct of planned activities;
4. Transparency and exchange of research plans, data, and findings minimise the need for environmentally disruptive experiments and maximise the learning from experiments that are conducted; and
5. Regular, independent evaluation and assessment of the extent of understanding and uncertainty is carried out to provide optimal information and confidence for the public and policymakers (The Climate Response Fund 2010b).

While the keywords used here are comforting, e.g. concern for our collective well-being, public involvement, clear oversight, transparency and independent evaluations etc., it remains the case that even small-scale trials can cause irreparable environmental damage—if they even work. The conference's closing statement presupposes that remediation and mitigation efforts will not succeed and, in doing so, makes a considerable cognitive leap to geoengineering as the necessary next step. They conclude that the testing and adoption of such technologies, when undertaken responsibly, can and must play a role in managing global warming.

Much concern has been raised about the connections between Margaret Leinen, one of the main organisers of the conference (and who I mention above), and her links to Climos, which her son, Dan Whaley, now runs. Under Leinen, Climos did plan to perform iron fertilisation trials and, subsequently, insert itself into the carbon credit market. This undermines the conference's claim to be impartial and balanced since one of its primary organisers has a clear conflict of interest. It is also of concern that the members of the conference's organising committee are almost exclusively from the West, male and white. The lack of participation by women and representatives from other communities is very troubling.

Finally, the Climate Institute is another not-for-profit body that vocally supports geoengineering. Its stated goal is "to inform key decision-makers, heighten international awareness of climate change, and identify practical ways of achieving significant emissions reductions" (Climate Institute 2010). Its board of directors and advisors include a slew of former White House staffers and people from the energy industry itself. Its chief scientist, Dr Michael C. MacCracken, has written several pieces for the Climate Institute and other bodies in favour of geoengineering. In one piece, written for the World Bank, MacCracken makes the case that because human induced global warming poses a direct threat to humanity, and in light of the fact that mitigation and adaptation will not suffice to reverse said threat, we must adopt geoengineering technologies. He asks: "*are there not some well-designed, intentional interventions that could be taken that would create a global cooling influence to counter-balance, at least in part, the warming and its associated impacts*?" (MacCracken 2010, 7)

To be fair, it must be said that the conclusions reached by MacCracken, and the Asilomar conference also include clear statements about how any testing and adoption of geoengineering, whether it is SRM or CDR, must be undertaken with due caution, international collaboration and under the direction of international law. However, it is clear that even such cautious testing fails to adequately consider who will be most affected by the unintended consequences of geoengineering. It also fails to consider who benefits—and these are the key questions asked by critical political economy.

Individual Corporate Actors

Recently, there have been reports that some notable entrepreneurs with large public profiles have become interested in funding and advocating for further geoengineering research. Bill Gates, for example, has been active in funding geoengineering research for the past four years. While none of the 4.5 million dollars of his own private money has gone towards actual experimentation, according to University of Calgary physicist David Keith and Ken Caldeira, of the Carnegie Institute for Science, Palo Alto—who are in charge of the funds—it has been focused on "the study of methods that could alter the stratosphere to reflect solar energy, techniques to filter carbon dioxide directly from the atmosphere, and brighten ocean clouds" (Kintisch 2010a). Geoengineering funding from Gates, according to Kintisch, a science reporter for *ScienceInsider*, has also gone to Armand Neukermans, a Silicon Valley inventor working on a spray system for marine clouds called the Silver Lining Project. This particular project studies how tiny droplets of seawater, when dispersed over the ocean, could sufficiently brighten clouds so that they reflect sunlight back into the atmosphere.

Money from Gates has also gone to support scientific geoengineering meetings in a variety of places such as Scotland and the United States. Kintisch also points out that Gates has been an investor in Intellectual Ventures, which is a company based in Seattle, Washington focused on the pursuit of inventions and research—including several patents, on techniques to geoengineer the stratosphere. In 2008, Gates applied for a patent "to sap hurricanes of their strength by mixing surface and deep ocean water" (Kintisch 2010a). This foray into patents and the protection of intellectual property related to geoengineering opens another potentially lucrative area of debate and concern. It is clear that a considerable amount of money stands to be made from geoengineering techniques and research. We have seen what happens when protection of said intellectual property extends in such a way that it shields dodgy research and prevents the necessary sharing of knowledge (e.g. in the case of medication).

Sir Richard Branson of Virgin Airlines is another successful entrepreneur who has been vocal, in both speech and money, in his support for geoengineering. What is different about Branson's support of geoengineering, as compared to Bill Gates', is that it tends to be much more grandiose and both media and personality driven.

Along with Al Gore, Branson has set up a USD 25 million "X-Prize" competition (called the Virgin Earth Challenge) for the invention of technologies, including geoengineering technologies, focused on CO_2 reduction. In a 2009 article in the *New York Times*, Branson is quoted as saying that "If we could come up with a geoengineering answer to this problem, then Copenhagen wouldn't be necessary…We could carry on flying our planes and driving our cars" (Branson as cited by Revkin 2009). This kind of framing of the climate change problem is telling since it speaks to and reinforces the dominant narrative of stasis. By emphasising the desire, on the part of Branson, to use technology to protect the existing economic, political and social system of consumption that led to global warming in the first place is precisely the kind of reasoning critical political economy outs as inherently flawed.

Also of note is a group called the "Carbon War Room" set up by Branson and others (including Michael Haas, the CEO of Orion Renewable Energy Group, and Strive Masiyiwa, the Chairman of South Africa's Econet Wireless) with a the stated mandate of harnessing "the power of entrepreneurs to implement market-driven solutions to climate change. The world [their website asserts] needs entrepreneurial leadership to create a post-carbon economy" (Carbon War Room 2011). What is most interesting about this website and project is how fully it has embraced the war metaphor. Their website is sectioned out into pages that defines this 'war' and outlines both its tactics and current operations. For example, there is a section titled "Theaters and Battles" comprised of the following areas: electricity, transport, built environments, industry, land use, emerging economies and carbon management. It is under the latter category that climate intervention, as they term it, is discussed (primarily in the forms of reforestation but other SRM and CDR options are discussed). Branson has also publically pledged to invest upwards of three billion dollars towards such research in the near future.

Overall, the unbalanced influence of wealthy individuals in support of geoengineering, through economic and symbolic support as well as by exerting political pressure, distorts the overall debate. It is also significant that both Branson and Gates have developed a public persona wrapped up in the discourse of progress, entrepreneurialism, scientific promise and individual ingenuity which they use to great success. However, it is also the case that this kind of commodification of information and science, led by Gates and Branson, undermines a more complex and socially equitable analysis. It is also a concern, in light of their wealth and connections, that a unilateral form of geoengineering research might potentially be undertaken sooner rather than later.

Conclusion

In light of, and in resonance with, the overall theme of this conference it is important to reiterate the fact that geoengineering represents a potentially lucrative solution to climate change that is as dangerous as the problem it seeks to solve.

Most support for geoengineering, as such, is self-interested and based on an attempt to ignore the underlying causes of climate change—particularly since the safest solution would require fundamental changes in the way we live. Taken as a whole, as argued in this piece, there are several overlooked actors in the geoengineering controversy who have an enormous amount of influence but are rarely closely examined. These actors include various university affiliated scientists and groups like the AGU and the AMA, many of whom are engaged in projects like the IAGP and SPICE, individual scientists, scholars and actors such as Jason J. Blackstock and Yuri A. Izrael, governments and government-funded endeavours like the LOHAFEX experiment and military-focused research as well as think tanks such as the Climate Response Fund and the Climate Institute in addition to individual corporate actors such as Sir Richard Branson and Bill Gates.

In using critical political economy what has been demonstrated is how, through the endeavors of the various actors mentioned above, geoengineering has become increasingly "subject to transnational corporate-commercial [and political] development" (McChesney and Schiller 2003, 6) and private interests far removed from public control. It is this multifaceted shift to neoliberal orthodoxy, with respect to the development of geoengineering research and testing, its discursive justification, its funding, and its overall transformation into a viable and even necessary option for dealing with climate change that is of extreme consequence. The mediation and interaction of all these actors and fields with one another, as Silverstone (1999) contends, provides a picture of geoengineering research and testing that is fluid, changing and made up of multiple interests and actors who are all interconnected. In this particular case, these actors and groups have successfully come to dominate geoengineering discussions symbolically, economically and politically.

As such, and to conclude, it is critical to acknowledge and act on a significant strain of contemporary critical political research that concentrates on the how politically and economically dominant modes of understanding and being can and must be challenged. This calls for a concerted effort by activists and the general public to transform and move the dominant messages and practices in favour of geoengineering, made by these elite and economically motivated groups, "in a direction which enhances democratic values and subjectivity, as well as equal participation in decision-making" (Hackett 2000, 64). Groups like the ETC. Group and GeoengineeringWatch, as well as activists like Vandana Shiva, have successfully used online media to draw attention to many of the issues I have laid out in this paper – particularly with respect to unequal distributions of power, self-interest, profit and symbolic control. This democratisation of technical and discursive choice, and political decision-making, as Andrew Feenberg (1995) argues, is essential as it constitutes our only chance to ensure that the way we deal with climate change is reflexive, democratic and concrete, rather than instrumental, reductive and exploitative.

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Author Biography

Tina Sikka is a Postdoctoral Fellow and Lecturer in the School of Communication. Her current research programme includes the study of geoengineering, or climate-engineering, technologies using a critical approach to technology studies coupled with critical discourse analysis. In the past, Tina has studied the philosophy of communication and international relations from the standpoints of pragmatism and deconstructionism. She received her PhD from York University's Graduate Programme in Communication and Culture, her MA from Carleton University's Department of Mass Communication, and her undergraduate BA from Simon Fraser University's School of Communication.

Chapter 36
An Engineering/Accounting Tool for Minimising the Cumulative Flood Threats of Rural Catchment Dams

John D. Pisaniello, Arthur Spassis and Roger L. Burritt

Abstract Small dam failures can be catastrophic. Small rural catchment dams pose failure threats at individual and cumulative levels and both must be accounted for during design of dams to minimise the flood risks to downstream communities and the environment. This chapter aims to address this need for an engineering/accounting tool through conceptual development of a cost-effective farm dam flood safety tool and its link to an international best practice dam safety assurance policy model. The tool's development process involves generating catchment data representing "hydrologically homogenous" regions using complex best-practice dams/flood engineering, to derive simple regionalised flood capability prediction relationships of reliable accuracy. Preliminary development in the Australian State of Tasmania has enabled testing of the tool's transferability to a wide range of hydrology-variant regions. Results demonstrate the tool's successful transferability to different regions; how the prediction relationships would be refined by future research; and how the tool can link to Tasmania's international best practice dam safety policy which includes "farmer friendly" elements. Overall the chapter shows how governments can provide adequate yet cost-effective dam safety accountability and assurance policy to ensure that individual potentially hazardous dams are kept safe and cumulative safety threats posed by rural catchment dams are minimised. Developing the tool in Tasmania, with its wide variety of regions,

J. D. Pisaniello (✉) · A. Spassis · R. L. Burritt
Sustainable Engineering and Law Group, Centre for Accounting, Governance and Sustainability, University of South Australia, North Terrace, Adelaide, Australia
e-mail: john.pisaniello@unisa.edu.au

A. Spassis
e-mail: arthur.spassis@unisa.edu.au

R. L. Burritt
e-mail: roger.burritt@unisa.edu.au

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illuminates the potential for transferability of the development process to other regions worldwide.

Keywords Rural catchments · Small dams · Cumulative flood threats · Spillway design and review · Cost-effective tool · Safety engineering and accounting · Best practice · Safety accountability and assurance policy

Introduction

Floods from dam failures constitute a widespread hazard to people and property (Walder and O'Conner 1997). Failures of large dams are spectacular and receive greater attention than those of smaller dams. However, small dam failures, particularly those of privately-owned farm dams, occur with greater frequency (Lewis and Harrison 2002; Pisaniello 1997, 2009, 2010). Prior research and evidence demonstrates that without appropriate design, construction, maintenance and surveillance, poorly managed small dams pose both significant individual and cumulative threats, and can cause considerable losses to the communities and environments downstream (Pisaniello 2009, 2010). Small dam failures internationally have had disastrous consequences (Silveira 2008). For example, in China the Shimantan and Banquia dams failed in 1975 because of the cumulative failure of 60 smaller dams, resulting in the death of 230,000 people (Si and Quing 1998). In the United States the 5 m Evans and Lockwood dams, which held only 89 and 39 mL of water respectively, both collapsed in a cascade manner in 1989, killing two people (Graham 1999). In March 2009, the Situ Gintung earthen dam in Indonesia, only 10 m high, failed by overtopping, which resulted in the death of around 100 people whilst also causing widespread damage in Jakarta. Reports indicate that inadequately designed and blocked spillways led to the failure (BBC News 2009; Pisaniello 2010). A study by Graham (1999) of dam failures in the United States from 1960 to 1998, found that dams less than 15 m high (i.e. the typical height range of smaller private and/or farm dams) caused 88 % of deaths.

A clear problem exists with Australian small/private dam safety because privately owned dams (farm dams especially) are in great abundance and have failed in the thousands (Pisaniello 1997; Pisaniello and McKay 2007). Australia has in excess of 735,000 farm dams (Baillie 2008). Victoria alone has 300,000 (Lake and Bond 2006) and around 1,000 are large enough to cause significant consequences if they fail (Murley 1987). In Tasmania private dams have failed in the past 80 years with serious consequences, including loss of life (Ingles 1984; Pisaniello 1997, 2009), and currently some 500 of the 8,000 registered dams pose significant safety risks (Pisaniello et al. 2011; DPIWE 2005, p. 21). ANCOLD (1992) estimated a 23 % failure rate for farm dams in New South Wales alone which, when considered on a cumulative level in a catchment above a public dam, would have catastrophic consequences for property and lives downstream. Despite this limited recorded information, it is apparent that the costs of private dam failures associated with public and private infrastructure and the environment are significant, as are the failure rates.

Specifically, sustainability of catchment basins is threatened because of the potential and severe consequences of farm dam failure at both the individual and cumulative levels. A need has therefore developed for (i) owners to manage their dams in line with current standards in order to reduce the possibility of failure and the risks involved from dam failures in extreme circumstances, and (ii) governments to account for, supervise and assist in management of the risks in order to provide increased dam safety assurance to downstream communities. This chapter aims to address these two needs by answering the following research question "Can a cost-effective flood safety engineering/accounting tool be developed to help minimise the interrelated individual and cumulative flood threats posed by rural catchment dams?" Hence, the objectives are to (i) provide better understanding of the interrelated flood threats of farm dam failure at both the individual and cumulative catchment levels, and (ii) to demonstrate and test the development of a regionalised, cost-effective flood safety engineering/accounting tool for rural catchment dams which can help dam owners and governments minimise these interrelated threats. The remainder of this chapter firstly establishes the scope and context of the research, then turns towards outlining the methods used before the results and their applicability are then considered, and finally discussion and conclusions are provided.

Research Scope and Context

Best practice in dam safety management and assurance policy internationally and in Australia

Countries have regulated dams as small as 1.8 m high (e.g. in Michigan, USA) and with a minimum storage capacity of 25 mL (e.g. UK) regardless of dam hazard potential, thereby recognising the need to assure the safety of even the smallest of dams (Pisaniello 1997, 2009, 2010; Pisaniello and McKay 1998, 2007). In Australia, minimum dam safety standards are set by the Australian National Committee on Large Dams (ANCOLD) whilst acceptable dam flood engineering methods and procedures are set by the Institution of Engineers, Australia (IEAust): these are both member supported non-governmental industry bodies whose purpose is to provide guidelines on current acceptable practice and standards in water/dams engineering that is applicable to all dams large and small, private and public, see for example ANCOLD (2000a, b, 2003) and IEAust (1999). The Bureau of Meteorology (BoM), a federal government organisation, generates and provides guidance on Australian rainfall data for use by the water/dams engineering profession (e.g. BoM 1994). In most common law countries, including Australia, owner responsibility exists under the common law of negligence to maintain dams according to these current prevailing guidelines and standards (McKay and

Pisaniello 1995; Pisaniello and McKay 2007). However, aside from common law, many jurisdictions have found that some form of government-implemented dam safety accountability and assurance policy is required, especially where privately owned dams exist (Bradlow et al. 2002; Pisaniello 1997, 2009, 2010; Pisaniello et al. 2011).

Key issues with private dam safety in Australia: the research problems

There are two key interrelated issues associated with farm dams in Australia (Pisaniello 2009, 2010) as follows.

Issue 1*: Stand-alone flood risks and impacts associated with individual farm dams of significant hazard*

Many private farm dams are unsafe because of improper design, particularly flood capability design, and general lack of review and maintenance as farmers generally look to avoid the associated costs (Pisaniello 2009, 2010). Inadequate spillway flood capability is common because advances made in the fields of meteorology and flood hydrology have updated both maximum probable rainfalls and design flood standards above those on which most existing dams were based (ANCOLD 2000a, b; BoM 1994). The result is that downstream communities are placed at unacceptable risk from individual dam failure (Lewis and Harrison 2002; Pisaniello et al. 1999; Pisaniello and McKay 2007).

Issue 2*: Risks and impacts of cumulative flood failure of small dams in large catchments*

Unsafe individual small dams can lead to cascade and cumulative failure during medium to large floods that can result in severe downstream consequences. Global warming potentially exacerbates the problem by increasing the probability of unusually heavy rains in Australia (IPCC 2007). Hence the likelihood of disastrous cumulative dam failure increases, especially in the catchments of large public dams. For example, a flood study of the Kangaroo Creek Dam, a highly hazardous public dam in South Australia found the dam's peak inflow would increase four-fold assuming all small dams in the catchment failed at the same time in a 1-in-200 years flood event (Kazarovski 1996): a reasonable assumption as Pisaniello et al. (1999, 2011) later found most small dams cannot pass such an event. This additional flow to Kangaroo Creek dam would exceed its spillway capacity, which should otherwise be capable of passing at least a 1-in-10,000 years flood event, putting downstream communities and the environment at unacceptable risk (LDC and SMEC 1995).

The Research Scope

Studies show that dams fail most often by overtopping because of inadequate spillway capacity; this failure represents 40 % of those recorded worldwide (Foster et al. 2000) with embankment dams (which typify private farm dams) being most susceptible representing 70 % of failures (Pisaniello 1997; Foster et al. 2000). Given the above individual and cumulative dam failure issues it is clear that private dams, especially those in catchments of large public dams need to be registered, and at least controlled for spillway adequacy regardless of size and individual hazard potential (Pisaniello 2010). It should be mandatory for such dams to at least meet ANCOLD's minimum fall-back design criteria for low hazard dams (1-in-100 to 1-in-1000 years design flood), and this standard should be upgraded whenever a higher hazard rating is warranted, because of either higher individual or cascade/cumulative hazard conditions (Pisaniello and McKay 2007; Pisaniello 2009, 2010).

However, when the number of small dams, especially farm dams, within a jurisdiction number in the thousands, administering and enforcing such mandates can be difficult and politically challenging (Pisaniello 1997). This is because the engineering consulting involved in modern flood capability design/review is expensive and often not affordable for private owners (Pisaniello et al. 1999, 2011). Hence, there is a need for appropriate cost-effective technology to complement dam safety accountability and assurance policies. Pisaniello (1997) assisted in this area by successfully developing a cost-effective, regionalised farm dam spillway design/review technology for South Australia (Pisaniello et al. 1999). The scope of this chapter is to (i) demonstrate and test the technology's transferability to a diverse range of regions with highly varying catchment hydrology characteristics, and (ii) illustrate the technology's potential integration with best practice through a "farmer friendly" dam safety accountability and assurance policy.

Study Area that Provides a Link to Best Practice "Farmer Friendly" Policy: Tasmania

Tasmania provides the highly varying topographic, morphological and meteorological (i.e. catchment hydrology) characteristics necessary for the regional diversity of this study. Compared with mainland Australia, and especially South Australia, Tasmania's topography is very mountainous and undulating and its geology also varies significantly ranging from rich, fertile basalt in the north-west to dolerite and sandy soils scattered throughout other areas (DPIW 2007; DoM 1983). The state has a temperate climate and variable rainfall: up to 2,500 mm per year in the west, but as low as 600 mm in the Midlands and south east (BoM 2009). Farming activity is scattered as reflected by the density of farm dams in different regions (see Fig. 36.1).

Tasmania is the only Australian state to have an extensive dam safety assurance policy which encompasses all dams, large and small, private and public, lower and greater hazard. Pisaniello (2009) and Pisaniello et al. (2011) provide comprehensive description and analysis of each provision of Tasmanian policy, finding that it represents a best international practice model for other states to use as a benchmark. The Tasmanian policy addresses both the individual and cumulative

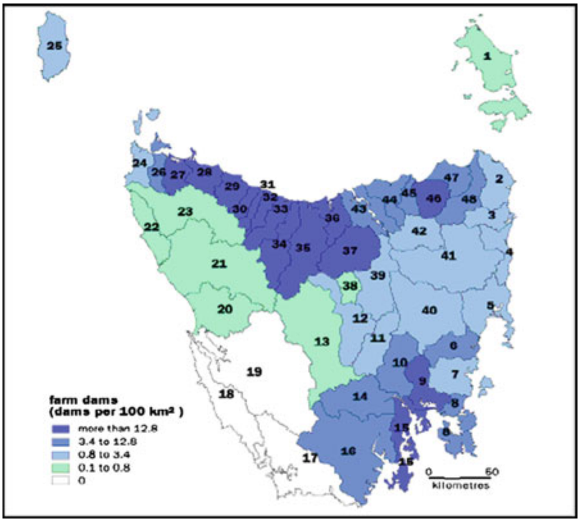


Fig. 36.1 Concentration of farm dams in Tasmanian planning and management catchments (*Source* State of Environment Tasmania 2006)

threats of catchment dams (Issues 1 and 2 above) by regulating dams as small as 1 mL (Pisaniello 2009). The policy was developed with the objective to balance the need for public and environmental protection against the imposition of restrictive and expensive requirements on builders and owners (DPIWE 2003). To avoid placing significant cost on owners, smaller, less hazardous dams do not require sophisticated engineering reports but owners may prepare the report with a guided "farmer friendly" pro-forma (DPIW 2009, see Appendix 3 of DPIW 2009). To complement this process the Tasmanian Department of Primary Industries and Water (DPIW) in 2008/2009 commissioned the study reported below to test the transferability of the Pisaniello (1997) cost-effective spillway technology to Tasmania.

Method

The study was based on the Pisaniello (1997) technology development process. This process is detailed in Pisaniello et al. (1999) and is in line with Australian best practice dam flood engineering, including catchment analysis, modelling and calibration, extreme flood hydrology and reservoir/dam hydraulics per IEAust (1999) and BoM (1994). In brief, the process is regionalised and involves developing flood capability prediction relationships that represent the hydraulic response of any size earthen dam/spillway(s) relative to the hydrological flood response of any rural catchment within a selected "hydrologically homogenous" region for a full range of design storm events up to the Probable Maximum Precipitation (PMP). An "hydrologically homogenous" regional relationship must primarily be developed to represent an entire study area based on 4–6 representative sample catchments and be tested for accuracy (Pisaniello 1997). Smaller sub-regional areas represented by more accurate sub-regional relationships are then developed. The aim is to achieve sub-regional relationships that are each based on their own 4–6 representative sample catchments and that are of reliable accuracy, with a coefficient of determination (R^2) greater than 0.95 and as close as possible to unity. If this accuracy cannot be achieved by the first round of sub-regional delineations, then further rounds are required so as to decrease the sub-regions in size and increase them in number, with more representative sample catchments established in each sub-region, until sufficiently accurate prediction relationships are achieved.

At its core the Pisaniello (1997) procedure involves development of the Reservoir Catchment Ratio (RCR):

$$RCR = \frac{SC}{PI_{PMF}} \times \sqrt{\frac{\sqrt{RA} \times SH}{1000 \times CA}} \times \frac{\log\left\{\frac{PI_{PMF}}{PI_{100}}\right\}}{\log\left\{\frac{PI_{100}}{PI_{50}}\right\}} \tag{36.1}$$

where:

SC	spillway overflow capacity (m^3/s)
PI_{PMF}	peak inflow for the Probable Maximum Flood event (m^3/s)
RA	reservoir area at Full Supply Level (km^2)
SH	maximum height of spillway overflow (m)
CA	catchment area (km^2)
PI_{100}	peak inflow for the 100 year ARI event (m^3/s)
PI_{50}	peak inflow for the 50 year ARI event (m^3/s)

For regions where no variation amongst sample catchments is observed in the Annual Exceedance Probability (AEP) of the Probable Maximum Flood (PMF), the RCR can take on the compact form:

$$RCR = \frac{SC}{PI_{PMF}} \times \sqrt{\frac{\sqrt{RA} \times SH}{1000 \times CA}} \tag{36.2}$$

Developing the RCR necessitates the collection and derivation of "calibrated" catchment data for a range of representative sample catchments within selected study regions. The formulation of at least 20 hypothetical dams on each sample catchment is required in order to achieve Dam Crest Flood (DCF) capability outcomes representing a full range of scenarios up to the PMP event (Pisaniello 1997).

The Tasmanian study looked to generate such data to primarily develop and test a relationship representing the whole state, and then develop three preliminary sub-regional relationships using the same data. The relative accuracy of these relationships would provide indication of the potential and scope of future research to finalise their development.

Table 36.1 Summary of Tasmanian study catchments

Catchment number	Catchment name	Catchment location/region	Catchment area (km^2)
1	Ouse River	Central	1.75
2	Ross Creek	Central	8.23
3	Allens Rivulet	Southern/Hobart	12.80
4	Mountain River	Southern/Hobart	24.25
5	Wilson's Creek	North-West "Basalt"	1.3
6	Port Creek	North-West "Basalt"	5.44

Selection of Study Regions and Catchments

Six study catchments in Tasmania were used for developing a preliminary flood capability prediction relationship representing the whole state. As requested by DPIW, rough prediction relationships were also to be developed, based on the same six catchments, in at least three preliminary sub-regions where farm dam concentration is greater than 0.8 dams per 100 km^2 (Fig. 36.1). Figure 36.1 provides useful guidance in the region delineation process. The three selected study sub-regions are represented by the following Tasmanian 'planning and management' catchments in Fig. 36.1:

- Central Region: 4, 5, 11, 12, 39, 40, 41 and 42.
- Southern/Hobart Region: 6, 7, 8, 9, 10, 14, 15 and 16.
- North-West "Basalt" Region: 24, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36 and 37.

The six representative sample catchments were selected so as to provide a reasonable spread for both size and location throughout Tasmania (Pisaniello 1997). Selected sizes range from 1–25 km^2 (see Table 36.1), enabling a larger range to be tested compared to Pisaniello (1997) who worked with catchments up to 10 km^2. The locations of the 6 study catchments are illustrated in Fig. 36.2. These were selected in order to provide a reasonable spread state-wide and at the same time ensure at least two catchments of varying separation represented each sub-region in order to enable rough development and testing of their respective sub-regional relationships.

Modelling and Calibration of Study Catchments

The RORB v.5 program (Monash University and SKM 2005) was used for modelling as it is recommended by IEAust (1999) for rural catchments. RORB is a computer based, non-linear catchment runoff routing model. The model is able to calculate streamflow hydrographs resulting from rainfall events and route hydrographs through hydraulic structures such as dams. The RORB model input

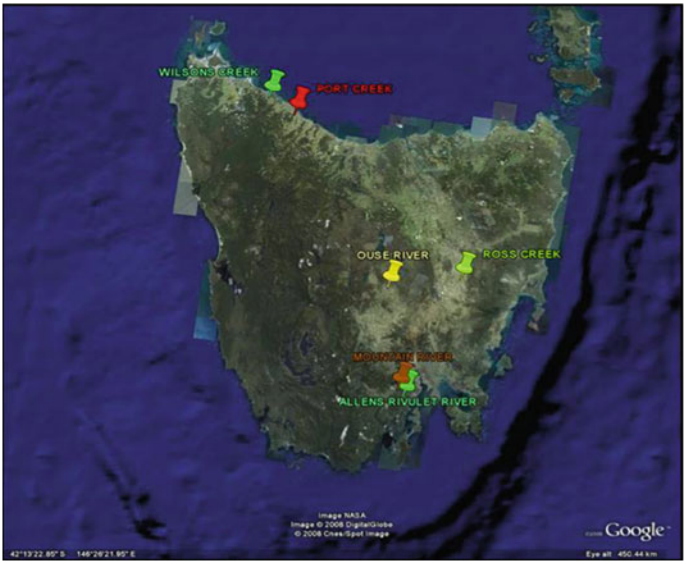


Fig. 36.2 Location of the six study catchments marked on a Google Earth satellite image of Tasmania (*Source* Google Earth 2008)

parameters (catchment non-linearity, storage and losses) were derived via one or a combination of the following methods in line with IEAust (1999): (i) direct calibration where actual gauged rainfall and streamflow data were available for the catchment being modelled, (ii) where gauged data was not available, modelling and calibration of similar nearby gauged catchments and transfer of the resulting data to the sample ungauged catchments and/or (iii) using previously developed regionalised prediction methods, e.g. Dyer et al. (1994), Pearse et al. (2002) and Hill et al. (1996). Catchment and sub-area delineations for the RORB models were made using 1:25,000 scale topographic maps (DPIW 2007). Catchment characteristics used for modelling (e.g. elevation, ground slope, vegetation, geology, etc.) were all derived from topographic and geological maps and past studies of the region (e.g. Dyer et al. 1994). The necessary design rainfall pluviographs applied to the sample catchment models were derived from IEAust (1999) for events in the observed range (i.e. up to 1-in-100 years) and BoM (1994) for storm events in the extreme domain (i.e. up to PMP of 1-in-10,000,000 years).

Development of Flood Capability Prediction Relationships

In order to create the flood capability prediction relationships based on the RCR, it was necessary to produce a wide range of flood capability outcomes relating to embankment dams placed at the outlets of the regional calibrated sample catchments (Pisaniello et al. 1999). This was achieved for Tasmania by performing the following:

- Generating, in the created RORB catchment models, a number of hypothetical dam cases at the outlets of the selected catchments, comprising varying size reservoirs and free flowing, weir-type spillways which will produce a wide range of DCF capability outcomes up to the PMP. A good variety of cases was obtained by: (i) widening the spillway, (ii) raising the dam crest which increases spillway height, and (iii) deepening the spillway which increases spillway height and decreases reservoir surface area and storage capacity.
- Using RORB to route design flood hydrographs through each of the hypothetical storages to determine peak inflow, peak outflow and water elevation for all events up to the PMP.
- Producing a design peak flow prediction equation for the PMP event from a scatter plot of catchment area (km^2) versus peak flow (m^3/s). This equation when substituted into the RCR (e.g. Eq. 36.2) establishes a Regionalised Reservoir Catchment Ratio (RRCR).
- Using the determined peak inflows and elevations to establish peak inflow-frequency and elevation-frequency relationships for each dam. With these relationships the DCF capability of each dam is determined as 1/AEP (years). The DCF is taken as the smallest flood which peaks at the lowest point of the non-overflow crest.
- These flood capability outcomes are used to create scatter plots of RRCR versus DCF. The plots are created in the logarithmic domain due to the vast range of order of magnitudes associated with flood-based events. Lines of best fit are then drawn through the scatter plots and the associated regression equations are determined, thus producing the required flood capability prediction relationships that follow.

Results: The Main Regionalised Flood Capability Prediction Relationships

Over 120 hypothetical dam cases were created in total on the study catchments representing all the possible combinations of reservoir size and spillway capacity to pass the entire range of AEP design floods up to the PMP. Flood capability studies were undertaken for each case as per the above method, generating a full range of DCF outcomes. All cases resulted in an AEP of PMP of 1 in 10^7 using the procedure in IEAust (1999). This therefore led to the RCR taking on the compact form, i.e. Eq. 36.2. When a design peak PMF flow prediction equation was derived for the six study catchments and substituted into the RCR, the following Regionalised Reservoir Catchment Ratio (RRCR) applicable to the sample region was generated:

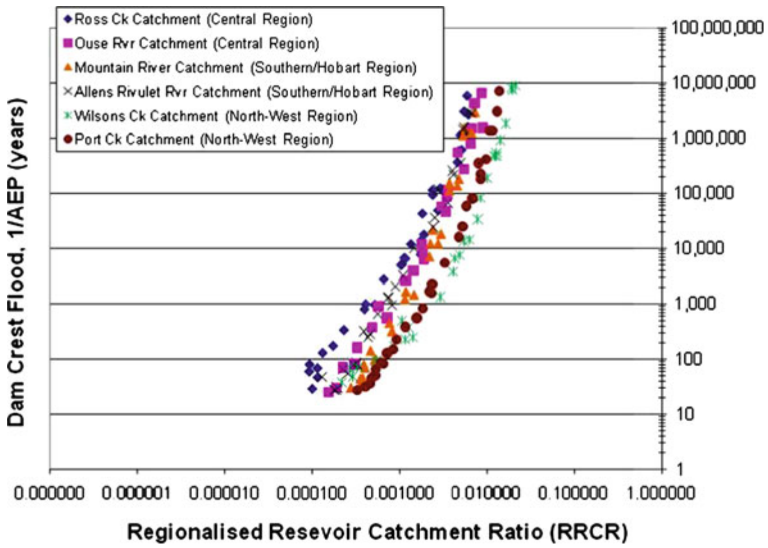


Fig. 36.3 RRCR sample data according to each of the study catchments/regions

$$RRCR = \frac{SC}{52.857 \times CA^{0.8774}} \times \sqrt{\frac{\sqrt{RA} \times SH}{1000 \times CA}} \tag{36.3}$$

The flood capability (DCF) outcomes for the six study catchments were then used to create a scatter plot of RRCR versus DCF as shown in Fig. 36.3. A flood capability prediction relationship was constructed using all the sample outcomes and the resulting scatter plot and line of best fit representing the whole State is presented in Fig. 36.4.

Figure 36.4 displays an $R^2 = 0.85$ which is insufficient to declare it a reliable predictor of DCF at state level. Figure 36.4 also demonstrates the band within which more refined and accurate sub-regional relationships would lie. To illustrate, when the state relationship was broken down into three sub-regional relationships—that is sub-relationships to each better represent the three selected study regions—and simple comparable linear regressions were used, much improved prediction accuracies are obtained (Fig. 36.5). It is also clear from Figs. 36.4 and 36.5 that if different forms of regressions were to be trialled (e.g. curvilinear) then accuracies could be further improved. In fact, in South Australia, Pisaniello (1997) found that the best fitting relationship was one made of three linear segments as illustrated in Fig. 36.6. Pisaniello (1997) was able to achieve accuracies as high as $R^2 = 0.981$ via this multi-segmentation process (Pisaniello et al. 1999). However, at this preliminary stage such processes are futile as the sub-regional relationships need to each themselves be based on a larger range of representative catchment sizes and locations (i.e. six catchments per sub-region) via future research (discussed in the next section) in order to ensure their credibility. Therefore, for now

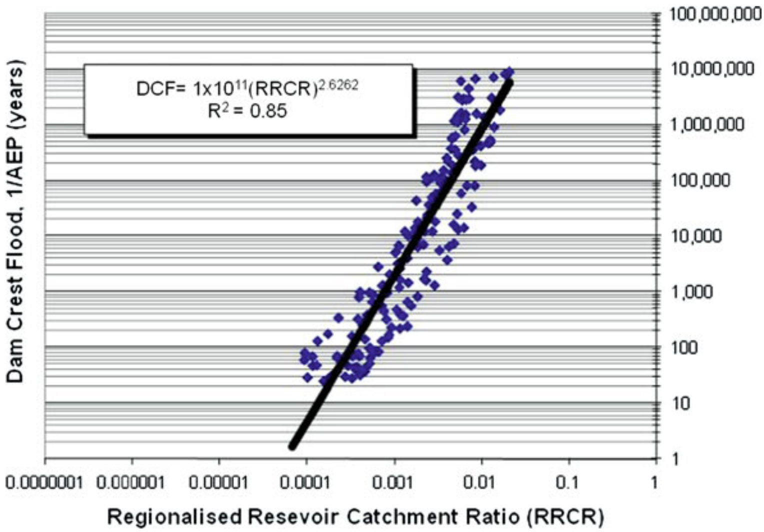


Fig. 36.4 Sample data and line of best fit for DCF prediction based on the RRCR representing the entire State

the relationships presented in Figs. 36.4 and 36.5 are only rough preliminary representations of flood capability prediction in the selected study regions of Tasmania, but they well illuminate the potential and scope of future research to fully develop the relationships which underpin the overall cost-effective spillway engineering/accounting tool that follows.

Applicability and Future Refinement of the Developed Relationships: a Cost-Effective Spillway Engineering/ Accounting Tool

The relationships presented in Fig. 36.5, once fully developed, provide a procedure to engineers, authorities and dam owners to readily and effectively review and/or design the spillway flood capability of reservoirs on small catchments (area up to 25 km^2) in Tasmania. For example, ANCOLD (2000b) "fallback" acceptable flood capacity criteria can be incorporated into Fig. 36.5 to create Fig. 36.7: the principal engineering/accounting tool in the form of Tasmanian sub-regional relationships.

The tool can be used in either review or design mode. However, the following four conditions are associated with the tool:

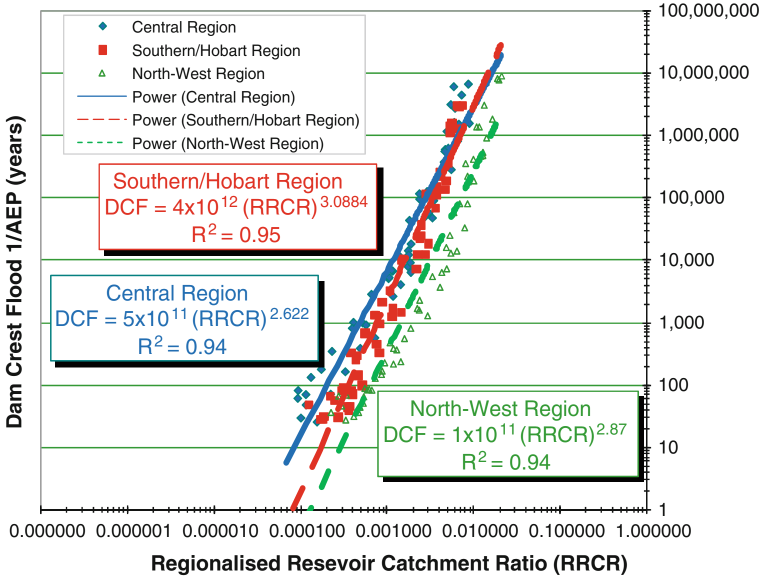


Fig. 36.5 Flood capability prediction in the form of more accurate sub-regional relationships

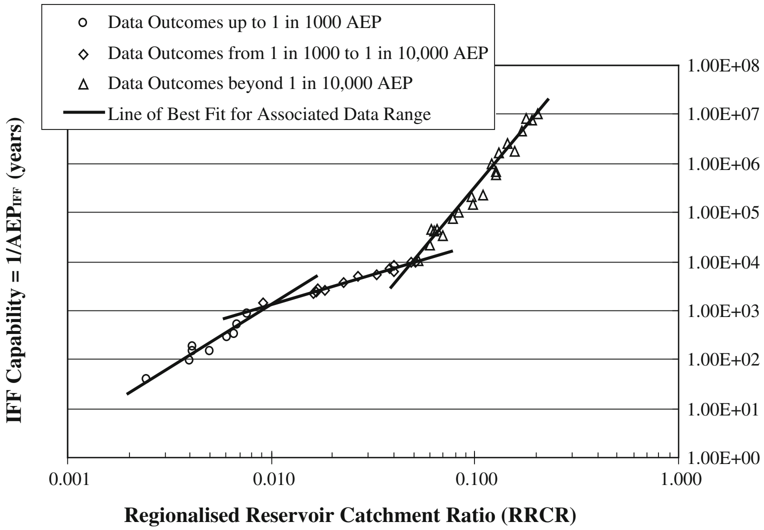
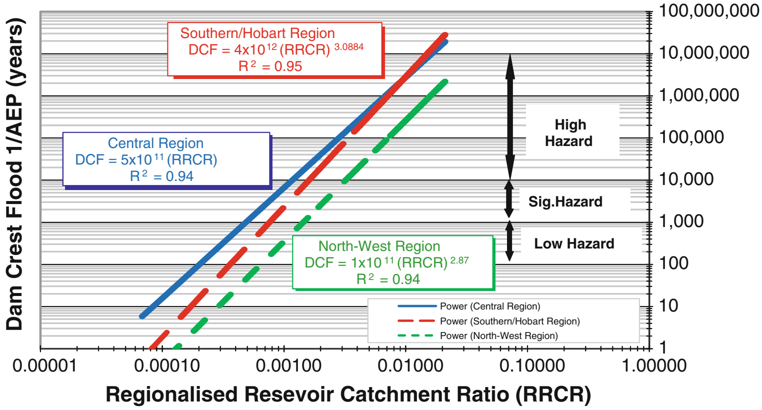


Fig. 36.6 Sample data and segmented lines of best fit for Imminent Failure Flood (IFF) capability prediction in the Mount Lofty Ranges region of South Australia (*Source* Pisaniello et al. 1999. *Note* IFF capability is equivalent to Dam Crest Flood (DCF) capability in modern engineering practice per ANCOLD 2000b)



$$RRCR = \frac{SC}{52.857 \cdot CA^{0.8774}} \cdot \sqrt{\frac{\sqrt{RA} \cdot SH}{1000 \cdot CA}}$$

where:

SC=spillway overflow capacity (m^3/s), and commonly for farm Dams the broad crested weir type spillway formulae applies:
SC = 1.69SW.$(SH)^{1.5}$ (Pisaniello, 1997)
SW = average spillway width (m)
SH= maximum height of spillway overflow (m)
RA=reservoir area at full supply level (km^2)
CA=catchment area (km^2)

Fig. 36.7 Preliminary reservoir flood capability design/review tool for Tasmania incorporating ANCOLD (2000b) criteria

1. It is based on the 100 % full "start" storage level *conservative* assumption which is recommended by ANCOLD (2000b) as appropriate for embankment dams.
2. If any dams are located upstream of the subject dam, the tool should first be applied to each upstream dam to ensure their spillway capability is adequate.
3. The principal spillway(s) must be free flowing and weir-type in nature.
4. The DCF capability must be taken as the smallest flood which peaks at the *lowest point* of the non-overflow crest in line with ANCOLD (2000b, p. 21) guidelines.

The hazard category for a dam for use in Fig. 36.7 can be assessed using ANCOLD (2000a) based on consideration of the "dam failure flood affected zone" against a matrix of both population at risk (PAR) and severity of damage and loss. DPIW (2009, Appendix 2) makes available a simple on-line spreadsheet for undertaking this hazard assessment process. This is a further "farmer friendly" element of the Tasmanian best practice dam safety policy (see also guided reporting pro-forma discussed under "Study area" above) that would link well with the cost-effective tool to minimise review/design cost burdens for dam owners.

When using the tool in review mode, the simple parameters required in the RRCR in Fig. 36.7 must be first determined for an existing reservoir. These parameters are then put into the applicable prediction relationship to read off the corresponding flood capability (DCF), which is automatically checked against the displayed ANCOLD criteria. When used in design mode, the same basic parameters are related to a proposed reservoir, or upgrade of an existing reservoir. The parameters must be varied iteratively in the RRCR until the ANCOLD safety criteria together with the owner's storage needs are satisfied.

In future works which are currently underway, the sub-regional relationships must be based on a larger range of sample catchments in order to ensure their representative credibility, and their accuracy needs to be $R^2 > 0.95$. This is achieved by undertaking the study processes on a sufficiently large range of sample catchment sizes and locations throughout Tasmania. It is recommended that at least one sample catchment be established in most of the smaller "Tasmanian Planning and Management" catchments which make up the study regions of this study (Fig. 36.1). With this larger range of sample catchment cases established, the regional areas represented by sub-relationships can be decreased in size and increased in number until sufficiently accurate prediction relationships are achieved.

Discussion

In Tasmania, once fully developed by future works the tool will provide a number of important benefits. Firstly, the tool minimises costs to dam owners due to its ease of application. This helps address the concern for government that dam safety assurance policy may place unacceptably high cost burdens on rural communities. This concern is further alleviated when the tool is used to complement the Tasmanian Government's "farmer friendly" dam safety reporting approach. Secondly, the tool is based on current standards and modern best practice engineering procedures. This satisfies the common law obligation of dam owners to maintain dams according to current standards, providing defence to liability in case of dam failure. Thirdly, it is easily applicable in either review and/or design mode. In design mode, the simple on-site input parameters can be selectively varied by the user to satisfy not only flood capability, but also other practical on-site factors, e.g. a farmer's minimum storage requirements for irrigation and fitting the spillway into the physical constraints of the valley with minimal excavation. Fourthly, the tool promotes consistency and uniform standards because no user judgement or discretion is needed as the tool has embedded in it the complex best practice engineering processes required to review or design spillways. Finally, DPIW is provided with a useful in-house checking/accounting tool for when it receives assessment reports for farm dams. This will help DPIW look after not only the interests of the landholder but also the downstream public against both (i) individual farm dam failures which currently occur so regularly and (ii) cumulative/cascade failures in larger catchments that present a real risk to large public dams.

In general, there is a clear need to mandate private owners to review the spillway flood capabilities of their dams in line with current acceptable practice and to take appropriate remedial action where necessary. The regionalised tool established here together with the Tasmanian government's "farmer friendly" dam safety reporting process can assist to achieve such a mandate in a cost-effective way. The preliminary relationships upon which the tool is based display excellent predictive accuracies for rural catchments up to 25 km^2 in size and for a diverse range of regional characteristics. This demonstrates their potential and scope for future development and the potential transferability of the tool's development process to other regions worldwide.

Conclusions

This chapter addresses the interrelated individual and cumulative flood threats posed by rural catchment dams in order to better understand them. In answering the research question in the introduction, research has found that a cost-effective flood safety engineering/accounting tool can be successfully developed on a regional basis to help minimise the interrelated individual and cumulative flood threats posed by rural catchment dams. The reported preliminary regionalised relationships upon which the tool is based display excellent predictive accuracies, demonstrating the future potential and scope for finalising their development in the study area of Tasmania, as well as the potential transferability of the tool's development process to other regions worldwide.

When the tool is used in conjunction with cost-effective, international best practice dam safety assurance policy, such as Tasmania's "farmer friendly" reporting process, dam review and/or design costs to private owners, and supervision costs to government can be minimised. As such, the cost-effective tool is capable of (i) encouraging and assisting farmers to review and/or design their spillways to minimise hazardous farm dams' risk of flood failure at the individual level (Issue 1) and (ii) assisting authorities to readily account for and supervise the flood capability of all farm dams within the catchments of large public dams in order to minimise the risk of catastrophic dam flood failure at the cumulative catchment level (Issue 2).

Overall, this research shows that governments can provide for an adequate yet cost-effective level of dam safety management accountability and assurance policy to ensure that not only individual hazardous dams are kept safe, but also the cumulative safety threats posed by rural catchment dams are kept in check. Development of the cost-effective flood capability engineering/accounting tool together with the Tasmanian government's "farmer friendly" dam safety reporting process provides an example of best practice for others to follow in Australia and internationally.

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Author Biographies

Dr John D. Pisaniello has transdisciplinary interests, with first class honours degrees in Civil Engineering and Law. Following 15 years of PhD and post-doctoral research, John is currently a Senior Research Fellow in the Centre for Accounting, Governance and Sustainability and leader of the Sustainable Engineering and Law Group at the University of South Australia. John's main interests comprise (i) integrating best-practice engineering design, accountability and legal compliance into cost-effective models, coupled with (ii) comparative analysis of international policy systems, including engineering technologies, processes and standards used, and the policies, laws and regulations adopted in varying contexts and jurisdictions, to identify lessons and elements of better practice, and (iii) consultation and engagement of communities and policy makers to assist Australian or overseas government policy and law reform.

Arthur Spassis has civil engineering qualifications together with a first class honours Bachelor of Arts degree in regional and sustainable development, acquired since 1993 from the University of South Australia and Flinders University. He has worked at the University of South Australia over the past 10 years to help develop cost-effective engineering procedures that promote consistency, sustainability, equity and uniform standards in dam safety. Arthur is currently a researcher in the Sustainable Engineering and Law Group, Centre for Accounting, Governance and Sustainability, University of South Australia. His main expertise is in catchment modelling, catchment hydrology and runoff routing using the widely recognised RORB modelling program.

Roger L. Burritt is Professor in Accounting at the School of Commerce, University of South Australia. His main research interest is in the relationship between the language of business, as captured by accounting, and the environmental and social environments in which business operates. Roger is founding Director of the Centre for Accounting, Governance and Sustainability in the School of Commerce which encourages the building of research talent and capacity in staff and higher degree research students across the areas of accounting, finance, education, engineering and law. His concern is to engage internationally in transdisciplinary research in which accounting and accountability play a critical part. His email contact is roger.burritt@unisa.edu.au.

Chapter 37
Climate Change and Disaster Risk Management: Evidence-Based Planning at Two Foster Homes in Kalimantan

Gerard Chew

Abstract Under-served communities in developing countries are more vulnerable to impacts in natural resources caused by climate change. Variability in these resources has the potential to result in disasters. This paper describes a study undertaken by one NGO to assist two off-grid foster homes, BK and LW, in Kalimantan in addressing rainfall variability for their domestic and agricultural water supply. Two satellite rainfall datasets were considered: CMORPH and TRMM. Monthly totals were obtained from 2003 to 2010, and compared against meteorological data from the closest airport using Friedman's test. Based on the results, the TRMM dataset was selected for analysis. Linear regression analysis was performed on the annual rainfall data at each foster home from 2003 to 2010 to analyse rainfall trends. The results for BK showed a marginal increasing trend ($y = 20x + 3964$), while LW showed an increasing trend ($y = 180x + 2770$). These results correlate well with reported observations, and the data reflected the El Niño drought in 2006 and 2009. Based on these findings and other studies to qualify alternative water supplies, BK will be encouraged to explore well water, while LW will be encouraged to expand rainfall harvesting.

Keywords Rainfall · Water · Satellite · Foster home · NGOs

G. Chew (✉)
Institute for Resources, Environment and Sustainability, University of British Columbia,
AERL, 428-2202 Main Mall, Vancouver, BC V6T-1Z4, Canada
e-mail: gchew@interchange.ubc.ca

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Introduction

Underserved communities in developing countries are among the more vulnerable communities affected by impacts from climate change. The IPCC 2007 Summary for Policymakers identified poor communities as being particularly vulnerable. "They tend to have more limited adaptive capacities, and are more dependent on climate-sensitive resources such as local water and food supplies" (Solomon et al. 2007). Variability in these key resources can lead to impacts which have the potential to become disasters for the communities, such as El Niño effects, fires, floods, drought, pests and vector-borne diseases (Costello et al. 2009). While the IPCC summary states that such impacts may be mitigated through appropriate management strategies, underserved communities may not have the education, resources and financial means to plan appropriately, much less react effectively. A paper by the International Water Management Institute describes the issue succinctly. The comments are directed at water management issues resulting from climate change, but could apply equally to other critical resources:

> Wise decision-making about water resource investments is uncommon. Evidenced-based planning is rare. Many governments leave the responsibility for small-scale interventions to community groups and NGOs. (Mccartney and Smakhtin 2010).

This paper describes the methods undertaken by one NGO, the Rotary Club of Kuching Central, to assist two remote and off-grid homes in Kalimantan in addressing the challenge of rainfall variability for their domestic water supply through evidence-based planning (see Map 37.1). The Balai Karangan home (BK, N = 100, GPS: 0.8704N, 110.4049E) is new, but built on the site of an older home. It is located at a small but growing border town near the Sarawak/Kalimantan border. The Living Waters Village (LW, N = 450, GPS: 0.5869S, 111.7631E) was established in 2002, and is located in deep jungle 250 km from BK (a 12 h drive on logging road). Both homes currently rely exclusively on rainfall harvesting for potable water needs, with LW additionally requiring irrigation water for food crops.

Historical Perspectives

Managers at the homes had reported anecdotal evidence of drought during the El Niño period in 2006 and 2009. However, during these early periods, the occupant load at the homes was relatively low (BK: N = 20, LW: N = 50). At the time, the drought problems were readily resolved due to the smaller size of the communities then. BK was able to truck in water from a nearby town, while LW had sufficient water reserves. However, the homes anticipate doubling their occupant capacity within the next few years, and have to make decisions regarding either scaling their current water resources or locating alternatives.

Site visits were conducted by the NGO at BK in June 2010. Presentations and meetings were also provided by the operator of LW to the NGO in March 2011. From these meetings, a set of initial objectives was established with the aim of planning for future water capacity at the homes:

- Determine the historical rainfall trend at each location;
- Identify and qualify other potential sources of potable and agricultural water: this is of particular relevance for LW, as the remote location and larger community supported by this home in deep jungle also requires that LW to be self-sufficient in food crops with appropriate irrigation planning;
- Identify low-impact water treatment alternatives: this is of particular relevance for BK, as it is currently using firewood-fuelled boiling to treat potable water, resulting in an expanding forest depletion area around the home;
- Using the evidence-based findings, generate proposals and solicit funds to design and implement sustainable water storage systems and practices at the homes.

Methods

This paper describes the technology and methods used to meet the first objective to determine historical rainfall trends. Due to the rudimentary and isolated location of these communities, there was no local source of meteorological rainfall data. In addition, hills and valleys separating the two locations 250 km apart are likely to generate localised weather systems, precluding the ability to share the same rainfall model.

Rainfall dataset from high-resolution satellites, derived from passive microwave and infrared data measurements, was considered: the NOAA CPC Morphing Technique (CMORPH) (Joyce et al. 2004) and the NASA/JAXA Tropical Rainfall Measuring Mission (TRMM). Both datasets use passive microwave techniques to estimate precipitation, with CMORPH being a technique for combining data from several satellites, while TRMM is exclusively from one satellite. The accuracy of the estimates from either data source depends on geographic features and latitude (Sapiano 2010). These datasets have been used in warning systems for pest monitoring (Ceccato et al. 2006) and flood monitoring applications (Sapiano 2010; Yilmaz et al. 2010). In order to determine the best dataset for this location, a control study was first conducted by comparing the satellite data against historical meteorological data from the Kuching International Airport (GPS: 1.487274N, 110.341966E).

Datasets dating from 2003 (the earliest complete CMORPH dataset) to 2010 were considered. Daily readings were entered into a Microsoft Excel spreadsheet. Monthly totals were obtained for each year, and the CMORPH and TRMM datasets compared against the meteorological data at the airport using Friedman's

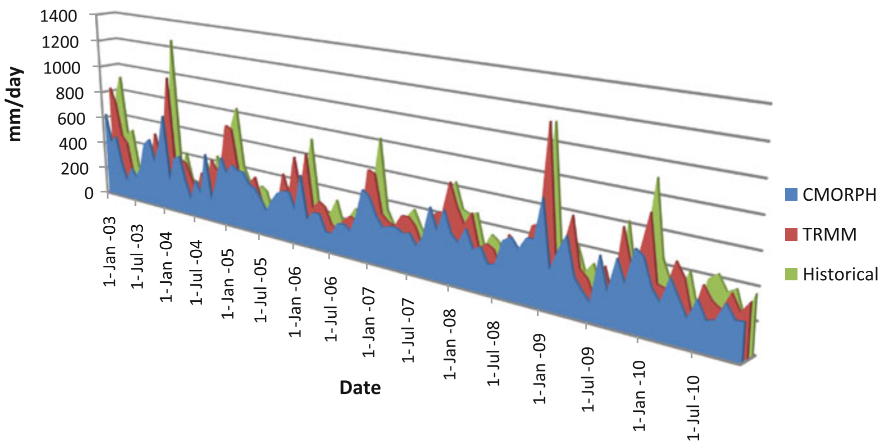

Fig. 37.1 Monthly rainfalls reported by CMORPH and TRMM, compared against historical rainfall at Kuching International Airport from 2003 to 2010

test. This test is a non-parametric ranked statistical test which avoids the need to normalise rainfall data. The results of Friedman's test for CMORPH ($p = 0.0072$) and TRMM ($p = 0.27$), meant that the null hypothesis for CMORPH was rejected, and that the TRMM data set selected as having the best fit to the airport meteorological data. This is also clearly illustrated visually (see Fig. 37.1). Linear regression analysis was then performed on the annual TRMM reported rainfall data at each home over the time period from 2003 to 2010 in order to analyse the trends.

Visual inspection of the data suggests that TRMM data ($p = 0.27$) is the better fit at this location compared to CMORPH ($p = 0.0072$).

Findings

The linear regression results for BK showed a marginal increasing rainfall trend ($y = 20x + 3964$, $r2 = 0.02$), while LW showed an increasing trend ($y = 180x + 2770$, $r2 = 0.49$). Kuching airport shows a marginal decreasing trend ($y = -34x + 4676$, $r2 = 0.03$). The findings correlate well with reported observations from the managers at BK and LW, and in particular the rainfall trends at all locations also demonstrate the drought periods in 2006 and 2009 from El Niño effects (Langner and Siegert 2009) (Figs. 37.2, 37.3, 37.4).

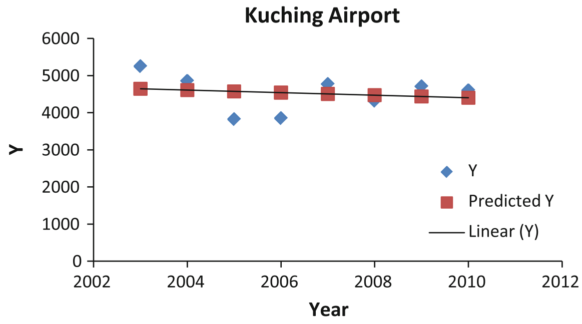

Fig. 37.2 Annual rainfall trend at Kuching Airport from 2003 to 2010: $y = -34x + 4676$, $r^2 = 0.03$

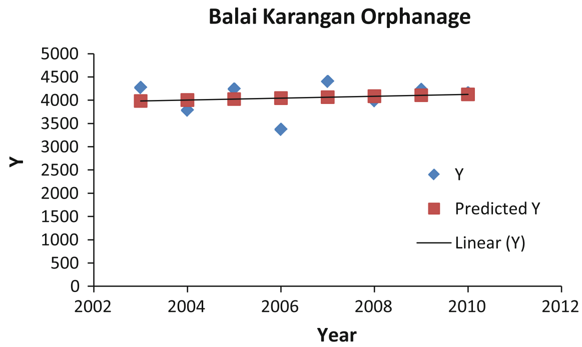

Fig. 37.3 Annual rainfall trend at Balai Karangan Home from 2003 to 2010: $y = 20x + 3964$, $r^2 = 0.02$

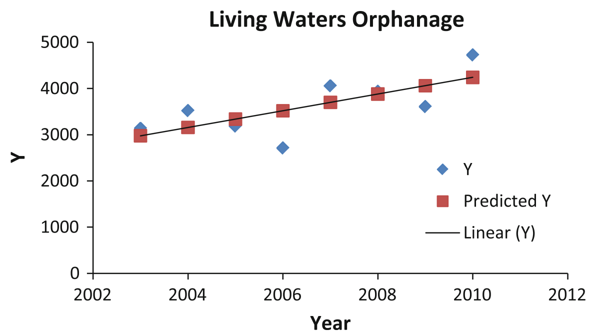

Fig. 37.4 Annual rainfall trend at Living Waters Village from 2003–2010: $y = 180x + 2770$, $r^2 = 0.49$

Discussion

Based on the linear rainfall trend and smaller surface area at BK available for rainfall harvesting, it is unlikely that there is sufficient scope to expand the rainfall harvesting at this home. However, this home also has a ground water well which is currently being used solely for bathing and cleaning purposes only. A prior water study and interview by the NGO with management staff at the BK home had determined that the ground water at this location is available year-round even during the El Niño years, and did not have significant organic, heavy metals or

Map. 37.1 Relative locations of the two foster homes on the island of Borneo

pathogenic contaminants. Hence, the NGO will propose the possibility of using the groundwater source in addition to, or as an alternative to, rainfall harvesting at this location.

On the other hand, based on the increasing rainfall trend at LW, this home has significant potential to expand rainfall harvesting options in support of domestic and agricultural activities. Prior attempts by this home to explore shallow and deep water wells failed to generate any success, and the home is currently studying the possibility of using downstream river water as an alternative water resource. However, utilising river water requires significant resources to pump the water upstream to the home. Hence, given the rainfall results seen in this article, the NGO will suggest the possibility of expanding rainfall harvesting and investing in expanded storage options at this home.

Finally, it must also be noted that the projected increasing rainfall trends at LW poses other disaster risks in the form of floods and landslides. LW is built on top of a hillside, with the surrounding trees and vegetation cleared to facilitate expansion of the facilities. The current hillside has been terraced to mitigate landslide, but the NGO will also inform the managers at LW of potential dangers from the increased rainfall.

Conclusion

In 2005, the Hyogo declaration resulting from the World Conference on Disaster Reduction recognised the contribution of multiple stakeholders, including Non-Government Organizations and volunteer groups to assist in reducing the vulnerabilities of societies, particularly those in disaster-prone developing countries

(UN 2005). This article describes an initial outcome from a partnership between the homes, an NGO, and the scientific community to develop evidenced-based planning and drought mitigation techniques at two off-grid homes in a developing country. Based on the results, the BK home will be encouraged to continue with existing plans to explore ground water options for domestic use. However, the LW home will be encouraged to give priority to expanded rainfall and storage techniques, as well as explore less energy intensive options to pump river water. Subsequent work by the NGO will develop low-impact water treatment options, and provide training in further monitoring of the impacts of climate change on rainfall and subsistence food production at LW. Both homes will also be encouraged to consider low-impact water treatment systems for potable water, such as the Canadian Slow Sand Filter System (Earwaker 2006).

Unfortunately, because of the significantly increasing occupant load at the two homes between their inception in the early 2000 s to the expected load, it is difficult to draw conclusions between the homes' prior ability to cope with existing rainfall patterns compared to their current situation. Both homes had a significantly smaller population to support; BK was able to truck in water during the worst parts of the drought during El Niño years, while LW had sufficient water reserves to tide over the drought. Nevertheless, due to the expected increasing rainfall at LW, the LW location is at risk from weather related disasters from potential landslides or flooding, and the NGO will inform the managers at LW accordingly.

Data Sources and Statistical Software

- CMORPH (http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP/.CPC/CMORPH/)

  The original analysis used rainfall data with 9 missing dates over the period 2003–2010, which were replaced with 0. 6 of these dates have since been restored, but 3 dates are not recoverable. The missing dates are: 2003: Jan 1, 2, 3: not recoverable. 2008: May 16, 17; June 20, Sept 20. 2009: April 1, June 4.

- TRMM (http://iridl.ldeo.columbia.edu/SOURCES/.NASA/.GES-DAAC/.TRMM_L3/)
- Historical data Kuching International Airport: (http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCDC/.GHCN/.v2beta/IWMO+96413000+VALUE/.prcp/T+exch+table-+text+text+skipanyNaN+-table+.html)
- Friedman's test: WINKS Statistical Software (http://www.texasoft.com/)
- Linear Regression and graphs: Microsoft Excel 2007 with Data Analysis Toolkit
- There is a website which features some of the remarkable work by Ron and Kay Heyboer at the Living Waters village, located here: http://www.heyboer.org/main/?page_id=19&lang=en

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Author Biography

Gerard Chew is a PhD candidate at the Institute for Resources, Environment and Sustainability in the University of British Columbia, Canada. He received his MSc in Computer Science, and he has over 10 years work experience in national and international commercial technology projects before deciding to pursue his PhD studies. He was motivated by a personal experience while volunteering at a refugee centre in Medan, North Sumatra, Indonesia after the 2004 tsunami, and has since pursued interdisciplinary studies in telemedicine, telehealth, and disaster management. Mr Chew is a Canada SSHRC Doctoral Fellow (disaster management), recipient of an IDRC Doctoral Research Grant (telemedicine) and a UBC Bridge Fellow (interdisciplinary studies). Mr Chew is currently in Borneo to complete his telemedicine project. Over and above these applications, Mr Chew has published one book and one book chapter on artificial intelligence, fuzzy logic and a number of peer-reviewed journals in the ACM. He also has several papers submitted. Mr Chew is an active member of the Rotary Club of Kuching Central. His research has focused on, and enhanced, many of the humanitarian and healthcare projects undertaken by the Club.

Chapter 38
Climate Change Impact Assessment of Dike Safety and Flood Risk in the Vidaa River System

Henrik Madsen, Maria Sunyer, Jacob Larsen, Mads N. Madsen, Bo Møller, Tobias Drückler, Martin Matzdorf and Jørgen Nicolaisen

Abstract The impact of climate change on the flood risk and dike safety in the Vidaa River system, a cross-border catchment located in the southern part of Jutland, Denmark and northern Germany, is analysed. The river discharges to the Wadden Sea through a tidal sluice, and extreme water level conditions in the river system occur in periods of high sea water levels where the sluice is closed and increased catchment run-off take place. Climate model data from the ENSEMBLES data archive are used to assess the changes in climate variables and the resulting effect on catchment run-off. Extreme catchment run-off is expected to

H. Madsen (✉) · M. Sunyer · J. Larsen · M. N. Madsen · B. Møller
DHI, AgernAllé 5, 2970 Horsholm, Denmark
e-mail: hem@dhigroup.com

M. Sunyer
e-mail: masu@env.dtu.dk

J. Larsen
e-mail: jla@dhigroup.com

M. N. Madsen
e-mail: mm@dhigroup.com

B. Møller
e-mail: ebm@mail.tele.dk

T. Drückler
DHI-WASY, Max-Planck-Str. 6, 28857 Syke, Germany
e-mail: tdr@dhi-wasy.de

M. Matzdorf
Kreis Nordfriesland, Marktstraße 6, 25813 Husum, Germany
e-mail: martin.matzdorf@nordfriesland.de

J. Nicolaisen
Tønder Kommune, Rådhusstræde 2, 6240 Løgumkloster, Denmark
e-mail: jn@toender.dk

W. Leal Filho (ed.), *Climate Change and Disaster Risk Management*,
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increase about 8 % in 2050 and 14 % in 2100. The changes in sea water level is assessed considering climate projections of mean sea level rise, isostatic changes, and changes in storm surge statistics. At the Vidaa sluice a mean sea level rise of 0.15–0.39 m in 2050 and 0.41–1.11 m in 2010, and increases in storm surge levels of up to 0.8 m in 2100 are estimated. The changes in extreme catchment run-off and sea water level have a significant effect on the flood risk in the river system. While most parts today have a low risk of dike overtopping with annual exceedance probabilities of 0.1 % or less, the worst case scenario in 2100 show annual exceedance probabilities of 5 % or more in the downstream part of the river system.

Keywords Climate change · Flood risk · Extreme precipitation · Sea level rise · Storm surge

Introduction

The Vidaa River catchment is a cross-border catchment located in the southern part of Jutland, Denmark and northern Germany. The Vidaa River discharges into the Wadden Sea through a tidal sluice. Extreme water levels in the lower part of the river system occur during storm surges where the sluice is closed over a prolonged period, and at the same time increased run-off from the catchment takes place due to heavy precipitation. The low-lying part of the catchment is protected by river dikes. Changes in flood risk and dyke safety in the Vidaa River system in the light of climate change with anticipated sea level rise, more severe storm surges and heavier extreme rainfalls have been evaluated in an EU INTERREG project (INTERREG 4A Syddanmark-Schleswig-K.E.R.N).

To assess the impacts of future climate change both changes in the meteorological forcing (precipitation, temperature and potential evapotranspiration) and changes in sea water level are considered. Changes in meteorological forcing data are estimated from regional climate model projections included in the ENSEMBLES data archive. Future sea water levels are estimated from current projections of the mean sea level rise in the area, estimated isostatic changes, and changes in storm surge statistics predicted from a hydrodynamic model run forced with a regional climate model (Rugbjerg and Johnsson in press).

To estimate the changes in flood risk in the Vidaa River system an integrated hydrological and hydraulic model has been set up and calibrated. This model forms the basis for simulation of water levels in the river system using meteorological forcing and sea water level data for the current (using observed records) and the future climate (using projected records), considering two projection horizons, 2050 and 2100. Extreme value analysis is applied to estimate the risk of dike overtopping at different locations.

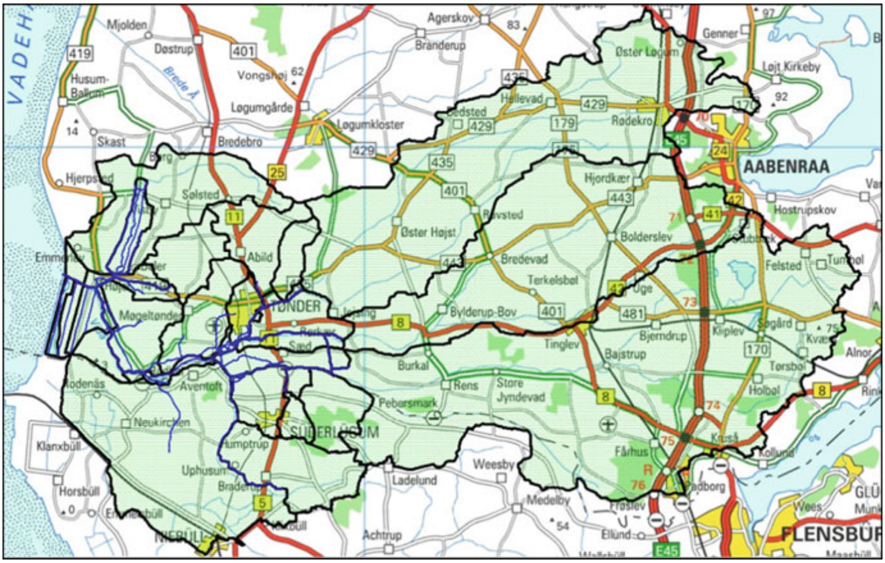

Fig. 38.1 MIKE 11 model setup. River basin (*green shaded area*), river network (*blue line*), and sub-catchments (*black line*)

Hydrological and Hydraulic Model Set-up

A MIKE 11 model (DHI 2009a) has been set up and calibrated for the Vidaa River basin (Fig. 38.1). The river network includes the Vidaa River and the major tributaries Gronaa, Sonderaa and Dreiharder Gotteskoogstrom as well as major drainage canals. The Vidaa River basin has a total catchment area of 1,342 km^2. For rainfall-run-off modelling the basin has been divided into 18 sub-catchments; four larger upstream catchments with a total area of 864 km^2 that drain to Vidaa, Gronaa and Sonderaa, and 14 downstream catchments with a total area of 478 km^2. Of the 14 downstream sub-catchments, four catchments are drained by pumping.

Rainfall-run-off models have been set up and calibrated for the 18 sub-catchments. Time series of run-off measurements were available for calibration of the four upstream catchments. No sub-catchment run-off measurements were available for calibration of the downstream catchments. These catchments were calibrated jointly against run-off measurements at the river basin outlet at the Vidaa sluice. Calibration results for one of the upstream sub-catchments and total catchment run-off are shown in Fig. 38.2. Both the rainfall/run-off dynamics and the catchment water balance are simulated satisfactorily.

Seasonal varying bed resistance has been adopted for the calibration of the MIKE 11 river model, in order to account for riverbed vegetation growth and cutting. Wind setup was included in the model and was shown to provide improved simulations of extreme events.

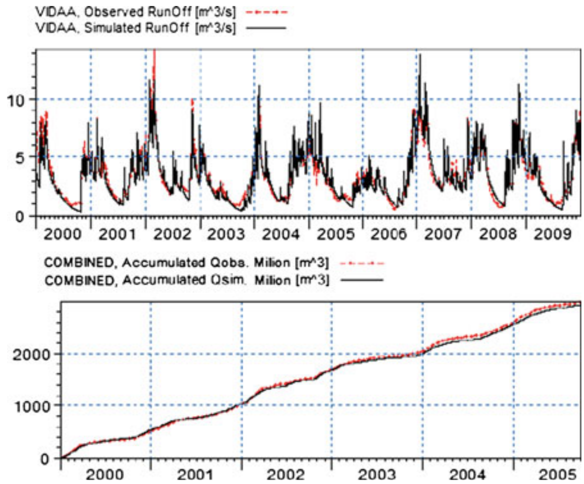

Fig. 38.2 Rainfall-run-off calibration results. *Top*: simulated (*black*) and observed (*red*) run-off at the Vidaa sub-catchment. *Bottom*: simulated (*black*) and observed (*red*) accumulated run-off at the Vidaa sluice

The integrated hydrological and hydraulic model was used for simulation of water levels in the river system, which was subsequently used in the extreme value analysis and flood risk assessment. For the long-term simulations, meteorological forcing data (precipitation, temperature and potential evapotranspiration) and sea water level at the Vidaa sluice are available for the period 1981–2009. The 10 events that cause the most extreme water levels in the downstream part of the river system are listed in Table 38.1. In general, extreme conditions with high water levels in the river system occur in periods with high sea water level at the Vidaa sluice and large run-off from the catchment. The most extreme event on record (29/10/1998)is mainly caused by extreme conditions of high sea water level at the Vidaa sluice (the most extreme duration on record) and less so on catchment run-off (rank 19 on record). Also the second (26/01/1993) and third (12/01/2007) largest events are mainly caused by extreme durations of high sea water level. On the other hand, the event 11/02/1988 (rank 6) is mainly due to extreme run-off conditions (rank 2) and less affected by sea water level. The table shows the complex nature of extreme conditions in the river system, which emphasises the need for integrated hydrological and hydraulic models for proper flood risk assessment.

Climate Change Projections

Hydrological Data

This project has used regional climate model (RCM) projections from the ENSEMBLES data archive to estimate the changes in hydrological variables in the Vidaa River basin for two projection horizons, 2050 and 2100. The ENSEMBLES

Table 38.1 Water level (H) at Rudbol Lake, total catchment run-off (Q) and peak sea water level and duration of high water level (above 0.5 m) at the Vidaa sluice for the 10 most extreme events in the downstream part of the river system

Date	Water level Rudbol lake		Total catchment run-off		Sea water level Vidaa sluice			
	H [m]	Rank	Q [m^3/s]	Rank	H [m]	Rank	Duration [h]	Rank
29/10/1998	1.79	1	71.5	19	2.39	> 60	70.25	1
26/01/1993	1.70	2	69.8	21	3.33	15	58.50	4
12/01/2007	1.66	3	70.5	20	3.28	18	58.25	5
14/01/1984	1.65	4	66.4	29	2.71	56	44.50	18
29/01/1994	1.63	5	55.0	>60	3.77	5	34.00	43
11/02/1988	1.61	6	85.0	2	2.73	53	33.00	52
21/01/2007	1.58	7	71.5	18	2.70	>60	22.00	>60
29/01/2002	1.56	8	67.4	26	3.64	8	22.25	>60
04/01/1988	1.56	9	76.8	8	2.32	>60	34.50	35
04/01/1984	1.55	10	53.5	>60	3.29	16	45.50	14

data include a number of projections for the A1B emission scenario using different RCMs forced by different general circulation models (GCMs).

To correct for biases introduced by the RCM/GCM model for simulating climate variables at the river basin scale, the climate model data are statistically downscaled. In this project, downscaling based on a general change factor methodology has been applied. In this case the RCM/GCM climate model simulations are used to extract future changes in statistical characteristics of climate variables (denoted change factors), and these changes are then superimposed on the statistical characteristics of the climate variables representing the river basin obtained from observed records. To take seasonal variations into account, monthly change factors are calculated.

A mean correction methodology (also known as the Delta change approach) was applied for statistical downscaling of temperature. Temperature data for the future climate are obtained by adding absolute changes in temperature from the RCM/GCM projections to the observed temperature record. In order to estimate changes in potential evapotranspiration a temperature-based method was used (Kay and Davies 2008). Potential evapotranspiration data for the future climate is obtained from the relative change in temperature from the RCM/GCM projections. For statistical downscaling of precipitation a method that uses both changes in the mean and changes in the variance was applied as seen elsewhere in the literature. In this case, the future precipitation is given by (Leander and Buishand 2007): $P_{fut} = aP^{b}{}_{obs}$, where P_{obs} is the observed precipitation, and a and b are estimated from the changes in mean and variance.

For the calculation of change factors, catchment averages of daily precipitation and temperature from the RCM/GCM have been used. The changes are based on 30-year periods of climate model data, with 1980–2009 representing the present climate, 2035–2064 representing the future climate in 2050, and 2070–2099 representing the future climate in 2100.

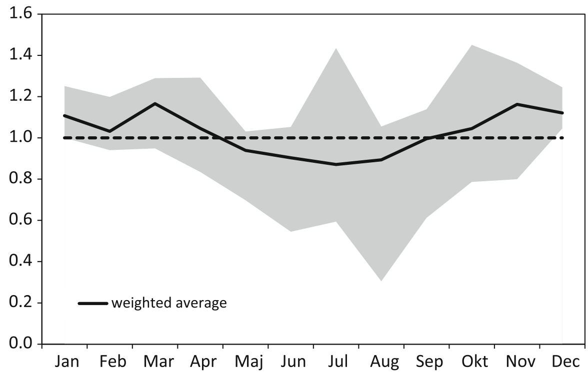

Fig. 38.3 Estimated variability of the change in mean precipitation in 2100 from the 15 RCM/GCM models (*grey shaded area*) and the weighted average

It is generally recommended to use an ensemble of climate model projections for impact assessments in order to take the uncertainties in the projections into account (Fowler et al. 2007). In this project, 15 RCM/GCM projections from the ENSEMBLES data archive were used for downscaling precipitation, temperature and potential evapotranspiration. Weighted average change factors were applied where weights for the 15 different RCM/GCM models were determined based on the skills of the models for simulation of present climate, considering the monthly variability of mean precipitation, variance of daily precipitation, and mean temperature.

A large variability in the estimated changes is seen for all statistics. As an example, the variability of the change in mean precipitation in 2100 of the 15 RCM/GCM models and the weighted average are shown in Fig. 38.3. Most models estimate an increase in precipitation in winter and a decrease in summer, but for all months, and especially in summer, a large variability is apparent. The weighted average change factors for 2050 and 2100 are shown in Fig. 38.4. The temperature increase is about 1–1.5° in 2050 and 2–2.5° in 2100. In general, precipitation increases in winter and decreases in summer and a larger variability is expected in all months, with the changes being more pronounced in 2100. The increase in potential evapotranspiration follows the changes in temperature with larger relative changes in winter than in summer.

The downscaled precipitation, temperature and potential evapotranspiration data for 2050 and 2100 have been used as input for rainfall-run-off model simulations. The changes in the estimated extreme value statistics of catchment average rainfall and total catchment run-off are shown in Fig. 38.5. The extreme daily precipitation increases about 9 % in 2050 and 15 % in 2100, and similar changes are seen in the extreme catchment run-off statistics (about 8 % in 2050 and 14 % in 2100).

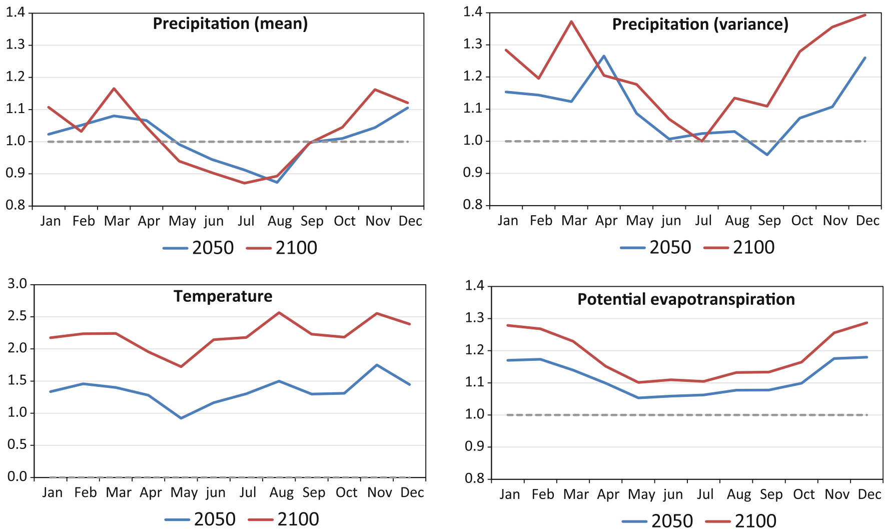

Fig. 38.4 Relative change in mean and variance of precipitation and mean potential evapotranspiration, and absolute change in temperature (degrees Celsius) for future (2050 and 2100) climate

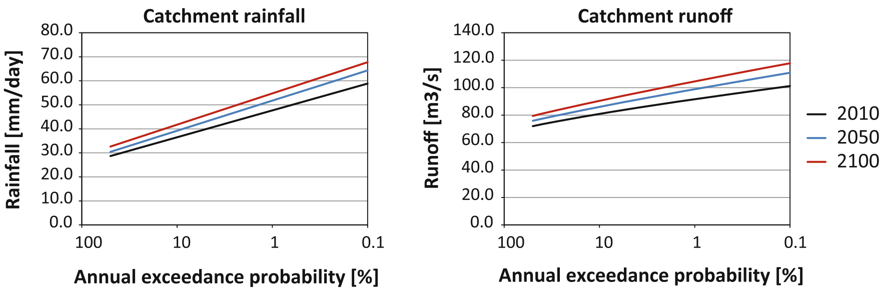

Fig. 38.5 Extreme value statistics of catchment average rainfall and total catchment run-off for current (2010) and future (2050 and 2100) climate

Sea Water Level

Changes in the sea water level at the Vidaa sluice are a combination of:

- Global increase in mean water level due to thermal expansion and melting of glaciers and ice caps;
- Local change in mean water level due to changes in water density and circulation patterns;
- Local change in mean water level due to isostatic change;
- Local change in storm surge levels due to changes in extreme storm intensities and changes in mean water level.

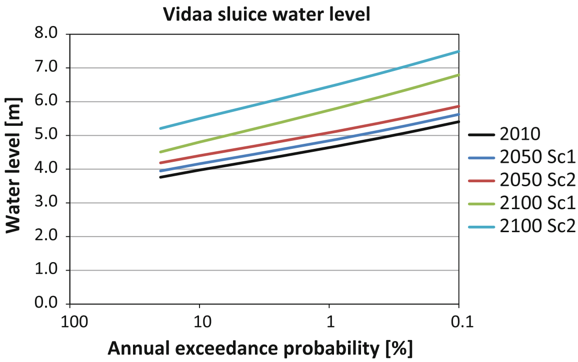

Fig. 38.6 Estimated extreme sea water level statistics at the Vidaa sluice for current (2010) and future (2050 and 2100) climate. Sc1 and Sc2 correspond to, respectively, the low and high scenario of mean sea level rise

According to the results published in the IPCC's Fourth Assessment Report (IPCC 2007) a global increase in mean sea water level of 0.18–0.59 m is expected by 2100, with an additional local increase in the waters around Denmark of about 0.15 m. New results, however, show that global sea level rise will be larger than reported in the IPCC's Fourth Assessment Report (e.g. Grinsted et al. 2009). Based on the new results, the Danish Meteorological Institute has estimated an increase in mean sea water level for Danish waters in the range 0.3–1.0 m in 2100 (Danish Climate Change Adaptation Portal 2011). Due to the large uncertainties in the projected increase in mean sea water level, two scenarios have been applied in the analysis corresponding to, a respective increase of 0.3 and 1.0 m in 2100. In order to estimate the mean sea level rise in 2050, the temporal development reported in Grindsted et al. (2009) was used.

Due to isostatic changes there is a continuous relative increase in the mean sea water level in the area. According to the Danish Coastal Authority (2007) there has been an increase in mean sea water level at the Vidaa sluice due to isostatic changes to the extent of 11 cm in the period 1891–1990. This relative increase is assumed to continue up to 2100, i.e. an annual increase of 0.11 cm per year has been applied.

For estimation of changes in storm surges, model simulations based on a hydrodynamic model covering the North Sea, Baltic Sea and inner Danish waters were used. The model was forced by wind and atmospheric pressure fields from one of the RCM models form the ENSEMBLES data archive (Rugbjerg and Johnsson in press). Time series of sea water levels at the Vidaa sluice were extracted from the hydrodynamic model simulations. Extreme water level statistics were calculated for 2010 using these time series (based on simulation results for the period 1980–2009), 2050 (2035–2064) and 2100 (2070–2099). Future extreme value statistics for 2050 and 2100 are then estimated by superimposing the changes in extreme value statistics to the current statistics (Danish Coastal Authority 2007) and adding the projected mean sea level rise and isostatic changes (see Fig. 38.6).

The changes in extreme value statistics caused by changes in the storm surge signal (i.e. without considering climate-induced mean sea level rise and isostatic changes) are in the order of 0.04–0.05 m for 2050 and 0.5–0.8 m for 2100 for

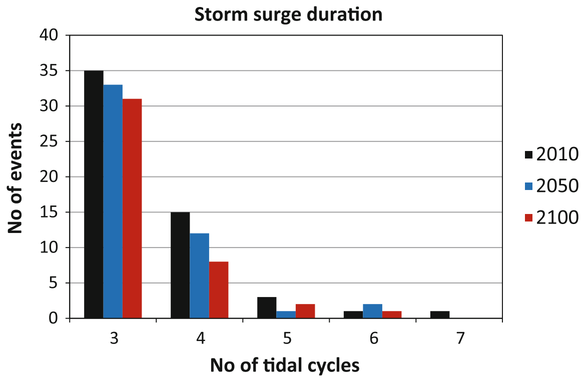

Fig. 38.7 Distributions of duration of storm surge water level above 0.5 m in terms of number of tidal cycles from the hydrodynamic model simulations for current (2010) and future (2050 and 2100) climate

annual exceedance probabilities ranging between 0.5 and 5 %. This corresponds well with results from other studies in this area (Madsen 2009). When adding the climate-induced mean sea level rise and isostatic changes, the extreme value statistics become much more severe. For instance, a 5 m water level has an annual exceedance probability of about 0.5 % according to the current statistics (corresponding to an event which is expected once every 200 years on average) but will in 2100 in the case of the high sea level rise scenario have an annual exceedance probability of about 30 % (1 in 3-year event).

As shown above, the duration of high sea water level at the Vidaa sluice is critical for storage of water in the river system. The duration of high sea water levels have been calculated from the hydrodynamic model simulations. In Fig. 38.7 the number of events with prolonged periods of high water level at the Vidaa sluice (above 0.5 m) are shown for the three 30-year periods representing 2010, 2050 and 2100 (without changes in mean sea level). As opposed to the extreme storm surge peak level, the durations of high water levels are not expected to increase in future climate. In fact, the number of events with larger durations tends to slightly decrease towards 2100.

Based on the above results, time series of sea water levels at the Vidaa sluice representing 2050 and 2100 climate were established from the observed time series by adding climate-induced mean sea level rise, isostatic changes, and changes in extreme water level statistics. The four different climate change scenarios applied in the risk analysis are summarised in Table 38.2.

Risk Analysis

The integrated hydrological and hydraulic model has been used for simulations using the observed records of meteorological data and sea water level at the Vidaa sluice 1981–2009, and the projected records representing the respective climates for 2050 and 2100 (see Table 38.2). From the simulations, water levels at selected

Table 38.2 Summary of applied climate change scenarios

Scenario	Projection horizon	Change in mean sea water level		Change in storm surge statistics	Change in precipitation, temperature and potential evapotranspiration
		Climate change (cm)	Isostatic change (cm)		
1	2050	+10	+5	Based on hydrodynamic model run 2035–2064	Based on ENSEMBLES data 2035–2064
2	2050	+34	+5		
3	2100	+30	+11	Based on hydrodynamic model run 2070–2099	Based on ENSEMBLES data 2070–2099
4	2100	+100	+11		

critical locations in the river system have been extracted and used for the extreme value and risk analysis.

The MIKE by DHI extreme value analysis software package EVA (DHI 2009b) has been used for the analysis. EVA includes both annual maximum series and peak over threshold (POT) estimation procedures. Several statistical distributions are included, and EVA supports parameter estimation using maximum likelihood, method of moments and method of L-moments. Several goodness-of-fit measures are available to support selection of a proper statistical distribution. In this study, the POT method has been applied for analysis of extreme water levels. The analysis showed that the Weibull distribution is preferable for the fitting of water level extremes.

An example of the results of the extreme value analysis at one of the selected locations is shown in Fig. 38.8. The figure shows the extreme water level statistics for current conditions and the four different climate change scenarios compared to the river dike levels. A significant increase in the risk of dike overtopping is projected at this location. For the current conditions, the annual exceedance probability of the dike level is less than 0.1 % (corresponding to an event that is expected less than once every 1000 years on average). In 2050, with the low mean sea level rise scenario the risk is still small (about 0.1 %), but with the high mean sea level rise scenario the risk increases to about 0.7 %. In 2100, the risk corresponding to the low mean sea level rise scenario is close to the risk of the 2050 high sea level rise scenario, but for the high sea level rise scenario the risk increase to about 10 %. Thus, in the worst case scenario the risk has increased from an event that is expected less than once in 1000 years to a 1 in 10 years event, which represents a significant increase in the flood risk at this location.

In Fig. 38.9 the flood risks for current and future climate at the selected locations are shown. Current conditions indicate that the flood risk in most parts of the river system is less than 1 %. The 2100 climate with the high mean sea level scenario has a considerably larger flood risk. In the upstream river branches the

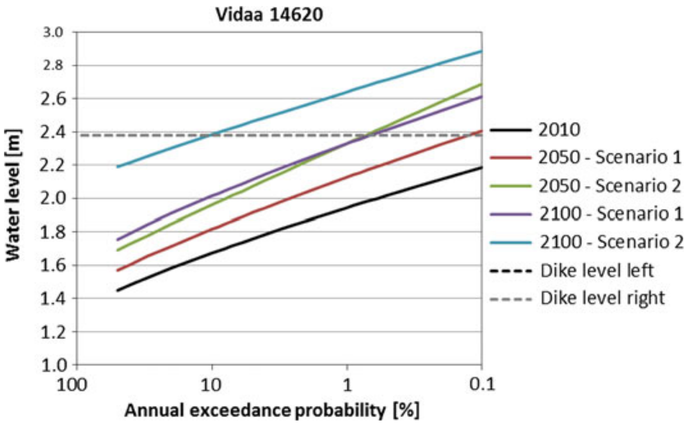

Fig. 38.8 Estimated extreme water level statistics at Rudbol Lake for current (2010) and future (2050 and 2100) climate. Scenario 1 and Scenario 2 refer to, respectively, the low and high scenario of mean sea level rise

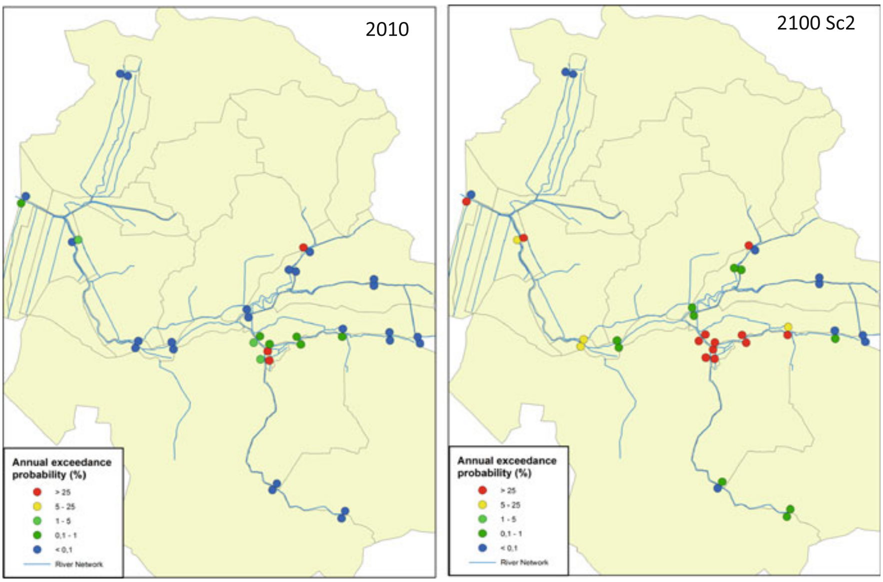

Fig. 38.9 Estimated flood risk at selected locations in the Vidaa River system for current (2010) and future (2100 with high mean sea level scenario) climate. For each location the annual exceedance probabilities for overtopping on the left and right bank are shown

risk is still small (annual exceedance probability less than 0.1 %), but the downstream parts of the Vidaa and Sonderaa Rivers have risk levels of 5 % or more.

Conclusions

The impact of climate change on the risk of dike overtopping in the Vidaa River system has been evaluated. Both changes in the meteorological forcing data (precipitation, temperature and potential evapotranspiration) and changes in sea water level have been considered. Results from 15 RCM/GCM projections from the ENSEMBLES data archive were used for estimating changes and downscaling future meteorological forcing. More extreme precipitation events are expected in the future, which will result in an increase in the extreme run-off in the Vidaa River basin of about 8 % in 2050 and 14 % in 2100.

Regarding changes in sea water level at the Vidaa sluice, climate projections of mean sea level rise, isostatic changes, and changes in extreme water level statistics have been included. Due to the large uncertainty in current projections of mean sea level rise, two scenarios have been considered. Hydrodynamic model results show increases in extreme storm surge levels at the Vidaa sluice of up to 0.8 m in 2100. However, durations of extreme water levels are not seen to increase.

For the projected changes in meteorological forcing and sea water level, changes in extreme conditions in the Vidaa river system have been analysed. Currently, there is a relatively low risk of dike overtopping with annual exceedance probabilities of 0.1 % or less in most parts of the river system. For the worst case scenario in 2100, pronounced changes in flood risk are seen with flood risks of 5 % or more in the downstream parts of the Vidaa and Sonderaa Rivers.

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Author Biographies

Henrik Madsen has more than 15 years' experience in hydrological modelling, water resources management, extreme value analysis, stochastic modelling, flood forecasting, and climate change impact assessment. He is head of innovation at DHI responsible for the research and development activities within climate change adaptation. He is co-ordinator of a major research project on risk-based design in a changing climate funded by the Danish Strategic Research Council (http://riskchange.dhigroup.com/) and member of the Science Core Group of the Centre for Regional Change in the Earth System (CRES) (http://cres-centre.net/).

Maria Sunyer has experience in working with climate data and climate change issues. Her expertise covers statistical downscaling of climate model projections, climate change impact assessment of hydrological systems, and flood risk analysis. She is currently a PhD student at the Technical University of Denmark working with methods for estimation of uncertainty in climate model projections.

Jacob Larsen has 12 years of experience in the application of computational models covering both coastal and inland waters. Most of the last eight years of his career have been spent on development, maintenance, and application of major flood forecasting and flood management systems in many different countries of the world, working with local river management authorities or private organisations. He has been responsible for the customisation and installation of hydrological and hydraulic flow forecasting systems in the USA, Asia, Europe, and the Pacific.

Mads N. Madsen has more than 20 years' experience in development and application of mathematical modelling systems for simulation of flows and water quality in rivers, estuaries, and reservoirs. He has extensive experience from assignments in Europe and Asia in relation to project management, training and teaching and business development. He has published several papers in international journals with emphasis on mathematical model development and application.

Bo Møller was employed in the county of Southern Jutland between the years 1988–2006 working in river management, including dike safety and the assessment of flood risk. From 2006 he has worked as senior consultant in a number of projects related to water resources planning and management.

Tobias Drückler has worked at DHI-WASY for two years. He forms part of the flood forecast team at DHI-WASY and is an expert in hydrological and hydraulic modelling.

Martin Matzdorf is head of the Water Management Division at the Nordfriesland County, Northern Germany.

Jørgen Nicolaisen is working in the Environment Department at the municipality of Tønder, Southern Jutland, Denmark.

Chapter 39
Climate Change Vulnerability Assessment: Case of Coastal Cities in South East Asia

Vilas Nitivattananon, Lam Vu Thanh Noi and Worapong Lohpaisankrit

Abstract As climate change is likely to have negative impacts on coastal areas in many regions including South East Asia, improved knowledge on the understanding of assessment methods and results is gaining interest. Based on an on-going project implemented by the asian institute of technology (AIT) and partners in South East Asia, with the goal to enhance local adaptive capacities through learning from the cooperative research results on climate change impacts in coastal cities of the region, this paper provides overall information and progressive results of the project, including a review of climate change vulnerability and risk assessment processes, as well as available tools/techniques for the assessment, whilst also conducting a rapid vulnerability assessment (RVA) with a case study. Conclusions and recommendations are also made for the next steps of the project and possible contributions to other related projects and cities.

Keywords Climate change · Coastal water management · Risk assessment · Urbanisation

V. Nitivattananon (✉) · L. V. T. Noi · W. Lohpaisankrit
Urban Environmental Management, Asian Institute of Technology, 4 Klong Luang, Pathumthani 12120, Thailand
e-mail: vilasn@ait.ac.th

L. V. T. Noi
e-mail: lamnoi2002@yahoo.com

W. Lohpaisankrit
e-mail: lohpaisankritw@yahoo.com

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Introduction

South East Asia is one of the world's most vulnerable regions to climate change due to its long coastlines, high concentration of population and economic activity in coastal areas, and heavy reliance on agriculture, natural resources, and forestry. Climate change is already affecting the region, as shown by the increasing frequency and intensity of extreme weather events such as heat waves, droughts, floods and tropical cyclones in recent decades (ADB 2009, 2010; World Bank 2008).

This paper presents an overview and the progressive results of an on-going research project in South East Asia implemented by the asian institute of technology (AIT) and partners in Indonesia, Thailand and Vietnam. The goal of this project is to enhance local adaptive capacities through learning from the cooperative research results on climate change impacts in South East Asian coastal cities. The contribution of this research is not only its aim of enhancing the adaptation capacities of coastal cities in South East Asia but also in its broader targets of improving urban environmental management and urban planning in studied countries. Other cities, countries and regions can be included in the study at a later date by sharing data gathered by the research results.

The scope of this presentation covers the results of investigating climate change risk assessment processes with potential tools/techniques based on a literature review and selection including conduct of case studies related to climate change vulnerability assessment. A case study of assessing risk and vulnerability in coastal cities is also presented with a focus on a rapid vulnerability assessment (RVA) for urban water and waste water infrastructures in Ho Chi Minh City (HCMC). Lessons learned from these progressive results with recommendations for next steps of the research, as well as for possible applications in other similar projects, are then made.

Review of Climate Change Vulnerability Assessment Processes with Some Potential Tools/Techniques

Climate Change Risk Assessment Process

This study explored several past research studies such as IDRC-CCAA (2007), CIDA-NOVASCOTIA (2007), ISDR (2003, 2004), IPCC (2001), (Paul et al. 2007), Tu and Nitivattananon (2011), etc. The main purpose of climate change risk/vulnerability assessment researches is to understand the various aspects of risks to human life presented by climate change in broad areas such as at regional, national, and state level. These previous research studies did not focus in detail on climate change risks to urban water management at local level. However, the common climate change risk assessment process in all researches includes four

Table 39.1 Summary of potential tools/techniques to be applied in climate change vulnerability assessment

Main step of risk assessment	Candidate tools/techniques
Identify the risk factors	PRA, problem tree analysis
Investigate vulnerabilities	MCA, impact matrix, GIS, PRA, Bayes' theorem
Assessing adaptive capacity	AHP, multiple criteria analysis,

general steps which are: identifying the risks, prioritising the risk (investigating vulnerabilities), selecting the response and adaptation measures, and the plan of action.

After reviewing the existing researches, a climate change risk assessment process was proposed with the following main steps: identifying the risks, investigating vulnerabilities, selecting adaptation measures/strategies and proposing appropriate adaptation measures/strategies. Following this process, the suitable support tools were selected for with the purpose of conducting a climate change vulnerability assessment in these study areas. The details of the vulnerability assessment are presented in the section "Rapid Vulnerability Assessment".

Potential Climate Change Risk Assessment Techniques/Tools

From the review of case studies for applied assessment tools/techniques, it was found that the application results show experiences and lessons learned for environmental management. The potential tools/techniques may be considered for climate change risk assessment because they already have already been applied in some aspects of assessment closely related to climate change impacts, such as common infrastructure risk (Paul et al. 2007), assessment hazards to livelihoods, flood-hazard assessment (Tinhsanchali and Karim 2010), and Environmental Impact Assessment.

The criteria for proposing potential tools/techniques are the tools that have been applied with successful results in case studies and cases that are closely related to impact assessments. A summary of candidate tools/techniques to be applied in the climate change assessment for urban water management is given in Table 39.1. Some candidate tools/techniques are presented below.

Participatory Rural Appraisal (PRA) can be applied to identify climate change risks to water and waste water infrastructures, and to prioritise the risks. In this research, PRA also can help to identify the degree to which assets and activities of urban water and waste water infrastructures will be affected by climate change risks.

Problem Tree Analysis is applied to investigate the context and inter-relationship of problems, and the potential impacts when targeting projects and programs toward specific issues. In this study, Problem Tree Analysis can help with the integration of climate change impacts and urbanisation on specific problems such as inadequate clean water and epidemics of skin diseases in areas afflicted by flooding.

Impact matrix can also be used to estimate the level of impacts, frequency and consequences of risks, as well as estimating the expected value loss for stakeholders. The results of applying impact matrix are tables to guide overall impact rating matrix and risk rating (likelihood and consequence) matrix.

Geography information system (GIS) can be used to establish a GIS baseline data and analysis data of climate change impacts. GIS software will be applied to display a summary of prioritised high and extreme risks with all information recorded in the identification as well as the agreed priority allocated in the evaluation review. The summary of the climate change risks to the various urban water and waste water infrastructure sectors is the output of GIS's analysis.

Bayes' theorem can support the decision-making process. It can be used to analyse the impacts of climate change, as well as predicting risks/vulnerabilities. Because of climate change and economic development, the chances for each event that happens will be considered as predicted probabilities. Bayes' theorem can be used for analysis and can provide more reliable estimates of the probability of occurrence of the various possible states of variables.

Multiple criteria analysis (MCA) is applied to rank levels of climate change adaptation and mitigation measures/strategies, and to analyse the impacts as well as supporting decision makers in assessing the effectiveness of other tools/techniques.

The application of the analytic hierarchy process (AHP) involves the selection of adaptation options that will reduce the vulnerability of target groups, based on the needs and priorities of socio-economic groups, productive sectors, environmental goods and services and specific geographic regions. This research implements AHP in terms of using expert choice software to analyse data in the decision-making process.

Selection of Cities

There are a number of coastal cities in the countries of South East Asia. They are distributed along several sea zones such as the Andaman Sea, the South China Sea and the Indian Ocean. In fact almost all of the coastal cities in this region have made attempts to combat the effects of climate change. As a result, this research proposes criteria in order to select 15 coastal cities located in three countries in South East Asia, namely Indonesia, Thailand and Vietnam, to represent the coastal cities in those countries and also the region as a whole. The basic criteria for screening coastal cities are:

- Evidence of climate change impacts related to water resources such as decline trends in the quality of those coastal cities because of habitat loss, increasing frequency of floods and droughts, and collapse of fisheries or loss of biodiversity.

- Size of the coastal cities area is appropriate for urban water resources management; in other words, the size is not too large as compared to associated river basins or coastal zones.
- Data is important in the research. Coastal cities must have available records which can then be looked at. The types of data required are hydrological, social, economic and environmental data.

After the coastal cities are screened, there are several cities that reach the basic requirements. In order to classify the coastal cities, the characteristics of the cities are analysed and formed in groups as follows:

- Geography of the cities is one of the natural factors that influence water resources. The coastal cities can consist of different geographical features such as mountainous areas and flat areas.
- Coastal zones can be considered not only temperate zones but also spatial zones. A location in next to a different sea or ocean may affect the coastal cities in different ways.
- Major economic activities in the coastal cities including fisheries, tourism and industry.
- Principal climate impacts and vulnerabilities related to water resources can be categorized such as coastal sea wave erosion, floods due to rising sea levels and changes in the water quality. Moreover, ecosystems along the coast are damaged because of strong winds and tidal waves.

The classification (ranking) of alternative cities in each category and by country can be applied to the basis of various criteria as a simple matrix. The main criteria used in the matrix are population, socio-economic aspects, target group, climate impacts.

- Population is one of indicators for social aspects.
- Socio-economic aspects of the coastal cities are coastal aquaculture, agriculture and industry. Furthermore, the level of wealth of families can be a factor used to evaluate and prioritise the selected cities.
- Target groups in the 15 coastal cities consist of coastal communities, villagers and farmers. This indicator describes the variety of the communities in cities.
- Possible direct and indirect climate impacts related to water resources.

Based on the above procedure and criteria, a tentative list of selected cities is presented in Table 39.2. According to the socio-economic aspects, the 15 coastal cities selected consist of several target groups such as coastal communities, villagers and farmers. These groups may suffer from the impacts of climate change on water resources because their businesses depend not only on the quality, but also on the quantity of water available.

Table 39.2 Tentative list of selected cities in Indonesia, Thailand and Vietnam

City, Region/ Province	Population	Target groups	Possible climate impacts and key water-related issues
Indonesia			
Banda Aceh, (North) Sumatra	223,461 (2010)	Coastal communities	Conditions of this city are vulnerable to abrasion and intrusion of sea water.
Bandar Lampung, (South) Sumatra	912,087 (2008)	Coastal communities	Extreme changes in rainfall frequency, increased intensity of rainfall during the rainy season causing floods; changes in the length of the rainy season
Cirebon, West Java	298,995 (2008)	Farmers, urban communities	Water supply is limited because of the short rainy season. Increasing rainfall also causes flooding if rice fields
Semarang, Central Java	1,507,826 (2009)	Farmers	Changes in rainfall intensity result in changes in cropping Wetlands (paddy fields) flooded because of sea level rise (SLR)
Makassar, (South) Sulawesi	1,500,000 (2010)	Coastal communities, fishermen	It is highly vulnerable to rise in the sea level
Thailand			
Bang Khun Thian, Bangkok, Central	151,547 (2010)	Coastal communities, shrimp famers	It is one of the hot-spot areas (being the most severely eroded coastal area in the country). Mangrove forest areas have decreased as a result of coastal erosion.
Songkla, Southern	72,028 (2009)	Local communities	Coastal erosion occurs along 2,012 m of the coast at a rate of 1.25 m/year.
Ban Laem Western/Gulf	13,046 (2009)	Local fishermen	200 m length along 5 km of coast was severely eroded. The rising sea level causes flooding and other effects.
Krabi, Southern	25,872 (2008)	Local villagers	2–3 m depth of the coast has been eroded along 10 km of coastal areas. Sea-level rise, strong wind and tide are endangering mangrove areas.

(continued)

Table 39.2 (continued)

City, Region/ Province	Population	Target groups	Possible climate impacts and key water-related issues
Prasae (Rayong), Eastern	5,561 (2010)	Local communities	Seawater intrusion in the river.
Vietnam			
Ho Chi Minh City (HCMC), Southern	8.3 million (2009)	Communities vulnerable to flooding	60 % land lies below 1.5 m, so floods happen by rain and tidal surge. Water-borne disease is one of important issues in flooding areas. Inadequate water supply in dry season
Hai Phong, Northern	1,837,302 (2009)	Flooding, fishing villages	SLR increases the risk of catastrophic loss of settlements, so this area is likely to be submerged by seawater.
Vung Tau, Southern	278, 188 (2009)	Coastal communities, Fishermen	Water supply is limited in dry season Saltwater intrusion affects farmland as well as water Fishing villages have the threat of SLR that causes abrasion.
Bien Hoa, Southern	1 million (2009)	Communities vulnerable to sea level rise	Sea level rise and saltwater intrusion Inadequate water supply in dry season Increasing frequency of water-related diseases affecting communities
Hoi An City, Central	121,716 (2008)	Communities vulnerable to SLR	Flooding, sea level rise, storm, public health

Case Study of Rapid Vulnerability Assessment

As coastal cities experience impacts of climate change such as water pollution, loss of wildlife habitat, water and waste water infrastructure vulnerable to SLR such as floods, saltwater intrusion and land subsidence were identified as immediate concerns of coastal cities. One case study in rapid vulnerability assessment of climate change impacts in HCMC is explored as the pilot vulnerabilities assessment in selected cities of the research project. Some potential tools/techniques presented in the previous section were selected and applied in this case.

The main objectives of this case study are to gain experience from using tools/techniques for conducting RVA for urban water and waste water infrastructures and recommend next steps for the project, as well as possible contributions to other related projects and cities. This case used rapid assessment for assessing climate change vulnerability at community level. The aim of this case focused on finding out the impacts of climate change on water and waste water infrastructures, livelihood capital, and vulnerabilities in the context of the impacts of urbanisation and current climate change adaptation measures/activities in HCMC.

HCMC has been identified as one of the ten cities most likely to be severely affected by climate change. It has been ranked fifth by population exposed to the effects of climate change by 2070 (ICEM 2009). HCMC is vulnerable to climate change because it is barely above sea level. If fact, as much as 40–45 % of land cover in HCMC is 0–1 m above sea level, 15–20 % is 1–2 m above sea level, whilst very little land sits above 4 m. Local development patterns, especially infrastructure development and urban development, are also affecting the local climate's vulnerability to the impacts of climate change.

The main steps of vulnerability assessment are identifying the risk factors, investigating vulnerability in study areas, and assessing current adaptive capacity, then recommending for climate change adaptations in study areas. The methodology in the assessment is summarised as shown in the following diagram (Fig. 39.1).

Steps and Methods Undertaken

The main steps of the rapid vulnerability assessment with specific tools and techniques applied in the case study of HCMC are presented in Table 39.3.

In the step of identifying risk factors, climate change related risk factors were investigated based on literature review and primary and secondary data. This step applied PRA and MCA techniques for investigating all CC impacts on water and WW infrastructures by interviews (individual households, key informants), surveys, group discussion, description of situation and trend analysis. In addition, Problem Tree Analysis also supported the PRA process to identify direct and indirect impacts as well as the relationship between them.

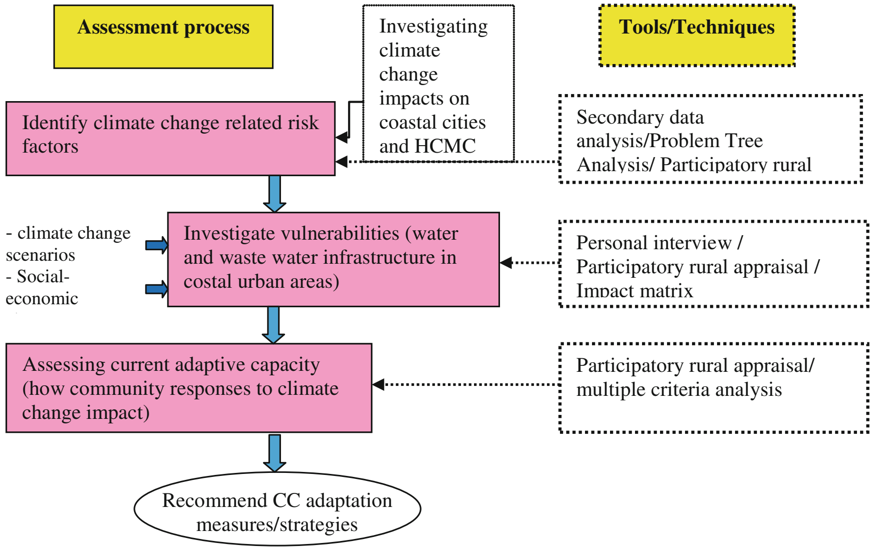

Fig. 39.1 Methodology in assessment of vulnerabilities to climate change

Table 39.3 Main steps and tools/techniques undertaken in case study of HCMC

Steps	Main tools/techniques	Data collection and analysis
Identifying climate change related risk factors in HCMC	Problem tree analysis	• Field observations, and analyses of causes and effects • Secondary data of SLR, flooding, salt intrusion, current status of water and WW infrastructures
	PRA: interview key informants	• Interview researchers, experts
	Impact matrix	• Rank main flooding impacts on HCMC (whole city)
Investigating vulnerabilities in Binh Thanh and Thu Duc districts	PRA: group discussion, interview key informants, survey	• Interview decision-makers, researchers • Survey with 214 households (Binh Thanh and Thu Duc districts) • Statistics with Excel and SPSS software
	MCA: rank level of climate change related impacts	• Statistics with Excel software • Interview researchers/decision-makers
	Impact matrix	• Statistics with Excel software
Assessing current adaptive capacity	PRA: group discussion, interview key informants, survey	• Interview, survey 242 households • Statistics with Excel software
	MCA	• Rank current adaptation measures/ activities

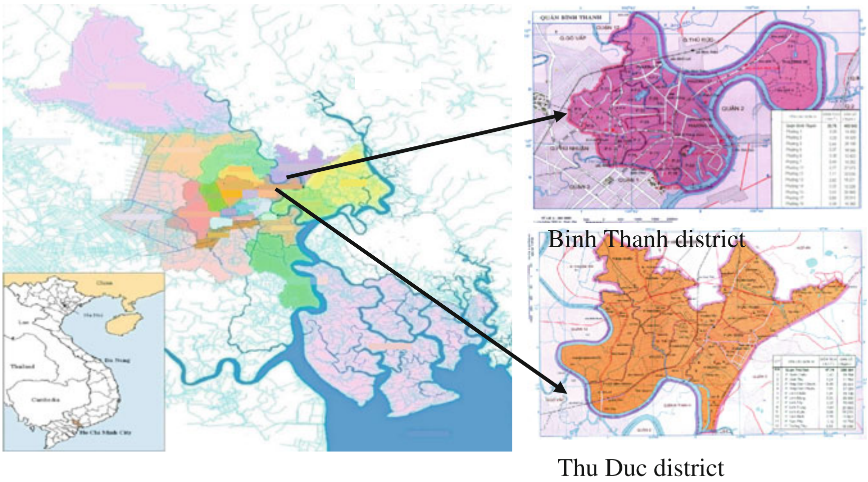

Fig. 39.2 Map of HCMC area and study districts *Source* Carew-Reid (2007) and HCMC's website

Whilst investigating the vulnerability, Problem Tree Analysis and impact matrix for RVA were used to find out coastal community vulnerabilities. Problem Tree Analysis can help collect information on the causes and effects of negative impacts related to climate change on water and waste water infrastructure in the study areas. Assessment of current activities/measures for prevention, preparation, mitigation, and response to climate change risks were assessed through the application of PRA and MCA techniques.

This case study was conducted by selecting 241 households at sample sites with target groups that are vulnerable to flooding, water pollution, inadequate water and other indirect vulnerabilities in two districts: Binh Thanh and Thu Duc. PRA was applied in terms of surveying, leading group discussions and interviews with local decision-makers, researchers, local residents (officers, commercial activities, domestic) at the two districts who could provide key information (Fig. 39.2).

Data collection has been carried out in order to ascertain potential climate change impacts on water resources and infrastructures, livelihood, vulnerability context, as well as identifying risk factors for qualitative potential climate change impacts. This step includes t in-depth interviews with environmental municipality researchers and consultants in order to discover the extent of climate change impacts affecting water and waste water infrastructure in the research areas. The main data collected is the probable climate change impacts on water and waste water infrastructures. Primary data has been analysed by using SPSS and Excel programs.

Table 39.4 Assessment of flooding impacts on water and waste water infrastructures in HCMC

Direct impacts of climate change to key water and wastewater infrastructures	P	N	Number of researchers to assess scale of impacts				Total = Σ (level x number researchers)	Rank
	+	−	(1)	(2)	(3)	(4)		
Drinking water supply systems								
Increase in water treatment costs and need for new form of water storage		x	19	1	0	0	21	8th
Impact to water quality and quantity		x	3	12	5	0	42	6th
Degradation, failure and replacement of pipe, sewer piping, waterway, and pipe structure due to increase in flooding events, change in groundwater		x	2	18	0	0	38	7th
Increase in maintenance and replacement costs of water supply, piping and waterway infrastructure		x	8	8	4	0	38	7th
Waste water management systems								
Overload in the capacity of sewage network resulting in overflow to drainage network		x	0	3	17	0	57	2nd
Pressure on drainage and sewerage systems and flooding of waste water treatment sites		x	0	0	20	0	60	1st
Situation of environmental pollution in waterway and surface water due to overload in the capacity of sewage network resulting in overflow to drainage network		x	2	12	6	0	50	4th
Increase in maintenance and replacement costs		x	3	12	5	0	42	6th
Drainage systems inundated for longer, waterlogging due to flooding		x	4	4	13	0	51	3rd
Irrigation systems								
Increase in maintenance and replacement costs		x	1	16	3	0	42	6th
Situation of environmental pollution in waterway and surface water due to overload in the capacity of irrigation drainage network		x	0	17	3	0	43	5th

Sources Data analysed from interviews and group discussion in November 2009

Results

From the interviews it has been determined that the direct impacts of climate change related to water management in HCMC are dominated by flooding. An impact matrix was applied for the impact assessment and the results of identifying risk factors in HCMC are presented in Table 39.4.

Table 39.4 shows that the highest significant impacts are pressure on drainage and sewerage systems, flooding of waste water treatment sites whilst the lowest significant impacts are an increase of water treatment costs and need for new form of water storage. The impact ranking is from level 1 to 8. The impact matrix is a useful tool for ranking the level of main climate change impacts on water and waste water infrastructure in HCMC. Interviews also confirm the information gleaned from the literature review as well as that from the secondary data. The main problems related to climate change in HCMC are flooding, salt water intrusion and inadequate amounts of safe water.

Community Vulnerability

Problem Tree Analysis can help collect information on the causes and effects of the main climate change impacts in Thu Duc and Binh Thanh districts of HCMC. The key information on study areas and target groups is presented in Table 39.5.

Sea level rise, heavy rain, high tides, inadequate waste water infrastructure and uncontrolled dumping of waste are the causes of floods in the research areas. Problem Tree Analysis was used in order to analyse qualitative data of water and waste water vulnerable to climate change in the study area. The causes and negative effects of this are shown in a problem tree in Fig. 39.3.

Secondary data concerning surface water quality as well as quality of water supplies and information from surveys showed that salt water intrusion is not a problem in Binh Thanh and Thu Duc districts. The results from this step did, however, show that flooding due to climate change and urbanisation is the main problem in the areas studied.

The main impacts of climate change and urbanisation processes in the districts of Binh Thanh and Thu Duc related to water and waste water infrastructure is flooding (Fig. 39.4). The survey focused on inadequate water supply, possible changes in components of water and waste water infrastructures due to damage or cost of repairing/upgrading, lost money due to inadequate water supply/use including reduced incomes and spending money to buy clean water from other areas.

The results from the survey show the real situation of water sources in research areas. The sources are water from SAWACO (Sai Gon Water Company), wells, and rain water. More than 60 % of households in this survey are using SAWACO water.

The information is divided intothree levels: Good, fair and poor for investigating the status of water quality in households. Nearly half of all households that were assessed in Thu Duc district (47.7 %) are subjected to water that is ofmpoor quality. Most of them are using water from open wells. This survey also has the intention of determining the situation regarding inadequate water at households in the two districts studied. The data showed that inadequate clean water is a significant problem in both districts (around 33 % in Binh Thanh and 23.6 % in Thu Duc).

Table 39.5 Key characteristics of the two study districts in HCMC

Characteristics	Units	Binh Thanh District	Thu Duc District
Total area	km^2	20.76	47.76
Total number of wards	Ward	20	12
Total population (2009)	People	451,526	442,110
Population density	People/ km^2	21,750	9,256
Target groups		Those who are vulnerable to SLR, inadequate safe water, water pollution	
Total length of drainage system	Metres	7,070	25,193
Occupation		Officers, commercial activities, domestic	Officers, commercial activities, domestic, farmers

Source Data collection in November 2009; HCMC's website

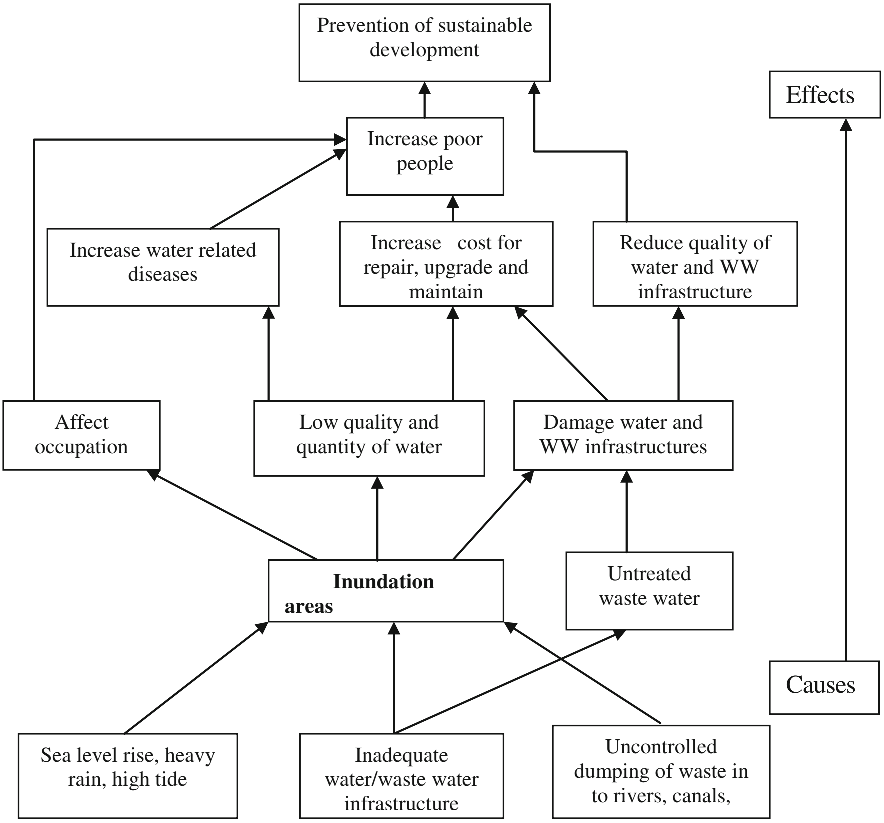

Fig. 39.3 Problem tree analysis for water and waste water vulnerable to CC at study communities *Source* Data collected during field observation and interviews (2009)

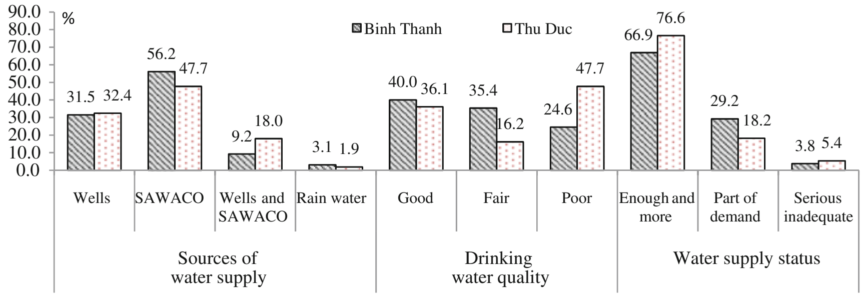

Fig. 39.4 Status of water supply at simple sites *Sources* Data analysed from surveys and focus group discussion in November 2009

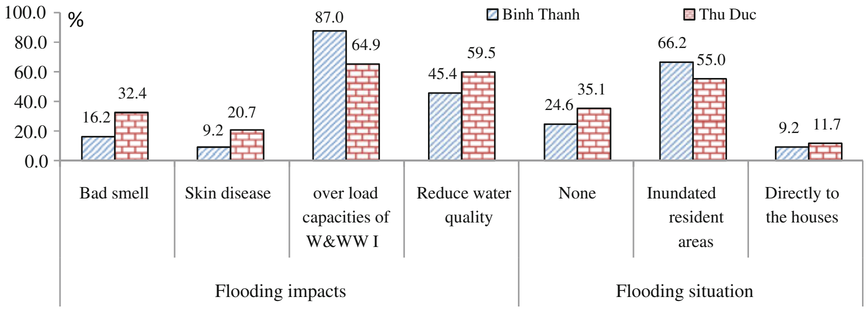

Fig. 39.5 Flooding situation and main flooding vulnerabilities *Source* Data analysed from surveys and focus group discussion in November 2009

As shown in Fig. 39.5, from the households that responded to the questionnaires, 55 % of households are affected by flooding (inundated resident areas and directly in houses) in Binh Thanh district and 66.2 % in Thu Duc district.

Comparing the data regarding income loss due to inadequate water (drinking water and irrigation/production water) at household level shows that more than 60 % of households did not suffer income reduction due to inadequate water. However, around 10 % of households faced significant reductions in their income (from USD 250–1,000 per year). According to Fig. 39.6, it is clear that most of the households spent an average annual amount on repairing/upgrading water and waste water infrastructures to the total of around USD 30 per year. However, it does not mean that the infrastructure was not damaged because most of the costs were the responsibility of government.

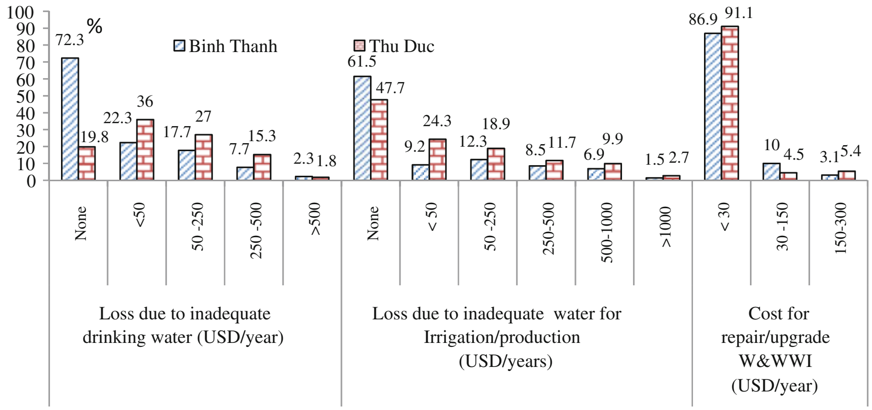

Fig. 39.6 Loss due to inadequate water and cost of repair and upgrade (USD) at simple sites *Source* Data analysed from surveys and focus group discussion in November 2009

Assessing Recent Adaptive Capacity

Due to a limitation of time and data availability for applying MCA techniques, only the perception of adaptation measures/activities in responding to climate change impacts is included here. Community knowledge was investigated through a PRA process. The main list of current adaptation measures/activities at study areas are: (1) clean and dredge drainage systems; (2) upgrade sewage and drainage and pipe networks/systems; (3) increase public awareness about water pollution and sanitation and climate change impacts through education systems; (4) upgrade/ building of dyke systems; (5) constructing more sewage and drainage systems; (6) Increase rainy water storage capability; (7) Change of land use; (8) No idea.

Figure 39.7 presents the personal conceptual climate change adaptation measures at a time when understanding of climate change concepts is still low. In relation to the current climate control adaptation measures, adaptation knowledge of communities is closely related to economic and institutional aspects.

Comparison and Lessons Learned

The case study uncovered the hazards and vulnerabilities, as wells as perceptions of climate change adaptation at community level in HCMC in addition to gaining experience on how to apply assessment processes with the candidate tools/techniques for conducting an RVA. The results of identifying risk factors show that sea level rise, heavy rain, high tide, inadequate waste water infrastructure and uncontrolled dumping of waste are the causes of flooding in the research areas. Through investigating vulnerabilities, it was found that flooding is the dominant cause of many problems in the communities studied.

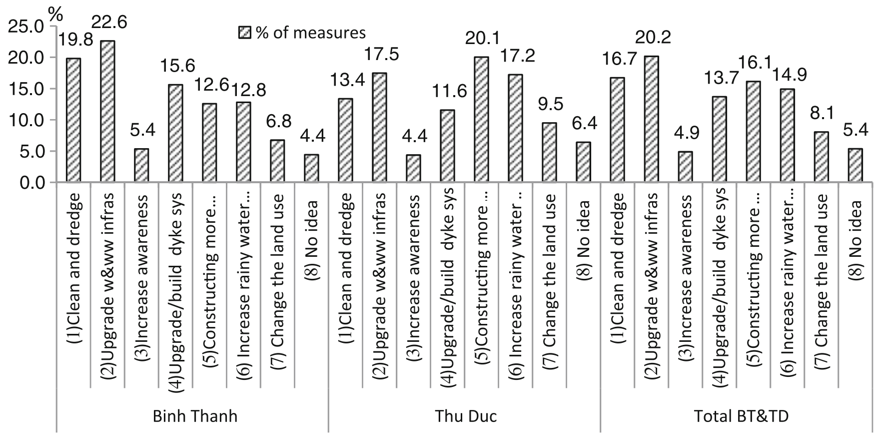

Fig. 39.7 Perceptions of climate change adaptation measures *Source* Data analysed from surveys and focus group discussion in November 2009

The comparision of vulnerability assessment results, among vulnerable groups in Thu Duc and Binh Thanh districts, shows that 47.7 % of selected households experinced drinking water with poor quality in Thu Duc district, compared with 24.6 % in Binh Thanh. The main reason for this is that the households in Thu Duc district used water from open wells affected by flooding. The results also show that inadequate clean water is a more significant factor in Binh Thanh district (around 33 %) because the selected households live in slums near a riverside with inadequate water and waste water infrastructure services. In addition, the data shows that inadequate water irrigation directly affects farmers in reducing the incomes of 10 % of households.

Some of the tools/techniques which include PRA, Problem Tree Analysis, MCA, and impact matrix have already been applied in case of vulnerability assessment to the effects of climate change on water and waste water infrastructure management in HCMC. PRA is more flexible to apply in terms of surveying, leading group discussions and interviews when compared with other tools/techniques. However, the effectiveness of PRA application depends on the characteristics of respondents. These include things such as education, income, and gender of the respondents, and they can bring about varying conclusions with regard to the same hazards.

Applying the tools/techniques of the HCMC case study shows that PRA, impact matrix, problem analysis, and multiple criteria analysis are simple and applicable tools and techniques in rapid assessment of vulnerabilities to climate change for local water and waste water infrastructures management. In addition, PRA is more efficient in identifying the risk factors and investigating vulnerabilities when compared with problem analysis and impact matrix.

The framework for RVA is not only applicable in HCMC but also in other coastal cities. The RVA process and the tools/techniques applied in this case study can be considered for both rapid and vulnerability assessment, as well as for other selected cities in Indonesia, Thailand and Vietnam. On the other hand, other candidate tools/techniques will be applied in the next phases of the project.

Conclusions and Recommendations

The main steps for climate change risk assessment processes applied in this study project are: identifying the risks, investigating vulnerabilities, selecting adaptation measures/strategies, and proposing appropriate adaptation measures/strategies. A total of 15 cities in Indonesia, Thailand and Vietnam were selected based on evidence of climate change impacts, size of coastal cities and available records or data to be used for conducting RVA in this on-going project, while a case of RVA has been presented to demonstrate the lessons we can learn from this investigation. Applying the climate change risk assessment process and tools/techniques in the HCMC case study shows that the assessment process is flexible with different assessment tools/techniques used in each step. It was found that PRA, impact matrix, problem analysis, and multiple criteria analysis are simple and applicable tools and techniques in RVA of climate change impacts on local water and waste water infrastructure management.

More cases of vulnerability assessment and applications of techniques/tools are to be applied, so that learning from this collaborative research can potentially enhance existing knowledge on vulnerability assessment and local adaptive capacity in the region. Sharing experience from the project's progressive results is expected to be able to easily link into other similar activities or projects, for possible improvement of this project's implementation as well as enhancing the capacity to learn from wider networks. This presentation contributes to sharing overall information and progressive results of a collaborative research project for enhancing local adaptive capacity against the impacts of climate change in the coastal cities of South East Asia.

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Author Biographies

Dr Vilas Nitivattananon is an Assistant Professor in Urban Environmental Management, AIT, Thailand. His areas of specialisation and interest include sustainable infrastructure development, strategic planning and decision-making, disaster and climate risk management, and economic and environmental assessment.

Ms Lam Vu Thanh Noi is a PhD student in Urban Environmental Management at AIT. She has been working for Dalat University from 2001 to the present date. Her areas of specialisation and interest include urban water management and climate change risk management.

Mr Worapong Lohpaisankrit is a Master's student in Water Engineering and Management at AIT. His areas of interest are water resources management and climate change adaptation.

Chapter 40
Conservation of Ligawasan Marsh in Mindanao, Philippines, Through an Indigenous Knowledge System: Climate Change Mitigation and Disaster Risk Management

Harris M. Sinolinding, Fe L. Porciuncula and Onofre S. Corpuz

Abstract The Ligawasan Marsh (LM) area, comprising 288,000 ha, is home to hundreds of thousands of Magindanawn Bangsamoro fishermen/rice farmers whose basic means of livelihood are wild fishing and traditional rice farming. This study assessed the indigenous knowledge system (IKS), laws and conservation practices in fishing and rice farming and the sustainability of the marshland for climate and disaster risk management. The fisher-farmers practised traditional fishing and farming beliefs/rituals, which promote sustainability. Indigenous laws banning electric and chemical fishing and fly catching were strictly enforced. A peaceful co-existence was preserved between the traditional and religious groups and the Bangsamoro mujahedeen leaders to enable them to work in unity despite their cultural differences. An exclusive open access regarding the rights to control over accessibility and utilisation of the marshland was practised. Aquatic wildlife with economic value remained abundant in the marshland (fish, crustaceans, molluscs, and other aquatic organisms). Values obtained on the physico-chemical properties of the marshland were within normal range, indicating that the area remains an ideal habitat for fish and other aquatic resources. The overall level of sustainability including factors such as ecological soundness, cultural acceptability, social justice,

H. M. Sinolinding (✉) · O. S. Corpuz
Cotabato Foundation College of Science and Technology, Doroluman, Arakan, Cotabato, Philippines
e-mail: harrissinolinding@ymail.com

O. S. Corpuz
e-mail: nfr_uplb@yahoo.com

F. L. Porciuncula
Central Luzon State University, Science City of Munoz, Nueva Ecija, Philippines
e-mail: flporciuncula@yahoo.com

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economic viability and technological appropriateness were rated moderate. This indicates that the marshland has gained some degree of degradation due to the occurrence of natural calamities and centuries of utilisation by the fishers-farmers. A sustainability framework is put forward to strike a balance between the socio-economic, bio-physical environment, IKS, and laws to enhance sustainability of the Ligawasan Marsh for climate and disaster risk management.

Keywords Indigenous knowledge system · Climate mitigation · Disaster risk management conservation · Sustainability

Introduction

The Ligawasan Marsh (LM) has been dubbed the largest collection of freshwater (288,000 ha) floodplains in the Philippines and is home to the Magindanawn Bangsamoro fishermen/rice farmers. It is located in the contentious areas of Mindanao and North Cotabato Province in Region XII, which is an autonomous Muslim region featuring many different geo-political boundaries and combining more than 20 different municipalities including the city of Maguindanao. Fishing and rice farming activities are forms of utilisation that are contradictory to conservation and protection measures. This study attempted to determine the existing indigenous knowledge system, laws, and bio-physical factors for the conservation and sustainability of LM in response to climate and disaster risk management. 120 fishermen/rice farmers in eight barangays of North Cotabato and Maguindanao Province served as respondents of the study.

Methods

An interview schedule was employed in this study. A prepared set of questions served as a guide in gathering information from the individual respondents. The interview schedule was intended for the description and assessment of dependent and independent variables to answer the objectives of the study. Since the majority of the Magindanawn Bangsamoro informants could hardly communicate in English and Filipino, the interview schedule was translated into the Magindanawn dialect.

A participant observation method was also used. The data gathered was intended for cases describing scenarios relevant to the study. The researchers stayed in the study areas, collected data, and observed the fishing and rice farming activities of the fisher-farmers. Guide questions were used during the informal conversations. Questions were prepared particularly for those which were not included in the interview schedule. A field diary was used to record descriptive events necessary in the study. This was very important, especially when the information needed explicit description. Likewise, documentation using pictures was done for clearer illustration and detail of the activities of the respondents.

Results and Findings

Bio-Physical Environment of Ligawasan Marsh

Aquatic wildlife found in abundance includes freshwater fish, crustaceans, molluscs and aquatic plants. Freshwater fish also highly available were tilapia (*Tilapia nilotica/mossambica*), species of carp (*Cyprinus carpio*) and climbing perch (*Anabas testudines*). Highly available crustaceans and molluscs were shrimps (*Macrobachium resenbergiii/M.lanceinfrons)* and different types of snails (*Pila luzonica; Pomacea spp*.). Turtles were also abundant while a few aquatic plants were identified with economic value. Trees found moderately available were balikakab (*Nauclea orientalis Linn*), and tabing trees. Several unidentified vines were also found in the LM such as *labanayu*, *lagisi*, *mengga* and *kagibpa-gibpa* while the known species were lubpegid (*Inchorapus volubilis*, *Merr*) and Sagiket (*Ipomea triloba Linn*.). The species of grasses found with economic value include pusawor water hyacinth (*Eichornia crassipes* (*Mart*) *Solms),* butilor water lily (*Nymphaea hybrid*), small leaf fern (*Athyrium esculentum*), sawa (*Nelumbo lutea*), bakong (*Ceratopteris thalictroides*), kangkong (*Ipomea aquatica Forsk*.), balabak (unidentified species), popo na baw *(Cyperus alternifolius)*, and bagumbung (unidentified species). Identified pests included rats, birds, snails, insects and weeds. Rodents, *Ratus ratus* or dumpaw, were considered most destructive by the respondents, followed by rice black bug, maya bird (*pamogon*), golden snails and rice stem borer.

The physico-chemical properties of LM freshwater (March 2000) showed an average depth of 96.67 cm, a temperature of 29.48 °C, a level of dissolved oxygen measuring 4.67 gm/L, a soil pH of 6.98–7.0, water turbidity value of 33.5 to 76.5 cm and total dissolved solids ranged from 101.33–185 mg/L. Generally, all values obtained were within the indicated normal range based on the standards of Boyle, C.E. (1990).

The majority of the fisher-farmers still cling to traditional fishing beliefs and rituals. They fully believe that LM is their ancestral land and a God-given wealth. It is sacred, inhabited and protected by unseen beings/spirits (*pagali*). They fully believe that industriousness (*makamangon*), luck (*bagi*), timing (*timpo/kotika*) of fishing and avoidance of jokes/foolish acts (*de sabelaw/de gelagela*) should be observed while fishing. The wearing of amulets as fish charms (*muntiya/agimat nu* *sida*) and doing token actions (*sa'lat/salawat*) as fish charms are also common beliefs. Two fishing rituals often practised are prayer requesting/pleasing the spirits (*tubad–tubad*) and food offering (kapagapal), as well as a prayer to Allah (*Dua/kapangani ngani kanu kadnan/Allah*) for a more abundant harvest.

For rice production, the use of the traditional farming calendar and heavenly stars and consulting rice ritualist *(Apo na palay)* are fully believed and practised. The other rice beliefs and rituals include a performance of supplicatory prayers and rituals through soil greetings during the rice sowing, the sprouting, vegetative, and flowering stages, as well as for the complete development of rice grain, as a repellent of pests and cure for diseases and for rice ripening (*papegkaluto*) and harvesting (*kapagagani*).

Fishing and Rice Farming Conservation Practices for Climate and Disaster Risk Management

The LM local authorities implemented as a priority direct and indirect conservation practices for climate mitigation and disaster risk management, such as a ban on electro fishing and chemical fishing/fish poisoning and fly catching. Less of a priority was the implementation of a prohibition on the use of small size fish nets and mesh nets. Two indirect fishing conservation practices for climate mitigation were also implemented across the board: the prohibition of flogging the top of water and the making of fish shelters and breeding areas (*layung*). A fairly common practice was the digging of ditches, sumps or miracle holes along the shoreline, especially during summer, for the conservation of swamp trees and grasses as well as setting free trapped juvenile sized fish.

On the other hand, the use of prohibited chemicals in rice production was observed, for it is considered destructive to the fishing ground. Other indirect conservation methods were practiced such as, allowing grasses to decompose, use of traditional varieties, construction of scarecrows and kites, minimal tillage management, multiplication of seedlings (*pedtalembing*), diking for flood control and water impounding during dry months. Rice production practices were a combination of modern and traditional rice farming. In land preparation, the most commonly practised clearing methods were slashing/cutting the grasses (*pedsid-sid*) and hooking of the grass before cutting (*pedsadengin*).

Sustainability of Fishing and Rice Farming in Ligawasan

Sustainability was measured using the indicators of ecological soundness, cultural acceptability, social justice, economic viability and technological soundness. Each indicator was given a point score of 20, using appropriate parameters with the following description: high (17–20); moderate (13–16); fair (9–12); low (5–8) and poor (0–4). Overall sustainability has a total point score of 100 with the following description: high (81–100); moderate (61–80); fair (41–60); low (21–40) and poor (1–20).

Ecological Soundness

All activities and conditions related to ecological soundness were rated by the fisher-rice farmer respondents as moderate with a mean of 16.55. Most of them believed that there was no harmful effect on the co-existence of the native fish species with the introduced exogenous stock. Fish deaths occurred because of the foul water from the decaying marginal vegetation that submerged after the flooding, which negatively affects fish survival chances, especially the gourami species. The simple fishing paraphernalia being used by the respondents were considered ecologically sound. The observation of anthropogenic stress was rated moderate while the importance of vegetation cover was emphasised. The vegetation cover served as breeding areas and shelter of aquatic and terrestrial animals. The existence of aquatic and terrestrial animals in the rice fields and the natural fertility of the soil were contributory factors to ecological soundness.

Cultural Acceptability

This was rated moderate with a mean of 16.58. Islam was influential for cultural acceptability. The observance of cultural values such as obedience to the law, helping one another, industriousness, unity, honesty and respectfulness were also believed to aid the conservation of LM. A system for sharing labour among the family and neighbourhood in rice farming and fishing activities was also practised. Respondents recognised the contribution of indigenous resource management with a more modern system when combined. Respondents indicated that terrestrial and aquatic resources were God-given. The moderate overall finding implies that the practice of traditional fishing and rice farming beliefs and rituals were restricted as contradictory to Islamic teachings. The strong cultural values of the respondents serve as a unifying force in moulding the directions to cultural acceptance.

Social Justice

This indicator was rated moderate with a mean reading of 13.28. The implementation of regulations/prohibitions, as well as the settlement and resolution of conflicts were considered crucial by the respondents. Adherence to indigenous laws such as accessibility, the right to own and control, as well as conflict resolution were cited as important by the respondents. The fishermen/rice farmers generally perceived a positive cooperation of the community people and authorities towards these conventions. Trading price of fish was remained to a large extent under the control of middlemen, but the extent of government support was rated at poor. The moderate rating on social justice implies the need for a more intensified cooperation on resource control, property rights, and conflict management among the inhabitants and leaders. Failed government support aggravated the dependence of the respondents on the resources of the marshland. Local leaders who have access to government agencies must intensify their efforts so that their constituents will receive the benefits they deserve.

Economic Viability

An overall rating of moderate economic viability (13.18) implies that the minimal yield and production cost resulted in a fair income from fishing and rice farming. This is because the fishing yield was dependent on the natural stocking capacity of aquatic resources, while the rice yield was always affected by the absence or presence of natural calamities. In light of this, respondents need to find alternative sources of income utilising the resources that abound in LM.

Technological Appropriateness

The data shows moderate technological appropriateness of fishing and rice farming activities with an overall rating of 15.48, which implies that the technologies in use in the area were not all indigenous. The introduction of efficient and expensive modern technology was found to deplete marshland resources very quickly and disturbed the natural setting of ecosystems. There is a need for extra precautions in the utilisation of new technologies. The existing indigenous technology that was found to be appropriate for the area must be enhanced and promoted through training and other forms of information dissemination.

Overall Level of Sustainability

The overall level of fishing and rice farming sustainability in LM was moderate with a mean of 75.06. This means that since time immemorial respondents have constantly utilised and exploited LM, which has been subjected to some degree of degradation in its resources. Expectations of significant government-led support were not met and indigenous resource management system implementation schemes were, in actual fact, deficient. In addition, occurrence of natural phenomena beyond the respondents control contributed to the moderate status.

With this situation, the level of sustainability for fishing and rice farming activities in LM presents the necessity of long-term planning, involving inhabitants and the local leaders of the area through collaborative efforts with government-associated authorities to improve the level of sustainability of the Magindanawn Bangsamoro fishermen/rice farmers in LM.

Factors Influencing Overall Sustainability of Fishing and Rice Farming Activities

Based on regression analysis, five out of the 28 variables were the best predictors of the sustainability of fishing and rice farming activities in LM. The variables were: respondents' years in Arabic schooling, years of fishing experience, accessibility practices, facilitation of conflicts and problems, and the abundance of aquatic trees and grasses. This indicates that education and experience create knowledge of how the area can be utilised wisely, which is reinforced by the exclusive accessibility to the native inhabitants only.

Identified Problems and Solutions

The respondents identified 13 problems in fishing and rice farming. Nine were related to fishing such as formation of islands, no support from the government, low pricing of fish, low fish catch in summer and during floods, presence of illegal fishers, movement of floating islands, growing number of fishers, possible disaster of oil drilling and chemical spill and unregulated size of fish catch. For rice farming, the problems included inadequate financing and no credit support, flooding of former rice fields and infestations of pest and diseases. The most serious problem revealed was the fragile peace and order condition in the area. The suggested solutions for this would be intensive reforestation and encouraging alternative livelihoods, a direct and honest support programme, infrastructure development, enhanced conservation practices, strict enforcement of rules and regulations, site selection of traps and community coordination. For rice production, the suggested solutions to the problems outlined above are honesty about the effectiveness of the government's support programme combined with traditional and modern methods of rice production, as well as the proclamation of LM as an ancestral domain and granting full autonomy or other alternatives acceptable to the Bangsamoro, even perhaps including granting independence to the Bangsamoro people.

Recommendations

Mitigation of climate change and disaster risk management of the Ligawasan Marshland via sustainability must be a major concern for all sectors/stakeholders based on current exploitative practices, fast human growth population and existing biotic and abiotic factors. There is a need to strike a balance between the socio-economic, bio-physical environment and indigenous resource management system and laws to attain a continuous level of sustainability and growth. The following are the recommendations based on the results of the study:

- An office or centre which is mainly concerned with the development of sustainability measures aimed towards conservation of LM must be put into operation. The centre should operate in consultation with the grassroots level (people and community leaders), in collaboration with State Colleges and Universities (SUCs), such as the Cotabato Foundation College of Science and Technology, and with other government research bodies in the region that can work on short and long-term programmes focusing on holistic community-based conservation, protection and utilisation of the LM for climate change mitigation and disaster risk management.
- The areas that must be given attention by the recommended office on marshland development must include aquatic and terrestrial habitats, community-based resource (socio-economic, cultural and political) management, practical roles for mass-based indigenous leaders, and integrated and holistic efforts by local governments (more than 20 municipalities, two provinces and one city).
- The influence of Bangsamoro mujahedeen leaders (MILF and MNLF) and local leaders in the area is insurmountable and undeniable. The government must settle once and for all a peace agreement with them. There should be formal integration with the existing government and active partnership in implementing sustainable development of the LM for climate risk management.
- The "peace agreement", if implemented, is only an initial phase, therefore the national government, particularly LGUs in the provinces concerned, must provide appropriate and adequate financial, technical, and manpower support for the sustainable development of the LM for climate change mitigation.
- Establishment of Arabic and secular schools both at primary and secondary level is seriously needed to include environmental awareness lessons to upgrade the level of knowledge to help improve the economic status and the participation of the people in protecting and conserving LM's bio-physical resources.
- Aside from formal education, a continuous campaign on environmental consciousness such as climate change mitigation and disaster risk management for sustainability of LM must be done through different information, education, and communication (IEC) modalities to be spearheaded by LGUs in cooperation with the heads of agencies, barangays and traditional leaders as a response by communities to climate change.
- There must be a continuing strict enforcement of laws implemented in the area by the community residents, local leaders and existing organisations. LM is an

ancestral land, the source of life and sustenance to the people; hence it must be preserved, conserved and protected to mitigate climate change.
- Flooding and continued build-up of islands (*midtampul a lupa*) which destroys the fishing grounds and decreases of the natural depth of the marsh as a natural reservoir of floodwater were attributed to the forest denudation in the surrounding hinterlands. The Department of Environment and Natural Resources must implement a comprehensive reforestation programme with the upland dwellers in order to minimise siltation and flooding, all the while providing risk and disaster management.
- The LM is a large natural body of wetland with thriving natural resources. Mature technologies on freshwater fish and rice farming technologies must be disseminated in order to attain optimum productivity and income considering existing indigenous management.
- Effective community-based conservation management of the fishermen/rice farmers that will entail consciousness, awareness and responsibility needs recognition and institutionalisation. The indigenous knowledge system and laws are considered beneficial and have bearings for continuance towards sustainability. These must be enhanced and upheld for climate change mitigation and adaptation techniques.
- To sustain the maintenance of family resources from fishing and rice farming activities, indigenous practices of utilising floating islands (be'ng) as rice seed bed will be improved into floating gardens for multi-cash crop production during flood time. This floating garden will also help deter the bulk release of floating grass islands, which can choke the end tail of major river systems such as the Rio Grande de Mindanao, which subsequently causes flooding to low lying areas in Mindanao.

Sustainability Framework of Fishing and Rice Farming in the Ligawasan Marsh for Climate and Disaster Risk Management

Based on the findings and lessons learned from the study, a sustainability framework for climate and disaster management was put forward to serve as a development setting towards sustainability of fishing-rice farming activities at LM. The framework (Fig. 40.1) viewed the LM as a social system made up of interrelated parts and elements composed of fisher-rice farmers, local leaders, Government Offices (GOs), NGOs, and POs.

The LM exists as a community endowed with resources, both human and natural, which are relied upon to further its sustainability for climate and disaster management. This is reinforced with indigenous laws and resource management systems combined with modern knowledge system undergoing a process of change which are deemed important to stimulate people participation and social cohesion, governance, and self-determination. As the LM exists in a dynamic relationship with its environment, it is envisioned that sustainability can be achieved by

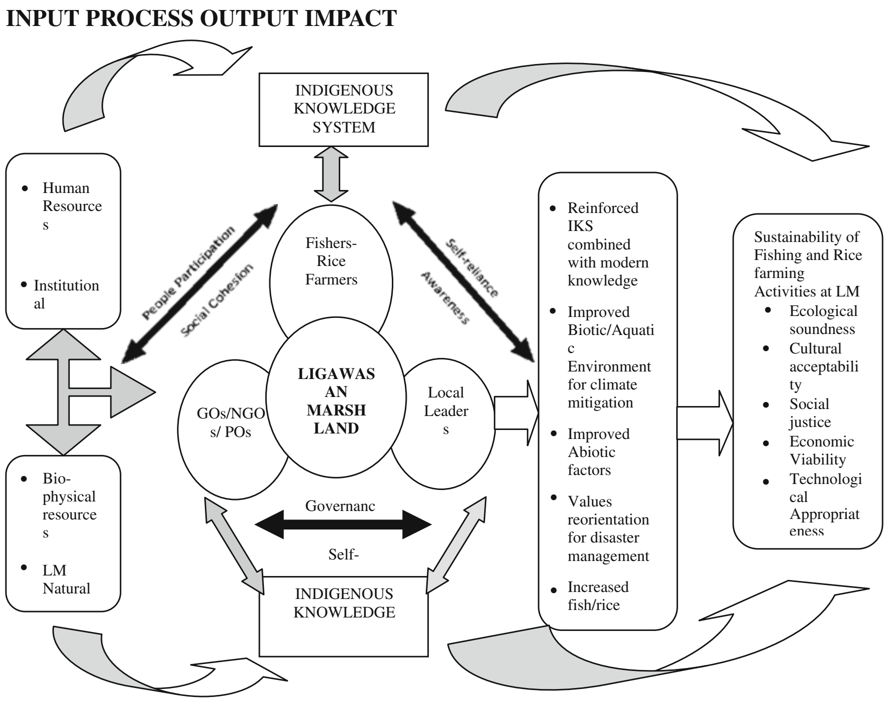

Fig. 40.1 Sustainability model/framework of fishing and rice farming activities in Ligawasan Marsh for climate and disaster risk management

enhancing ecological and economic soundness, cultural acceptability, social justice, and technological appropriateness of fishing and rice farming in LM. To increase the sustainability of LM, the plan is to look in particular at the following factors: fish-killing mitigation (ecological soundness); finding balance on the restrictions of the Islamic teachings (cultural acceptability); a more intensified cooperation on resource control, property rights and conflict management among the inhabitants and leaders (social justice); improving productivity from fishing and rice farming (economic viability); and enhanced utilisation of existing indigenous technologies (technological appropriateness).

Conclusion

The Ligawasan Marshland continues to serve as the major source of livelihood by offering opportunities for fishing and farming, and other activities even in the midst of calamities both natural and man-made. The respondents' knowledge in fishing and rice farming is extensive, creative and resourceful. It showed the Muslims in this area possess the ingenuity to survive. The existing informal association of fisher/farmer sectors indicated a promising initial step towards formal organisation. This will enhance existing indigenous resource practices in the area and may empower people to link with other GO/NGOs to promote sustainability of LM, mitigating climate change and manage risk and disasters.

Bio-physical factors, fish and other aquatic resources remained abundant at various different locations. Marsh grasses were generally abundant in the whole area except that swamp trees were strategically located at specified parts of LM. Areas that were silted into an island full of grasses are conducive for reforestation of endemic trees. With the population growth of the inhabitants, there is a greater need to pursue sustainability measures in LM in order to mitigate climate change.

The Magindanawn Bangsamoro of Ligawasan has high regard for fishing beliefs and rituals. Observation of these beliefs promoted sustainability since giving respect to these areas as sacred allowed overexploitation to be minimised, or even saved them being used at all.

The fishermen/farmers have been braving self-survival techniques and have become dependent on their individual ability and indigenous skills. However, the inclusion of new technology in rice farming and fishing was inevitable. In fishing, the introduction of gill nets/entangling nets as fishing equipment promotes efficiency of harvest in the area. In addition, efficiency was also dependent on the use of small-eye nets, which harvest all fish regardless of size. This situation needs reinforcement of regulation regarding permitted net sizes. To attain sustainability of LM for climate change mitigation and disaster risk management, continuing the information drive in all surrounding barangays must be promoted. Improved or modern rice and fish management strategies that will optimise fish population and other abiotic species, as well as rice productivity, need to be explored to increase income derived from LM.

In terms of indigenous laws, Magindanawn Bangsamoro fishermen/rice farmers have recognised the crucial roles and responsibilities of government, revolutionary and religious and non- governmental organisations in implementing the rules and regulations surrounding life at LM. Co-existence with formal organisations and indigenous non-formal groups like the village/community clans has worked effectively with their local laws. State laws and customary laws have been harmoniously implemented, with high regard given to leadership protocol that involves both the formal and informal leaders in decision-making. The formal leaders were the head of the barangay, the chairman and his councillors. The informal authorities were the traditional leaders, religious leaders and Bangsamoro mujahedeen leaders (MILF). All of them were encouraged to work in unity, despite their differences.

The moderate result on the overall sustainability level indicates that LM has been subjected to some degree of degradation due to centuries of utilisation and exploitation by the inhabitants, particularly the fishermen/rice farmers. With this, therefore, the vigilance of the people and awareness of the prevailing status of the LM must deduce solutions and implement programmes and projects that will protect, conserve and enrich the LM before it is too late. This must be the primary concern of the government and the people of LM.

Author Biographies

Dr Harris M. Sinolinding, Associate Professor, faculty, researcher and development practitioner at the Cotabato Foundation College of Science and Technology, Arakan, Cotabato, Philippines. Director, CFCST-Pikit External Unit. Fields of Specialisation: rural development/organisation and management.

Dr Fe L. Porciuncula, Professor, researcher and development practitioner at the Central Luzon State University, Science City of Munoz, Nueva Ecija, Philippines. Director at the Ramon Magsaysay Center for Agricultural Resources and Environment Studies. Fields of specialisation: socio-economics, community development and environment studies.

Dr Onofre S. Corpuz, Assistant Professor, Faculty researcher and extension practitioner of CFCST. Fields of specialisation: silviculture, agroforestry, operational research and statistics.

Chapter 41
Decision Support System for Small Reservoir Water Harvesting Technology in Drought-Prone Areas for Climate Change Adaptation

Orlando F. Balderama

Abstract A computer-based decision support system was designed, developed and tested to address a range of advisory support for rain-fed farming, i.e. crop selection, scheduling, water management and optimisation. The system was utilised for agricultural planning on sustainable agriculture in the rain-fed ecosystem through the use of indigenous water harvesting technology for supplemental irrigation, thereby increasing production and at the same time managing soil and water resources for a climate change adaptive strategy. The application of the model was carried out using crop, soil, and climate and water resource data. With the analysis of 30-year rainfall data from an agro-meteorological station based at Echague, Isabela, simulations for Cagayan Valley conditions were undertaken on probabilities of wet and dry periods, and with various capacities of the water reservoir used for supplemental irrigation. Through the analysis, useful information was obtained to determine feasible project sites, suitable crops in the region, cropping schedule and pattern appropriate and optimisation of the use of the land and water resources that can be achieved in areas irrigated by small water harvesting systems.

Keywords Support system · Climate change adaptation · Rain-fed agriculture · Small farm reservoir

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O. F. Balderama (✉)
Department of Agricultural Engineering, Isabela State University,
Echague, 3309 Isabela, Philippines
e-mail: orly_isu@yahoo.com

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Introduction

It is accepted in the scientific community that our climate is changing due to rising anthropogenic greenhouse gas emission. According to the Intergovernmental Panel on Climate Change, the degradation of soil and water resources is set to become a major future challenge facing global agriculture (IPCC, 2001 as quoted by GRID, 2002*)*. The effects of climate change on agriculture will vary by region and are expected to bring myriad changes. For the most part, the impacts of climate change that will affect agriculture will be adverse changes in temperature and precipitation resulting in droughts and floods. Drought effects include crop losses due to insufficient soil moisture availability.

The Cagayan Valley, Philippines, is the major production region of rice and corn in the country. More than 60 % of the region's agriculture is rain-fed so that any changes in precipitation will affect the majority of the farmers' livelihoods. Hence, the groups that are most vulnerable to climate change are the low-income farmers in drought-prone areas. In 2009 at the onset of summer, the country experienced the adverse effects of El Niño, especially in the agricultural sector. The Philippine Astronomical, Geophysical and Atmospheric Services Administration (PAGASA) estimated that a reduction in rainfall between 40 and 60 % was an effect of the phenomenon and that the prolonged drought lasted until June of 2010. The hardest hit areas were Cagayan and Isabela provinces in Cagayan Valley with an estimated loss of 6 billion pesos in agriculture (Dar 2010).

Emerging issues on climate change and dryland agriculture have been at the centre of discussions and interests among top policymakers as manifested by the recently concluded conference, the National Dryland Conference, and the eventual creation of the Philippine Dryland Institute (PhilDri). A Geographic System (GIS) analysis showed that 43 %, or 13 million hectares, of the country will be under dryland environment as a consequence of climate change (Dar and Obien 2008). Isabela and Cagayan provinces are at the top of the list, registering 432,916 and 319,102 ha respectively. In drought-prone areas, the India-based International Crops Research Center in semi-arid tropics (ICRISAT) suggested a science-based approach in coping with this extreme event with the following measures: (1) growing of drought tolerant crops to match the available length of growing season and low soil moisture and; (2) efficient management of natural resources, harvesting water in the rainy season, arresting land degradation and conserving soil moisture (Dar 2010).

In the region, many small farms are not covered by conventional irrigation systems due to various technical and financial constraints. As a result, they encounter the perennial problem of limited water supply every year. Although these areas are endowed with annual rainfall that often exceeds crop water requirements, the variability of distribution in both space and time is so great that drought occurrence is prevalent in some periods of the year.

To alleviate the damage caused by drought and increase farm productivity, many farmers and groups of farmers, with assistance from governmental and non-governmental agencies, have developed their own irrigation systems at on-farm level by storing excess rainfall and run-off water during heavy rains and using it for irrigation during dry periods. This on-farm type of water storage is called small farm reservoir (SFR). The Bureau of Soils and Water Management, defines small farm reservoir (SFR) as a water harvesting system designed to collect and store rainfall and runoff for use in a single farm. It has a reservoir area of about 300–5,000 m^2 and can serve 0.50–1.00 ha. The height of the embankment is 4 m and below. Water from the reservoir is delivered to the canal through siphons. The cost per unit is about USD 600.00.

Along this backdrop, a simple, integrated and practical computer program was developed as a means of decision support for SFR-based farming systems. It addresses options on crop selection, crop scheduling, and water resource and area optimisation. This paper highlights the application of the model, focusing on its contribution to agricultural planning in rain-fed areas and features in providing decision support under various climate change conditions.

Objective

To develop a computer-based decision support system on crop selection, crop scheduling, and water resource and area optimisation with a focus on small farm reservoir irrigation systems for climate change adaptation. Specifically, it aims to:

- Develop criteria and parameters as a basis for sustainable planning and adaptation strategies for climate change.
- Design and develop a computer program that can be used to facilitate the conduct of simulation under various farming system options and climate change conditions.
- Test and apply the computer program using actual data and assumptions in Cagayan Valley, Philippines.

Methodology

Development of a Computer-Based Decision Support system

The integrated system is composed of three modules: crop selection, crop scheduling, and water management and optimisation. The first two modules make up an expert's system, and the third is used for the simulation and optimisation of available water and cropping area.

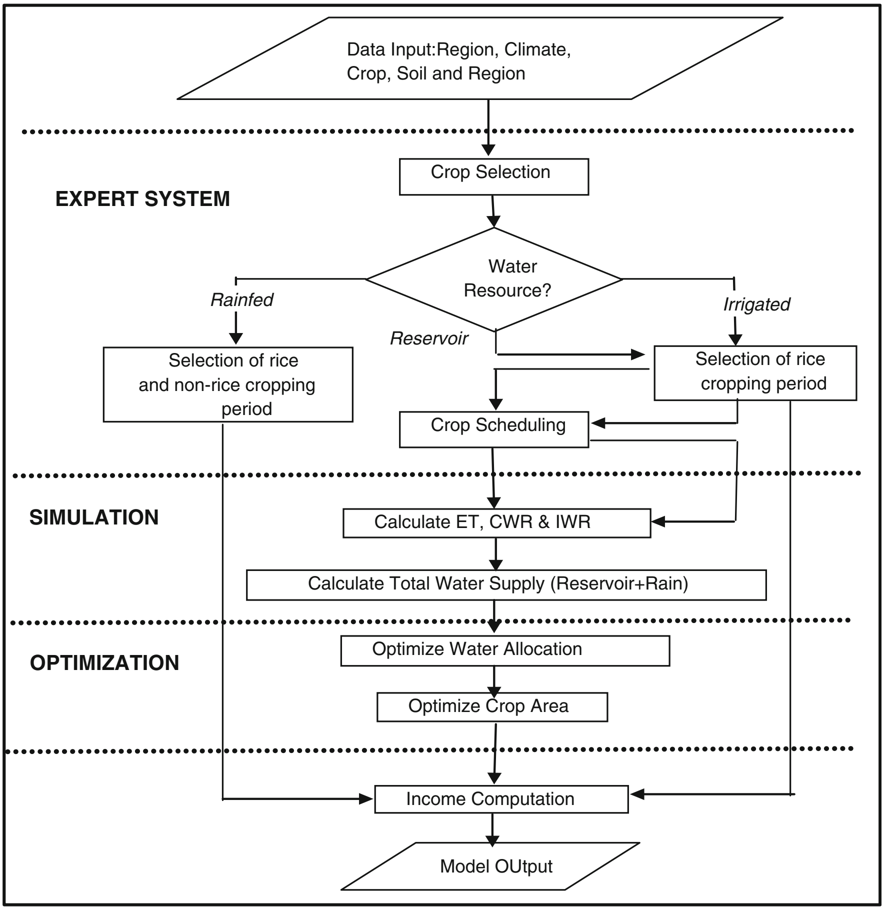

Fig. 41.1 System flowchart of the program

Figure 41.1 shows the system flowchart of the program. It begins with the establishment of a database providing a description of the area in terms of physical profile, soil conditions (i.e. pH, texture, salinity, and drainage) and climate. Data on a selection of crops with their physiological characteristics and responses to physical environment is also included. Suitable crops are selected based on temperature requirements, soil pH, salinity, texture, drainage, and rainfall parameters that match the requirements of the crops and the climate database. The model has a special support feature for a rice-based cropping system, which provides information on rice growing periods in order to maximise rainfall availability.

The program is designed to address decision support for three possible water resource systems as follows: rain fed production, reservoir irrigation, and full irrigation. In a reservoir irrigation scheme, water is supplied from the small farm reservoir when rain water is not enough. A full irrigation scheme is an option when water supply is not a constraint and therefore potential production is always attained while rain-fed production selects rice and non-rice cropping periods possible during the year based on rainfall pattern and crop growing periods. Crop evapotranspiration (ET), crop water requirement (CWR) and irrigation water requirement (IWR) were computed following the standard formulas provided by the Food and Agriculture Organization (Doorenbos and Pruitt 1977). In the case of reservoir and full irrigation, rice can be selected as the first crop during periods of heavy rain, and then non-rice crops are scheduled when rainfall amount decreases. Furthermore, partial irrigation from reservoir, water allocation and determination of cropping area is solved using a linear programming (a mathematical method to choose the best solution from many possibilities) and simplex method in the water management module.

Parameters for Agricultural Planning

A climate map of the Philippines based on rainfall distribution is shown in Fig. 41.2. The country has a humid tropical climate characterised by a temperature regime that is favourable for year-round crop production. While rainfall is abundant based on annual total, distribution is uneven and periodic in many parts of the country. As a tropical country, radiation and other climatic elements do not vary significantly, leaving rainfall as the single most important factor in crop production it was considered the major factor for rain-fed agriculture planning in this study. For analysis of all climate types, four data sets of representative rainfall were chosen for analysis and input in the model.

The program installs a built-in feature of managing a sustainable land and water resource system.

The crop scheduling module was programmed to provide selections for suitable crop rotation patterns on land use planning for sustainable farming, which were incorporated in the program design as follows: (a) rice-vegetable-legume pattern, and (b) rice-deep-rooted, crop-shallow-rooted crop pattern. From these cropping patterns the program has arranged its database into crops and groups of crops for easy selection.

Another important provision of the scheduling module on land use planning is the option of leaving the land fallow for some part of the cropping year. The program asks the user the percentage of the time during the year where a fallow period is desired before making the schedules.

Parameters for Developing Drought Criteria

Dependable rain approach developed by the Food and Agriculture Organization as an index for analysing levels of drought was used in this study due to its advantage

Fig. 41.2 Climate map of the Philippines (Source: Flores and Balagot 1968)

for irrigation planning applications and its relative easiness to apply in terms of data requirements and calculation procedures. Using the above approach, rainfall values at different levels of probability were used to run the model. Rainfall at a 50 % probability level is the value that approaches an average year while 80 % could be a worst dry year. Rainfall at a 20 % probability is considered a wet year.

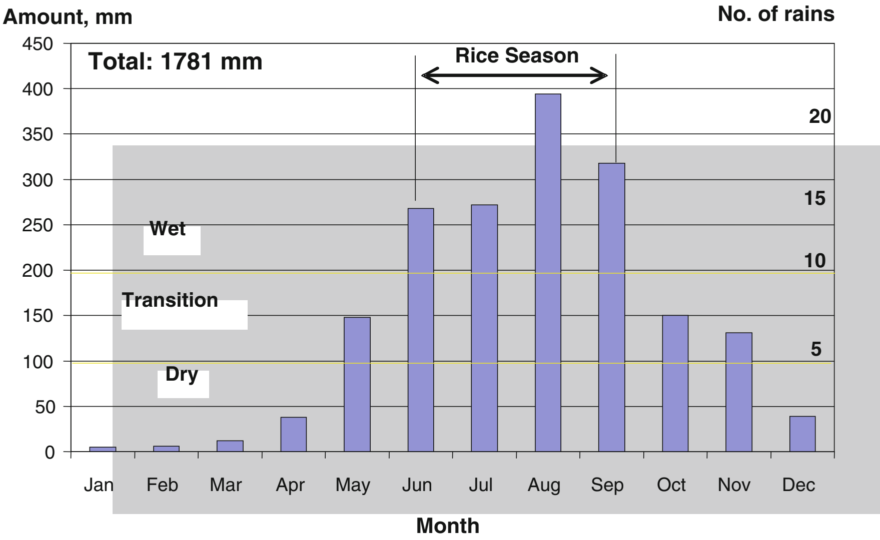

Fig. 41.3 30-year rainfall data from Echague, Isabela, Philippines, from 1977 to 2007 (Source: PAGASA, climate station at ISU, Echague, Isabela)

Results and Discussion

Analysis of Soil, Crop and Climate Data

The study used actual soil, temperature, and rainfall data sets as parameters in crop selection. Temperature and rainfall used were actual data averages from the representative location. For crop selection, it was determined that there are 11 crops from the database that matches the environmental and soil conditions of the country: rice, peanuts, mung bean, soyabean, tomato, okra, squash, onion, garlic, corn and sorghum. A rainfall data set is presented in Fig. 41.3 for a Type III Climate which prevails in most agricultural areas in Cagayan Valley. The model follows criteria where rice is scheduled first provided that 200 mm of rainfall is available in four successive months. With a monthly rainfall of between 100 and 200 mm non-rice crops will be scheduled, and with a rainfall below the 100 mm value, there will be no crop grown without supplemental irrigation from on-farm reservoirs. Selected crops are then scheduled according to the cropping pattern desired by the user.

Model Simulation for Sustainable Agricultural Planning in Rain-Fed Areas

In the following discussion on analysis of farming systems, recommendations for different climate types are presented:

Type I Climate

This type of climate is uni-modal in nature with most of the rain coming during the months of May to October. If a farmer operates an on-farm reservoir with a capacity or 1,000 m^3 for every hectare, only one rice crop can be grown during the season from June to September. Although the ideal pattern (based from output of the crop selection module) would be legume–rice–vegetable or deep rooted-rice-shallow rooted crops, the available water supply will not warrant a third crop. This result conforms to the present practice of reservoir owners who are experiencing difficulties in planting a third non-rice crop. Hence, planting a third crop could be possible if reservoir capacity is increased.

Type II Climate

Areas covered by this type of climate environment are located mostly in the eastern part of the country facing the Pacific Ocean, and are characterised by continuous rainy periods throughout the year. Two rice crops can be grown without irrigation from July to February, but only short duration non-rice crops like soybean and mungbean can be grown as a third crop for short period. The recommended cropping patterns are only limited to rice–rice–soybean and rice–rice–mungbean.

Type III Climate

This type of climate is similar to Type I, but the available rice growing period is shorter, from July until October. Likewise, this type of pattern needs supplemental irrigation in order for a second, non-rice crop to grow.

Table 41.1 Recommended farming system approach in rain-fed areas

Climate type	Cropping Pattern Options (Jan. → Dec.)	Remark
1	legume – rice – vegetable shallow root – rice – deep root	Needs a farm reservoir system for irrigation after the rice crop
2	rice – soybean – rice	No irrigation needed for rice and non-rice crops
3	legume – rice – vegetable shallow root – rice – deep root	Needs a farm reservoir system for irrigation after the rice crop
4	vegetable – legume – corn shallow root – rice – deep root	No irrigation needed for non-rice crops but requires irrigation for rice crop

Type IV Climate

Mindanao Island in southern Philippines is characterised by this type of rainfall, which is evenly distributed throughout the year. The fact that this region is far away from typhoon paths, and yet water is abundant throughout the year, means that choices for possible crop schedules are plentiful. However, results suggest that rice cannot be grown in this area without supplemental irrigation but any non-rice crops are possible throughout the year without irrigation. Two general sets of patterns were used in running the program: vegetable–legume–corn, and deep-rooted, crop-shallow-rooted crop-corn.

Table 41.1 summarises the recommended farming systems approach for each of the climate type classifications in the country.

Model Application for Drought Planning and Seasonal Climate Change

An evaluation of seasonal climate impacts on crop production as well as on crop growth and development will enable agricultural managers and researchers to formulate strategies and mitigation techniques to counter such impacts. In this study, the dependable rainfall approach (Oldeman and Frere, 1982) was used as an index for drought due to its good advantage in irrigation planning application, and its relative simplicity to use in terms of data requirement and calculation procedures.

Figure 41.4 shows the result of data analysis at different levels of rain probability using dependable rainfall approach. 80 % probability approximates an extreme dry year which was compared to the 2009 rainfall data to determine the applicability of the method. As can be observed, the approach employed closely

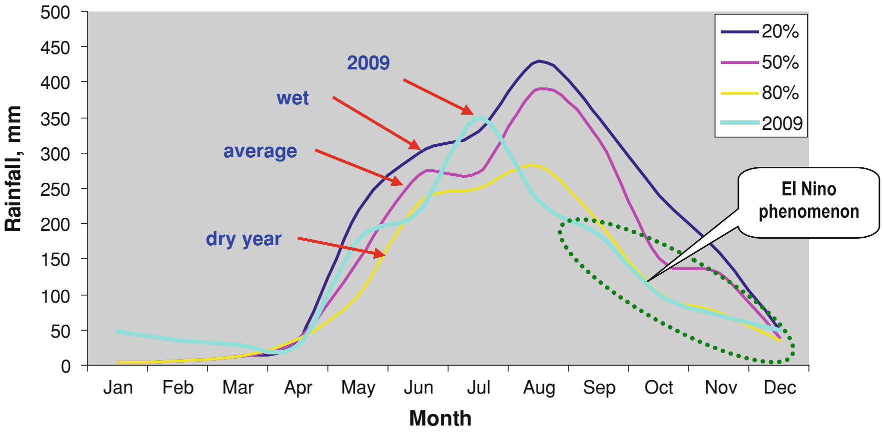

Fig. 41.4 Rainfall at different probabilities compared to 2009 data

simulates PAGASA's forecast that the El Niño event was 40 to 60 % lower than the historical average.

Under a Type III climate, further simulation runs were done to establish a relationship between reservoir volume and rain probabilities and their effect on income. Important results of the simulation for selected crop combination planted after rice are presented in Table 41.2.

From a sample result of the simulation, the following points are revealed:

- At different levels of drought, the income derived from the top three crop combinations is affected significantly on dry years, particularly for long duration crops like garlic-mungo and garlic-groundnut combinations. The difference in income is up to 33 %.
- Simulation also reveals that increasing reservoir volume will have a significant effect on the income of non-rice crops during normal (50 % probability) and dry (80 % probability) years.
- If a wet year (20 % probability) is expected in this type of climate, and planting commences right after harvest of rice on October 1, optimum yield and cropping intensity will be realised provided that a minimum of 2,000 m^3 of reservoir water is available for supplemental irrigation.

Conclusion

Through this study the following important conclusions were obtained:

- In the four rainfall classifications, Type I and III (the site of study area) would require supplemental irrigation through the use of a reservoir to grow non-rice

Table 41.2 Effect of varying volume of reservoir and rain-fed conditions to gross income

Rainfed condition	Reservoir capacity, cu. m.	Income for selected cropping pattern in Pesos		
		Garlic–mungo	Garlic–groundnut	Tomato–soybean
La Nińa year, (wet year)	1000	75416	75416	52800
	1500	81708	79200	56584
	2000	86724	81708	60324
Normal Year	1000	72908	72908	51524
	1500	80476	78584	54076
	2000	85492	80520	59092
El Niño Year, (dry year)	1000	62876	50292	50600
	1500	79200	77924	51524
	2000	84216	79200	56584

1 US dollar = 44 Phil. Pesos

crops after the main rice season for increased cropping intensity and, subsequently, a higher income. On the other hand, the farmers under the Type II pattern can grow two rice crops and a cash crop like soybean or mung bean without irrigation. Type IV is found to be ideal for non-rice crop diversification since rainfall is available throughout the year and choices for combinations are numerous.

- It was found out that both reservoir volume and different levels of rain probability can have significant effects on the income levels of non-rice crops. With the onset of more frequent occurrences of drought periods, it is strongly recommended that a reservoir capacity of 2,000 m^3 or more should be constructed in areas covered by Type I and III climates to bring about optimum economic returns.
- The determination of a drought index approach is a very important basis to approximate the extent of drought as measured by rainfall reduction from normal values. This method subsequently provides better and more practical solutions to address climate change induced problems in the upland and rain-fed areas.
- The decision support system has been proven to be a versatile and practical tool that can be used by agricultural planners and extension workers as a decision support system to increase farm productivity, as well as a tool for developing strategies for climate change adaptation in rain-fed areas.

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Author Biography

Dr Balderama has 25 years of experience as a professor, researcher, institutional development specialist and research manager, project development specialist and consultant to various water-related projects (i.e. irrigation and drainage, hydropower, water conservation, water and sanitation, river basin environmental research, development and extension). In addition to his recognised technical expertise on water resources management, he has had an excellent career as an institutional specialist-manager in the development and management of soil, water and energy projects in local governments, national agencies and international agencies (International Crops Research Institute in Semi-Arid Tropics, European Union, Dutch government, etc.) as well as with NGOs.

Chapter 42
Reading the Weather: Climate Risk Adaptation in Mongolia

Wang Xiaoli and Ronnie Vernooy

Abstract This article investigates the underlying forces that have led to the disastrous impact of recent extreme climate events in Mongolia and explores strategies to better deal with such events. In-depth field research was carried out following the 2010 extreme winter known as *dzud* making use of a combination of participatory research techniques, individual and focus group interviews, and surveys. The harsh winter of 2010 was one of the worst of its kind resulting in the death of eight and a half million livestock. In the last decade, this kind of extreme weather event has been on the rise. Herders have encountered serious difficulties in coping with them, preparing for them and mitigating their impact. Following the transition from a Soviet-dominated regime to democracy and a free market, pastoral livelihoods have become much more exposed to three interrelated forces: climate change and weather dynamics, natural resource degradation, in particular of grasslands and water, and rapid societal change. Co-management of natural resources is a form of collective adaptive management that reduces risks related to climate and societal change. Co-management could benefit from the timely delivery of improved weather forecasting, in particular on a local level. The scaling-out of co-management would benefit from stronger government support in terms of legal protection of new organisational forms, technical and financial support, and improved rural services. The results of this research deepen our understanding of the complexity of the forces that have made herding much riskier. It also opens a window to the benefits of co-management which the

W. Xiaoli (✉)
Center for Women Studies, Shantou University, 243 Da Xue Road,
515063 Shantou, P.R. China
e-mail: wangsalome@gmail.com

R. Vernooy
Bioversity International, Via dei Tre Dinari 472/a, 00050 Maccarese, Italy
e-mail: ronnievernooy@hotmail.com

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government of Mongolia aims to scale out nationally as a means to deal with climate change and related risks.

Keywords Climate risk management · Co-management · Extreme weather · Mongolia · Pastoralism

Pastoral Livelihoods Subject to New Vulnerabilities

Impacts of climate change have become more visible in Mongolia, first observed and felt by herders about a decade ago and only more recently addressed by the Mongolian government and by national and international agencies (Ministry of Nature, Environment and Tourism 2009; Government of Mongolia and UNDP Mongolia 2009). In the last decade, severe weather events, in particular storms, drought, and extremely harsh winters known as *dzud*, have been on the rise. The 2010 *dzud* was one of the worst ever resulting in the death of eight and a half million livestock, 20 % of the 2009 national herd. 770,000 herders were affected, of whom 43,500 were left without a single animal and 164,000 lost more than half their livestock (United Nations Mongolia Country Team 2010). Previous *dzuds* occurred between 1999–2000 and 2000–2001, killing three million animals, equivalent to 10 % of the total herd in 2000 and another 25 % of the total surviving herd in 2001. And so the question emerges: how best to explain the massive scale of these disasters, in particular the most recent, labelled "historic", in a country that has been exposed to harsh weather for centuries?

The authors suggest that the main reason is the exposure of pastoral livelihoods to a *new* constellation of vulnerabilities related to three interrelated forces: climate change and weather dynamics, natural resource degradation, and societal changes. In addition to a more unpredictable climate and weather risks, pastoral livelihoods have become dependent on increasingly degraded and scarce natural resources. Grassland degradation is occurring nationwide, in large areas resulting in desertification. Water has become a scarce and frequently contested resource in most parts of the country. Economically, since the "opening up" of the country in the early 1990 s, herders have become more independent now operating in strongly individualised herding "enterprises" subject to the ups and downs of "free" market forces, but also more vulnerable as social and economic protection by the state ended. They continue to face tenure insecurity in particular concerning grasslands.

How to respond to this new reality of increased and more complex vulnerability that herders are facing? In a number of regions across the country herders are practising co-management, in collaboration with local governments, researchers, and supported by a number of new policy measures and laws. Co-management is a form of collective adaptive management that builds resilience and contributes to sustainability, much needed to deal not only with compounded vulnerabilities, but also to reduce or avoid dramatic losses due to extreme weather events, such as those of the 2010 *dzud*. Building on 10 years of co-management experience, Mongolia now faces the challenge of scaling-up co-management.

This article first summarises the central characteristics of today's pastoral livelihoods in Mongolia with a focus on the three kinds of vulnerabilities referred to above. This is followed by an introduction of co-management. The observations are illustrated with a case study from Khotont *sum* (county) in the centrally located Arkhangai *aimag* (province), which is representative of the Hangai steppe and steppe-forest ecosystem in the central and northern part of Mongolia. This kind of ecosystem represents about 30 % of all Mongolian grasslands, 40 % of the total herder population and 30 % of the total herd (2009 data; National Statistics Office of Mongolia 2010).

Transition Period: New Opportunities, New Challenges

The main resource of nomadic livestock development in Mongolia is pastureland. According to the 2005 (national) Land Inventory Report, 116 million hectares or about 74 % of total land is pastureland. In 2009, the total number of livestock was estimated at 44 million (National Statistics Office of Mongolia 2010); due to the impact of the 2010 *dzud* the number was reduced to about 35.5 million animals. More than these numbers indicate, however, herding is a way of life rooted in the country's long history. Herding also remains one of the backbones of the economy (Ykhanbai et al. 2004). But making a living from herding is not easy. The country's per capita GDP is among the lowest in Asia. Poverty and hardship are common features of both many rural areas and cities alike. Since 2006 rural poverty has been on the increase, despite several years of macro-economic growth (National Statistics Office of Mongolia 2010). Some herders have benefitted from the growth, but most have not.

During the Soviet era (1921–1990), citizens had almost no right to own livestock. They worked for the state and used pasturelands to herd state-owned animals for a salary. The basic form of economic organisation was the *nedgel*, or union, a Mongolian term for a state-run, collective herding farm. The pasturing of livestock was carried out according to a schedule approved by the *nedgel* chairman, and during the seasonal movements, tractors and trucks were sent from the *nedgel* and used by households to move to new pastures. Monotype herding management of livestock was carried out called *suuri*: livestock was herded separately according to type (sheep, goats, cattle, horses and camels), age (new-born, young or old) and sex by the *nedgel* member households. Milking seasons, hay making and *otor* movements or the fattening of livestock in distant pastures for 6 months were all determined by the *nedgel* depending on the yearly situation (Enkhbat 2010).

With the move away from the centralised, Soviet-style management system toward a more market-oriented one, which began in 1992, private ownership of animals was re-instituted (land remained and remains state owned with the exception of a small lot which household now have the right to possess for building a home). Following privatisation, the *suuri* herding management practice was abandoned and herd composition was changed according to traditional patterns. Households sharing kinship ties camped together and herded their livestock together. The production system returned to what was essentially subsistence-based herding. Today, most households own four or five types of animals: sheep for meat, goat for cashmere, cows for milk, and horses or camels for transport. They largely make production decisions on their own.

The dramatic transition to a "free" market led to a rapidly increasing number of unemployed people as many state-run enterprises were closed. For thousands of them, herding offered some relief although many lacked the required skills to properly manage animals. Between 1992 and 1999, the number of households involved in herding more than doubled and livestock numbers increased by 30 %. In addition, household differentiation based on livestock resources began to occur. The livestock population reached 30 million heads for the first time in history. But a decade of increasingly strong pressures on pasturelands, which have low carrying capacity in Mongolia, has resulted in serious degradation of pastures and other natural resources (Ministry of Nature, Environment and Tourism 2009). A very large number of herders graze too many animals per hectare. Water sources have depleted everywhere in the country. As a result, animal concentrations around remaining water sources increased, leading to a further degradation of certain pasture areas. Widespread degradation is hampering herders' practices of moving between ecological zones and resource niches, usually according to the seasons, quality of grasslands, and availability of water. Reaching workable agreements on access to and use of natural resources has become a major challenge.

Since the "opening up," commodities and markets have become central to everyday life, but opportunities and risks related to operating in the market economy are nowadays assumed by each household. This has impacted on all key material aspects of nomadic livelihoods from income sources to employment opportunities. Market prices tend to go up and down, and production and processing are, more than ever, influenced by climate change and extreme weather events, compounding economic uncertainty. The state has done very little to support herders in their attempts to function in this new economic environment (Janes 2010). Risks related to production and marketing have intensified for most herders, and risk management practices that were supported by the state during the Soviet period disappeared completely (Swift 2007).

During the process of transition, the successive national governments focused their attention and limited resources on urban development and mining. Pastoralism was not totally ignored—several important new policies and laws were approved by parliament (Upton 2008; Ykhanbai et al. 2009), but herders have benefited little from the macro-economic growth that has occurred. Tenure insecurity has remained a major problem (Fernández-Giménez and Batbuyan 2004; Swift 2007; Upton 2008; Schulze 2009). The provision of social and economic services for rural areas, including health care, education, transportation, communication, credit, in most areas have remained poor or collapsed altogether (Enkhbat 2010). A weak state presence has also led to the collapse of regulatory regimes needed to safeguard critical common pool resources. Survival of the fittest has become the driving force in many localities. These changes taken together have produced considerable social differentiation in the countryside, a breakdown in cooperative institutions, and increasing and increasingly fierce conflicts over water and pastures.

Climate and Weather Related Vulnerabilities

Climate/weather risks are a normal part of herders' livelihoods, although the nature and frequency of them seem to be changing (Ministry of Nature, Environment and Tourism 2009). Extreme weather events are increasing and their impact appears more devastating than before, as the 2010 *dzud* indicates in telling numbers. According to the latest national assessment on climate change in Mongolia, the observed trends since 1940 are: (1) the annual mean temperature increased by 2.14 °C during the last 70 years; (2) winter precipitation has increased, and (3) warm season precipitation has slightly decreased. While research on climate change projections (2011–2099) suggests that: (1) winters will become milder and snowy; (2) there is a high probability of climate anomalous phenomena, such as harsh winters, and heavy snow; (3) summer seasons will become warmer, and (4) annual precipitation will increase by up to 20 % (Ministry of Nature, Environment and Tourism 2009).

Recent research carried out in the desert-steppe region offers a local perspective on these trends. Herders identify longer and more intense droughts and sand storms as the most important recent climatic changes relevant to their livelihoods. In addition, they record detailed changes in the precipitations regime. Thus, they are unequivocal that rains have become patchy—"silk embroidery rains"—(forcing pastoralists to move farther and more frequently), more intense (thus less effective due to run-off) and that summer rains are delayed (reducing the growing season) (Marin 2010). Other recent field research carried out in the Ikhbulag community, Khotont *sum*, in the forest steppe region provides another example of how trends are "read" by herders at the local level. This example is emblematic of trends that have been observed across the country (Government of Mongolia and UNDP Mongolia 2009).

Herders in the Ikhbulag community of Khotont *sum* started observing some major changes in climate phenomena affecting them about a decade ago. The area has become dryer, while the number of extreme weather events, such as storms and *dzuds*, seem to be on the rise. In the last ten years, there has been less rainfall every year, except for in 2010. Among those dry years, 2002, 2003 and 2009 were the worst, resulting in the drying-up of many rivers. For the community, within a 50–60 km area, there is no major river anymore. In a dry summer, grass does not grow as tall as usual and animals cannot get enough grass to gain fat against the harsh winter. This makes livestock more vulnerable when heavy snow comes. Another reason is that they eat up all short grasses during the dry summer. Then when winter comes, there is not enough grass left, and stuck in the heavy snow, many animals die.

From what the elders say, in the "old" times, before 1990, a white *dzud* (characterised by extremely heavy snowfall) was likely to happen once in every few decades; however, nowadays, the frequency has increased to a rate of every couple of years. In some cases it has happened in consecutive years, such as the *dzuds* of 1999–2000 and 2000–2001. According to herders from Khotont, *dzuds* are likely to happen more as a result of climate change, for the following reasons: (a) decreased grass-yield due to reduced rainfall during the summer and water shortages. Due to the drought, only two springs are left from the 20 that existed before in the Ikhbulag Valley; (b) sand movements related to increased wind and sand storms in the spring and summer seasons, creating overall soil erosion and land degradation; (c) loss of traditional management practices and a lack of mobility: using the same pasture year-round, and high concentration of animals around limited water sources, and (d) the absence of risk management mechanisms since the collapse of the *negdels*. Elders in Ikhbulag often mention that 20 years ago grasses were "so tall that you could not see a calf, but now they barely cover the soil" (interviewed August 2010). Even Ikhbulag, regarded as relatively less vulnerable to climate uncertainty (due to its comparatively good pasture and forests) has been affected more by *dzuds* over the last few years, mainly due to the droughts that have started to occur. Animals suffered the most from the increased frequency and number of *dzuds* and drought (Vernooy and Wang 2010).

Herders in Ikhbulag summarised the major climate/weather extreme events since 2000, and further analysed the major impacts caused by the extreme events (see Tables 42.1 and 42.2)

As Table 42.1 indicates, the impact of extreme weather events usually plays out over a considerable time period (Table 42.2).

Weather Forecasting

To date, local herders across most of Mongolia have not benefitted from location specific weather forecasts. This represents one of the major challenges related to climate risk management (Government of Mongolia and UNDP Mongolia 2009). NAMHEM, the National Meteorological and Hydrological Agency of Mongolia, provides information on temperature, precipitation, wind speed and direction, as well as general weather conditions on a daily basis. Monthly forecast bulletins, including temperature and precipitation forecast based on the data from twelve automatic weather stations across the country, are given in the form of categories using analogue methods. Other forecast information generated by NAMHEM includes: monthly and ten-day agricultural weather forecasts disseminated to all line ministries and other meteorology agencies in the provinces, as well as to

Table 42.1 Major extreme climate/weather events since 2000: Ikhbulag community, Khotont *sum*

Event	Frequency (since 2000)	Comments
Summer drought	Often	2009 was very dry. This drought aggravated the impact of the winter *dzud* that followed. Spring and summer of 2010 (post *dzud*) were rainy, more than usual. This had a positive effect on grassland recovery, but huge animal losses had already occurred.
Heavy rain	Often	Increasing in frequency and have a very bad impact on grass growth. Soil cannot absorb large quantity of rain at once causing compacting of soil.
Wind/dust/ snow storm	Often	Increasing in frequency. Dust storms can seriously affect animals, often leading to death. Sheep and goats are particularly vulnerable. Herders do not receive early warnings about storms. They often do not have enough time to shelter animals.
Hail storm	Rarely	
White deep *dzud*	2010	The drought of the 2009 summer aggravated the impact of the *dzud* itself. Already weakened animals did not have the energy to dig through the snow to find grass. Herders did not receive early warning information on time and were therefore under prepared.
Black *Dzud*	2000–2001	This *dzud* followed a prolonged drought in the spring and summer.

Source: Vernooy and Wang (2010): 29

sum-level NAMHEM stations; forecasts of pasture growth and pest infestation, dates for haymaking, ten-day reviews of summer weather and winter snow cover, predictions of pasture carrying capacity, and six monthly weather forecasts in March and August each year.

However, although available forecasts are circulating widely at national and *aimag* levels, at community level circulation is very limited due to the weak communication system below sum level. Internet is used between Ulaanbaatar and *aimags* and, where connections exist, between *aimags* and sums. But there is no internet connection between sum centres and herders. In winter, communication between some areas becomes more difficult due to heavy snow cover. Mobile phone use is constantly increasing, but in many areas, the signal is weak or not functional as mountains block transmission. Warning information transmitted from NAMHEM is in scientific language and often not well understood by users at a regional level. No systematic mechanism is in place to translate warning information in simple language that allows easy identification of impacts. There are no established feedback mechanisms in place allowing local users to comment on the services or express their demands (Vernooy and Wang 2010).

Forecast information is only useful for local users when tailored to site-specific conditions (e.g. in the Gobi desert region, herders are most concerned about wind and snow storms) offering sufficient lead time for community users to be well

Table 42.2 Major impacts caused by extreme climate/weather events*: Ikhbulag community

Impact	Comments
Price increase of animal feeds and medicines	During and post *dzuds* in particular, feeds are in high demand but often scarce due to lack of adequate preparation. Medicines are also in high demand post *dzud* to treat animals that have fallen ill.
Increased incidents of disease among livestock	Surviving animals are extremely weak post drought or *dzud*. There is always a marked increase in diseases.
Reduced benefits from livestock	Drought and *dzud* reduce herd size, leading to reduced production of wool, cashmere, hair, milk and meat. The quality of products is also negatively affected.
Reduced number of young and pregnant animals/ changes in herd composition	Drought and *dzud* affect the young and pregnant the most. This has immediate impact on herd composition in the year of the event and in following years. Most vulnerable are horses followed by yak, cows, sheep and goats. Few or no lactating animals has a severe impact on milk production and therefore also on household food security and income.
Feed (hay, fodder) shortage	Extremely cold winters exhaust feed supply quickly. Many herders were not well prepared for the 2010 *dzud* in terms of feed stocks.
Water shortage	Water sources are drying up in the valley. Herders have to search further away for scarce water. Some conflicts have emerged in recent years over water access and use.
Insufficient fuel sources	Although to date the forest surrounding the community supplies has had abundant firewood, extreme winters burn up household supplies more quickly than usual. Since 2007 all households have a solar panel supplying a small amount of electricity. Solar energy has not been affected by extreme weather events.
Shortcomings in sheltering of livestock	Heavy snowfall causes damage to shelters. Herders have not been well prepared for *dzuds*.
Psychological impact	Loss of animals has dramatic impacts on economic and social aspects of livelihoods. Herders mention that the absence of baby/young animals post *dzud* not only leaves them without milk but also deprives them of much joy. Several herders experienced depression in the months following the *dzud*.
Migration	Post-2010 *dzud*, six of 32 households decided to migrate to urban centres to find another source of livelihood. This urban migration affects the social fabric of the community in various ways, reducing pressure on natural resources on the one hand, but disturbing social relationships on the other.

*Herders assessed impacts without *systematically* differentiating extreme weather events
Source: Vernooy and Wang (2010): 30

prepared (e.g. gathering livestock and moving them out of the storm channel). In summer, weather information would be useful for decisions regarding the planting of crops (e.g. potatoes), use of pasture land for grazing, and stocking density. In autumn and winter, the information would be useful for preparing hay and fodder, for pasture-moving decisions, and for livestock pooling to avoid the negative impacts of extremely low temperatures and heavy snow fall.

For local herder communities, the potential use of weather forecast information varies from season to season. In summer, the climate information would be useful for decisions made about planting, use of pasture land for grazing, *otor* movements, and stocking density and composition. In autumn and winter, the information would be useful for preparing hay and fodder, for pasture rotation (autumn), for livestock sheltering and livestock pooling to avoid the negative impacts of extremely low temperatures and heavy snow fall. In spring, information could be used for the timing of movements, use of pasture land for grazing, and stocking density and composition.

Vulnerabilities Due to Dependency on Grassland Dynamics

Herders' livelihoods depend on the quantity and quality of the grasslands they can access and use; season after season; year after year. This has not changed in the hundreds of years that pastoralism has been the heart of Mongolia's society, although the precise features of the dependency has undergone important changes—not in the least as a result of the changing climate/weather dynamics described in the section above. At national level, one of the most dramatic changes has been the significant reduction of grassland biomass production (20-30 % in the last 40 years) and fodder production reduction (30 % compared to 1986) (Government and Mongolia and UNDP Mongolia 2009: 15). Another major change has been the expansion of desert areas which are steadily moving northward from the Gobi region, estimated at 150 km every 20 years (ibid: 16).

All four seasons are critical when considering the vulnerability of grassland dynamics. The short summer season arrives in June and ends in late August. If grasses have grown regularly (which depends on the pattern and intensity of rainfall and sunshine, as well as on the grazing practices in previous years), it is an abundant time, and both humans and livestock feel (more) relaxed after the usually long winter and harsh spring. As households stay near a water source during this time, the women and children can carry water easily; however, lots of firewood is used for cooking and for processing the milk and storing the dairy products for winter and spring consumption. Both water and firewood have become scarcer in recent years, contributing to increased stress on households, and, increasingly, to conflicts about water rights in particular, both between households and communities.

Autumn starts in September; however, herders say "after the national summer holiday of *Naadam* [the] autumn starts" which means that effectively by mid-July (when *Naadam* is celebrated), the summer holiday season has ended and the work required to prepare for winter is on the doorstep. The most important work in the autumn is hay and fodder making and storing it for winter and spring use. Drought can have a dramatic and negative impact on hay and fodder production; very dry summers can easily lead to no hay and fodder production at all. In a normal year, herders sell their livestock for meat in autumn as the livestock are at their fattest.

During the summer and autumn, in the case of drought or other adverse grassland growing circumstances, some herders move to so-called *otor* or "special fattening pastures"; these are pastures held in reserve under normal conditions. But this is only possible through collective action at the community and supra-community level: it requires that all households in an area do not use *otor* pastures prior to the summer or autumn seasons, and that collective agreement is reached about which households can access and use them, for how many and which type of animals, and for how long. In winter, which lasts from November to the Lunar New Year in February, the grassland is "at sleep". However, winter conditions have a direct impact on the potential for grassland development and health in the following seasons. Extreme winter conditions, including those leading to *dzud*, can delay and hamper adequate spring growth, which will directly impact summer and autumn grassland health. Therefore, herders are very concerned about the particular weather conditions that mark winter, most notably concerning snowfall and frost. Little snowfall can lead to a spring drought; whilst large amounts of snowfall can make it difficult for livestock to move on time to spring pastures and/or make spring grazing extremely difficult as animals are not able to dig through the snow to reach the young grasses. Extreme frost in terms of temperature or duration will have similar negative effects on livestock. The main labour tasks remain weather dependent during winter and include herding and protecting sheep and goats, and cows, checking on the horses left in the *otor* pasture, bringing in firewood from the forest, and fetching water. Spring season starts just after the Lunar New Year and ends in late May. This is the time of awakening from the cold and, of new grass growth (if winter has ended on time and there has been no *dzud*). It is a time of scarcity, however, as most herders have finished their food and hay/fodder reserves by then. After the hard winter time, they are able to gain some income by selling their cashmere, pay off any debts they might have, and buy new items.

Community-Based Management of Climate Risks

Climate/weather risks are a normal part of herders' livelihoods, although the nature and frequency of them seems to be changing. Before 1992, during the Soviet regime, the state played a major role in assisting herder households to deal with these risks (and risks in general). After 1992, herders have more or less been left "on their own", although in recent years, some have benefitted from project-based collaboration and support. Herders have not been passive in the light of these changes, but have instead developed a series of management practices to deal

Table 42.3 Overview of climate/weather events, associated risks and risk management practices

Climate/weather event	Risk	Risk management practice
Summer drought	Fodder, hay, and vegetable production lower than expected Livestock health worsens leading to lower production/lower quality of livestock products Reduces water resources in the autumn If followed by *dzud,* usually leads to heavy livestock losses	*Otor* pasturing Pasture rotation Move to autumn camp earlier than usual Adapt herd composition Reduce herd size Income diversification Seasonal labour
Heavy rain	Weakens livestock health Can slow down pasture growth Compacts soil	Pasture quality improvement Pasture rotation
Wind/dust/snow storm	Weakens livestock health Can impede timely movement to new camp Can cause death of livestock	Improve quality of livestock Reduce herd size Prepare adequate and enough shelters (winter)
Hail storm	Weakens livestock health Can impede timely movement to new camp Can slow down pasture growth	Pasture quality improvement Improve quality of livestock
White deep *dzud*	Weakens livestock health leading to lower production/lower quality of livestock products Can cause huge loss of livestock Exhausts winter food, fuel and fodders provisions quicker than expected Can impede timely movement to spring camp	Adapt herd composition Reduce herd size/sell weaker animals Prepare adequate and enough shelters Prepare enough fodder and hay Move to spring camp earlier Income diversification Seasonal labour/migration
Black *dzud*	Weakens livestock health leading to lower production/lower quality of livestock products Can cause huge loss of livestock Exhausts winter food, fuel, and fodder provisions more quickly than expected Can impede timely movement to spring camp Impedes timely regeneration of pastures in spring	Adapt herd composition Reduce herd size/sell weaker animals Prepare adequate and enough shelters Prepare enough fodder and hay Move to spring camp earlier Income diversification Seasonal labour/migration

with them, either individually or collectively. Not all herders use these practices: some lack the knowledge and skills, whilst others lack the resources. The table below represents the "menu" of practices that can be found at present (Table 42.3).

Co-management is a holistic and dynamic approach that covers many of the practices listed in Table 42.3. Co-management is a strategy that goes beyond dealing with climate/weather risks, aiming to strengthen the overall resilience of pastoral livelihoods. Co-management processes establish effective roles and responsibilities of the stakeholders who manage, either directly or indirectly, livestock (privately owned), land and water (state owned), and other natural resources (e.g. wildlife). The main stakeholders are herders and herder groups, local leaders, local government authorities, and the state (represented through local government, as well as ministries). In the case of transitional economies, such as Mongolia, the implementation of co-management approaches requires adequate time as well as clear stipulation of what the government will and will not do to support agreements.

Co-management was first introduced in Mongolia at the end of the 1990 s in a number of pilot sites across the country; in the dry steppe (Lun *sum*), forested steppe (Khotont *sum*), and high Altai mountains (Deluin *sum*) (Ykhanbai et al. 2004; Ykhanbai et al. 2009). More recently, co-management has been introduced for forest resources (e.g. in Batsumber *sum*). According to Mongolia's new *Articles to the Law on Environmental Protection* (2005) and the Minister's Decree 114 (2006) on "Community procedure for protection, sound use and allocation of natural resources," co-management will be scaled-up and used in all provinces and districts of Mongolia.

Based on 10 years of experimentation and the building up of experience, the co-management efforts have led to more productive pastureland, healthier herds, and increased incomes at the pilot sites. Herders are organised into associations that are taking the lead in reshaping the use of the grasslands through reductions in the size of herds, novel rotational grazing schemes, introduction of more productive grassland species, intensified hay and fodder production, and better coordinated livestock movements throughout the season (Ykhanbai 2011). Working alongside government officials, schoolteachers, forest wardens, and others, the herders, including women, have helped to put together agreements that spell out how the grasslands and related resources are managed (Ykhanbai and Odgerel 2006). The co-management results and lessons learned have also led to changes in national policies and laws governing forests, water use, and environmental practices.

Implementing co-management includes activities that address material, socio-economic and institutional dimensions of pastoral livelihoods and associated vulnerabilities. They cover the drafting, discussion, negotiation and signing of co-management agreements with the *sum* and local governors and its members to ensure access to the community land (pasture) area, using site-appropriate seasonal pasture shifting methods at the community level, allowing the restoration of degraded grassland; protecting wells and rivers, or accumulating snow and rain water (in small reservoirs); clearing the forest, using stumps or dried branches of trees for fuel use, and forest restoration or transplantation of trees from densely wooded area, as well as by creating a salt-marshy area as a drinking source for livestock.

Co-management includes the development of a variety of skills, for example, to design and formulate co-management contracts with community members, register each family and members as belonging to the community and (co-management) group, and to register forest and other natural resources in the community area as belonging to the community and (co-management) group. Other developments include setting up a community fund, discussing ways to accumulate and spend it among the all community members, involving young people in the community activities as a way to train the new generation of herders in co-management of natural resources, and organising activities to increasing the availability of useful information (for example, related to markets and prices, related to weather dynamics), through newspapers and other means of communication.

Increasing household and community income takes place through joint hay and fodder making, organising hunting among the men, vegetable growing, making hand-made felt and other handy crafts, making quilted rugs, and making farm carts for both community use and for sale, using forest resources like wood, berries and nuts according to relevant permissions and regulations, as well as the processing and marketing of dairy products. More recently, some co-management groups have initiated the establishment of community shops through which local products can be sold thus retaining a higher profit margin than through sales via middle-men.

Conclusions

Challenges of risk management due to the Mongolian nomadic livelihood style are numerous and complex. Herders are moving from season to season, always dependent on the weather. Their livelihoods are centred on livestock-dependent income sources. They have to deal with scarce natural resources which, in many parts of the country have become seriously degraded. After the "opening up" in the early 1990 s, herders have become *both* more independent (individualised) *and* more vulnerable as protection by the state ended (employment, social security, health care, education services were no longer secured) and the country moved quickly to a free market development model. Parallel to this societal change, impacts of climate change have become more visible, first observed and felt by herders over a decade ago. In the last decade, severe weather events, in particular storms, drought, and extremely harsh winters known as *dzud*, are on the rise. The un-predictability of these (extreme) weather events, in a large nomadic society where vulnerability is part of everyday life, remains a major issue to deal with.

Herders have had hard times coping with these extreme weather events. Preparations to mitigate impacts, by both herders and the state, have also had serious shortcomings. The authors suggest that the main reason is the exposure of pastoral livelihoods to a *new* constellation of vulnerabilities related to three interrelated forces: climate change and weather dynamics, natural resource degradation, and societal changes. In addition to more unpredictable climate (change) and weather risks, pastoral livelihoods have become dependent on increasingly degraded and scarce natural resources.

More effective adaptation practices and institutions are urgently needed to avoid dramatic losses due to extreme events, as shown by the winter of 2010. Current adaptive practices include *otor* pasturing, pasture rotation, moving to a new camp earlier than usual, adapting herd composition, livestock breeding to improve quality, reducing herd size, income diversification, seasonal labour, and permanent migration. Co-management was introduced across the country as a response to changing ecological, socio-economic and political conditions, and to reduce pressure on the natural resource base. Co-management takes time and effort to be introduced, tested and integrated in local practices and in national policies/laws, but 10 years of experience have demonstrated that collective action for natural resource management strengthens the adaptability of herders. Climate risks can be managed more effectively through joint actions in the case of nomadic livelihoods which are characterised by high interdependency of people and natural resources.

Weather forecast generation and dissemination capacities cover and function in the large country to a certain extent, but have some limitations particularly regarding the capabilities to reach local communities, and receive feedback from them. In the context of increasing weather/climate uncertainty, addressing this shortcoming has become a policy priority of the government and several national agencies responsible for pastoral development. Early warning information (useful weather forecasts that are location specific and cover a number of lead times) could help herder communities to make better-informed and less risk-prone decisions concerning key livelihood practices, particularly concerning the co-management of grasslands. Better-informed decision-making could strengthen the disaster-preparedness capacity, lead to reduced losses in case of disaster, and contribute to the improved adaptation of both individual herder families and herder communities.

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Author Biographies

Wang Xiaoli is a lecturer and researcher at the Center for Women Studies of Shantou University. She obtained her PhD in Rural Development and Management from the College of Humanities and Development, China Agricultural University, Beijing. In 2010 she worked for the Regional Integrated Multi-hazard Early Warning System (RIMES), Bangkok, Thailand as part of the Climate Risk Management-Technical Assistance Support II project funded by the United Nations Development Programme. Mongolia was one of the countries supported by this project.

Ronnie Vernooy is a rural development sociologist with a particular interest in agricultural biodiversity and natural resource management. He obtained his PhD from Wageningen Agricultural University, the Netherlands. He was a programme officer at the International Development Research Centre, Canada, from 1992 until 2010. He has supported and carried out research in Mongolia since 2003. He recently joined Bioversity International in Italy as a genetic resources policy specialist.

Chapter 43
The Potential of Latin American Coffee Production Systems to Mitigate Climate Change

Henk van Rikxoort, Peter Läderach and Jos van Hal

Abstract A carbon footprint is used to define the amount of greenhouse gas (GHG) that is emitted along supply chains and is the first step towards reducing GHG emissions. In the coffee sector specifically, there is little literature and data regarding the carbon footprints of different coffee production systems and supply chains. Therefore, GHG data from different coffee production systems has been compiled for this study and compared to on-farm carbon stocks and the relevant carbon footprint. To quantify on-farm carbon stocks and carbon footprints the cool farm tool (CFT) has been used. The CFT uses the Tier II methodology of the intergovernmental panel on climate change (IPCC) and is based on empirical GHG quantification models built from hundreds of peer-reviewed studies. Field data has been collected in five countries across Latin America, from the following coffee production systems: (i) traditional polycultures, (ii) commercial polycultures, (iii) shaded monocultures, and (iv) unshaded monocultures. The results show low mean carbon footprints for coffee produced in traditional polycultures (3.7 kg CO_2-ekg^{-1}) and commercial polycultures (3.9 kg CO_2-ekg^{-1}), versus high carbon footprints for shaded monocultures (9.2 kg CO_2-ekg^{-1}) and unshaded monocultures (9.4 kg CO_2-ekg^{-1}). The same trend is observed with regard to mean on-farm carbon stocks; polycultures (70.9 t C ha^{-1}) versus monocultures (17.8 t C ha^{-1}). Based on these results a framework for site-specific mitigation has been developed to assist coffee farmers in

H. van Rikxoort (✉) · J. van Hal
Hoevestein 239-12C-003, 6708 AK, Wageningen, The Netherlands
e-mail: henk.vanrikxoort@wur.nl

J. van Hal
e-mail: Jos.vanhal@wur.nl

P. Läderach
International Center for Tropical Agriculture (CIAT), Residencial San Juan de Los Robles, Casa 303, Apartado Postal LM 172, Managua, Nicaragua
e-mail: p.laderach@cgiar.org

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defining climate friendly farm practices in order to accelerate climate change mitigation in Latin American coffee production.

Keywords Carbon footprint · Climate change · Coffee ecosystem conservation · Latin America · Site-specific mitigation

Introduction

According to the Intergovernmental Panel on Climate Change Fourth Assessment Report (IPCC 2007) global temperatures increased by 0.74 °C during the twentieth century. Most scientists agree that this warming in recent decades has been caused by human activities, such as the burning of fossil fuel and deforestation, which have increased the amount of greenhouse gases in the atmosphere (Oreskes 2004). In most tropical and sub-tropical regions, such as Latin America, climate change threatens to become an environmental disaster, with high reductions in crop yields, decreased water availability and new or changed insect and pest incidence (IPCC 2001, 2007). In this region crops like coffee form the backbone of thousands of families' livelihoods and contribute significantly to national agricultural gross domestic products (GDPs).

Besides suffering from the effects of climate change, agriculture is also contributing significantly to the effects of climate change. Agriculture alone is responsible for 14 % of global GHG emissions, mainly as a result of soil erosion, poor irrigation practices, the uncontrolled use of fertilisers and other agrochemicals, biomass burning and livestock production (IPCC 2007). When deforestation from farmland expansion and tree plantations is included into the calculations, agriculture is estimated to account for 30 % of total GHG emissions globally.

Responses to global warming as proposed in the signed and ratified Kyoto Protocol (UNFCCC 2009) includes the mitigation of the amount of greenhouse gases emitted into the atmosphere. Within the coffee sector specifically, the first signs that the need for climate change mitigation in agricultural supply chains are visible. Frontrunners among private companies such as Nestlé and Tchibo started with estimating the amount of emitted GHG in some of their coffee supply chains by means of applying life cycle analysis (LCA) and product carbon footprint (PCF) methodologies. Tchibo for example, initiated a study on the carbon footprint of a coffee product in their portfolio. The study revealed that the carbon footprint of the coffee product researched was 8.4 kg CO_2-ekg^{-1} coffee produced, processed and consumed (Tchibo 2008). This result excludes the emissions of CH_4 which occured during coffee fermentation and the generation and discharge of waste water and carbon sequestration in the coffee ecosystem.

Furthermore, Salomone (2003) used an LCA to quantify the effect of coffee production on climate change. The results show that the processing/packaging stage of the researched coffee supply chain contributed the least to GHG emissions with 1.7 %. Cultivation had a much greater GHG impact, contributing 12 % to the total amount of GHG emissions. According to, Salomone (2003) more than 80 % of the GHG emissions in the researched supply chain are attributed to the consumption of the coffee. The study is largely based on a general coffee production system and does not take into account different farming systems and geographical contexts, assuming a yield figure of 190 kg ha^{-1} as an average.

With regard to carbon sequestration, the available literature supports the theory that agroforestry systems store more carbon than unshaded systems (Lal et al. 2005; Davidson and Janssens 2005; Anim-Kwapong and Osei-Bonsu 2009; Bellarby et al. 2008; Flynn and Smith 2010). A wide variety of studies are available stating figures on carbon sequestered in coffee farms. Aguirre (2006) reports carbon stock figures in shade trees in two different systems in Chiapas, Mexico; natural coffee 47.6 versus 23.1 t C ha^{-1} in a shaded monoculture. Soto-Pinto et al. (2009) estimates a 147.2 t C ha^{-1} in a high management system versus 84.5 t C ha^{-1} in a low management system.

Although these studies on carbon sequestration and carbon footprints in coffee production, which combine the interest from the voluntary standard community and the coffee private sector for climate change mitigation, are encouraging, there are still knowledge gaps that prevent stakeholders within coffee supply chains from making informed decisions regarding the definition of high-impact climate change mitigation strategies. These climate change mitigation strategies are important in reducing the potential risks and catastrophes that climate change can mean for coffee farmers. The current available studies on carbon footprints of coffee products differ in the methodologies applied and are therefore difficult to compare. Regarding carbon stocks in coffee ecosystems, a wide variety of literature is available but only a few studies compare different coffee production systems in the Latin American region (Aguirre 2006; Soto-Pinto et al. 2009).

The main purpose of this study is therefore to assess how different coffee production systems are contributing to, or mitigating climate change. This has been done by defining on-farm carbon stocks and carbon footprints of four different coffee production systems characterised by Moguel and Toledo (1999) in Latin America. Finally, based on the findings a framework for high-impact climate change mitigation in different coffee farming systems is presented. This framework aims to reduce the risks and disasters that are triggered by climate change and improve the resilience of coffee ecosystems in Latin America.

Materials and Methods

Sampling Design and Data Compilation

The population for this study is defined as the coffee production systems described by, Moguel and Toledo (1999) which covers the range of coffee production systems in Latin America. The two main criteria by which Moguel and Toledo (1999) distinguished these coffee production systems have been used in the field. These criteria are: (i) vegetational and structural complexity and (ii) management level observed in the different coffee production systems. The underlying indicators belonging to those two main criteria have been used to make the two main criteria measurable and to discriminate between production systems in the field. Table 43.1 shows the sample size of each system, a complete overview of the criteria and indicators, and how the four different production systems perform with regard to each indicator.

The data collection was conducted in close collaboration with technicians in order to facilitate logistics and secure additional expert knowledge on farm inputs, outputs, practices, management level, and the procedures at cooperative level. Data collection at each individual farm started with a semi-structured interview with the corresponding farmer to compile data on farm management, fertilisation, crop protection, shading, coffee and shade tree densities, yields, processing methodologies and energy use. Afterwards the coffee plots were visited to double check information gathered in the interview, to measure shade and tree diameters at breast height, and to gather GPS coordinates. To verify the accuracy of the shade tree species and their number per hectare at each farm, counting in a 10×10 m area was undertaken. Extrapolating the findings to the hectare and comparing these results with the initial data defined a final more cross-validated value. Further verifications consisted of checks regarding coffee tree spacing, mulching status, weeding practices, canopy heights, and the presence of different shade stratum. If soil organic matter (SOM) and the pH data of the soils of the farms were not available, soil samples were collected at the researched coffee farms and analysed using the rapid soil and terrain assessment (RASTA) methodology (Cock et al. 2010).

GHG Model Selection

In selecting a GHG quantification model that would serve the scope of this study the following criteria have been identified: (i) compute context specific variables such as country, soil and climate, (ii) quantify GHG emissions and carbon stock stored in coffee eco systems including the annual carbon sequestration, (iii) quantify methane emissions that arise from coffee cherry de-pulping and fermentation processes, and (iv) calculate and present results both in [kg CO_2-eha^{-1}] and [kg CO_2-ekg^{-1} product] to illustrate the performance of farming systems in terms of land-use efficiency and efficiency per unit product (PCF). We reviewed the CALM Calculator (CLA 2006), the EX-ACT Carbon Balance Tool (Bernoux et al. 2010), the Cool Farm Tool (Hillier et al. 2011), DAYCENT (Del Grosso et al. 2001) and the DNDC (Li et al. 1994). The only model that complied with the established criteria was the cool farm tool (CFT), in addition to meeting the criteria the CFT has considerable scope to be used in global surveys on current practices and potential for mitigation (Hillier et al. 2011), which is exactly what this study seeks to achieve.

Table 43.1 Criteria and indicators to distinguish between production systems

System	Sample	Vegetational and structural complexity				Management level		
	(# Farms researched)	Shade tree density (trees/ha)	Co-product density (trees and plants/ha)	Canopy height (m-MAX)	Coffee plant density (plants/ha)	Production level (kg parchment/ha)	Fertilisation level	Pesticide level
Trad-poly	29	Very high	Medium	20–30	Very low	Very low	Very low	Very low
Com-poly	27	High	Very high	<15	Low	Low	Low	Low
Shad-mono	29	Medium	–	<15	Medium	Medium	Medium	Medium
Unshad-mono	24	–	–	–	High	High	High	High

In a summary the CFT GHG quantification model calculates the GHG emissions of: (i) emissions from fuel and electricity use utilizing IPCC default values, (ii) soil carbon sequestration based on an empirical model (a model based on the results of several published studies) and built from over 100 global datasets, (iii) carbon sequestration in above and below ground biomass. The allometric equation model developed by Segura et al. (2006) for *coffea arabica* and a wide variety of shade trees has been used for this purpose, (iv) emissions from pesticide production utilising IPCC default values, and (v) N_2O emissions from fertiliser application based on an empirical model built from an analysis of over 800 global datasets. These datasets refine gross IPCC Tier I estimates of N_2O emission by factoring in the guiding drivers of N_2O emissions such as climate, soil texture, soil carbon and soil pH.

The CFT bases its calculations on several empirical sub-models to estimate the overall GHG emissions, namely: (i) simplified model for machinery emissions derived from (ASABE 2006a, b), (ii) GHG emissions from fertiliser production (Ecoinvent Centre 2007), (iii) N_2O emissions from fertiliser application (Bouwman et al. 2002), (iv) changes in soil C based on IPCC methodology as in (Ogle et al. 2005), and (v) the effect of manure application on soil C based on (Smith et al. 1997).

GHG Quantification

The data has been collected on individual farms. Consequently the data from each farm was analysed individually with the CFT GHG quantification model. Table 43.2 illustrates the function to translate input data into CO_2 equivalents.

During the field data collection a wide variety of different units of measurements were encountered. As well different conversions, default values have been maintained for certain processes during the coffee production stages. Table 43.3 gives a complete overview of the different units of conversion, ratios, and the default values used throughout the study.

Assumptions

Within the calculation procedures of the study, several assumptions have been made for certain factors in the coffee production process for all four of the production systems researched. The assumptions are based on peer-reviewed publications. Table 43.4 shows the amount of leaf litter pruning residues coming from coffee plants and shade trees in the different production systems, and Table 43.5 the annual biomass increase in shade trees and coffee plants.

To quantify the amount of sequestered carbon in coffee plants (*Coffea arabica*) and shade trees (*Cordiaalliodora, Juglansolanchana, Inga tonduzzi and Inga punctate*) two allometric equations developed by Segura et al. (2006) have been

Table 43.2 Overview on the function of the CFT in transforming data

Emission/ sequestration factor	Input data needed	Output data by CFT
Pesticide production	# of applications	kg CO_2-e ha^{-1}/ kg CO_2-e kg^{-1}
Gas use	Litres/kg	kg CO_2-e ha^{-1}/ kg CO_2-e kg^{-1}
Diesel use	Litres/km	kg CO_2-e ha^{-1}/ kg CO_2-e kg^{-1}
Electricity use	kWh	kg CO_2-e ha^{-1}/ kg CO_2-e kg^{-1}
Off-farm transport	km/weight/mode	kg CO_2-e ha^{-1}/ kg CO_2-e kg^{-1}
Crop residue management	kg/management practice	kg CO_2-e ha^{-1}/ kg CO_2-e kg^{-1}
Waste water production	Litres/management practice	kg CO_2-e ha^{-1}/ kg CO_2-e kg^{-1}
Fertiliser induced N_2O	Fertiliser type/# and kg of application/ Management practice	kg CO_2-e ha^{-1}/ kg CO_2-e kg^{-1}
Fertiliser production	Fertiliser type/# and kg of application	kg CO_2-e ha^{-1}/ kg CO_2-e kg^{-1}
Carbon sequestration	Tree species/DBH/D/# per ha/ # clear-felled or planted	kg CO_2-e ha^{-1}/ kg CO_2-e kg^{-1}

used (Table 43.6). The allometric equations were developed using empirical data from Matagalpa, Nicaragua and are thus highly representative for the geographical context of this study (Latin America).

It was assumed that the coffee plants in a mature system do not show a net biomass growth taking into consideration the yearly pruning activities by coffee farmers observed. A diameter (D) value of 9 cm at 15 cm from ground level has been maintained as an average for coffee plants in all systems. The system boundary of the carbon footprint has therefore been defined as; the delivery of dried coffee parchment to the location where dry milling takes place and the dried coffee parchment is processed into green coffee.

Results and Discussion

Visual Profile Coffee Production Systems

The visual profile will help the reader in distinguishing between the different coffee production systems throughout the study (Figs. 43.1, 43.2, 43.3, 43.4).

Table 43.3 Conversion ratios and default values maintained throughout the study

Conversion/item	Ratio/value	Reference
Manzana: hectare	1:0.7	http://www.convertunits.com
Manzana: cuadra	1:16	http://www.convertunits.com
Quintal: kilogram	1:45	http://buscon.rae.es
Libra: kilogram	1:0.45	Skinner (1952)
Cherry: parchment	1:0.2	El Salvador
Parchment: green coffee	1:0.8	El Salvador
Energy use de-pulper diesel	0.11 L/kg parchment coffee	Coltro et al. 2005 El Salvador
Energy use de-pulper electric	0.22 kWh/kg parchment coffee	Coltro et al. 2005 El Salvador
Water use of manual de-pulping in an ecological process	4.4 L/kg parchment coffee	Nicaragua
Water use of de-pulping in a standard process	28.8 L/kg parchment coffee	Guatemala
Water use of cherry de-pulping and parchment fermentation in a traditional fully washed process	80 L/kg parchment coffee	BIOMAT 1992 Nicaragua
Content ̈bombä (spray container for foliar fertilisation)	18 L	Guatemala

Table 43.4 Amount of residue in different production systems

Production system	Leaf litter and pruning residue from coffee plants (kg/ha)	Leaf litter and pruning residue from shade trees (kg/ha)	Total amount of leaf litter and pruning residue	Reference
Traditional polyculture	2,000	10.000	12.000	Beer (1988), Coltro et al. (2005)
Commercial monoculture	3,000	7,500	10.500	
Shaded monoculture	4,000	5,000	9,000	
Unshaded monoculture	5,000	–	5,000	

Table 43.5 Periodical annual diameter increment (PAI) values used for the production systems

Production system	Periodic annual diameter increment (PAI) in coffee plants (cm^{-1} yr^{-1})	Periodic annual diameter increment (PAI) in shade trees (cm^{-1} yr^{-1})	Reference
Traditional polyculture	0.0	0.4	Carvalho et al. (2004)
Commercial monoculture	0.00	0.6	Somarriba (1990)
Shaded monoculture	0.0	0.8	
Unshaded monoculture	0.0	0.0	

Table 43.6 Allometric equation models used for all production systems

Allometric equation model used for coffee plants	Allometric equation model used for shade trees
$Y = 0.0659 * D^{1.991}$ where Y = aboveground dry matter [kg $(tree)^{-1}$] D = diameter at 15 cm from ground (cm)	$Y = 0.1466 * DBH^{2.223}$ where Y = aboveground dry matter [kg $(tree)^{-1}$] DBH = diameter at breast height (cm)

Differences Between Coffee Production Systems

Differences in On-Farm Carbon Stocks

The comparison between the four researched coffee production systems (Fig. 43.5) shows that on-farm carbon stocks in both shade trees and coffee plants increase from a mean of 10.4 t C ha^{-1} in unshaded monocultures, to a mean of 81.5 t C ha^{-1} in traditional polycultures. This is because traditional polycultures combine a high number of trees per hectare with high DBH figures, which are a consequence of a high tree age and the use of indigenous species. Therefore traditional polycultures contain the highest on-farm carbon stock of all the systems researched.

Commercial polycultures also show high amounts of trees per hectare although the DBH figures are lower in these systems due to lower tree age and an increased use of *Inga* spp.; a shade tree that remains smaller compared to indigenous species. Furthermore, a high use of *Musa* spp. (banana and plantain) is observed in this production system, plants that are unable to sequester carbon in the long run (Roshetko et al. 2002). Consequently commercial polycultures show lower on-farm carbon stocks compared to traditional polycultures.

Shaded monocultures completely abolish the indigenous trees that can be found in the latter systems. Instead a shaded monoculture system uses one species only, often *Inga* spp., or *Gliricidiasepium*, these shade trees show very low DBH figures compared to indigenous species and the maximum canopy height of this species reaches only a fraction of the height reached by the indigenous shade tree species featured in polycultures. For this reason shaded monocultures show a drastic

Fig. 43.1 Traditional polyculture

decrease in on-farm carbon stocks compared to the two polyculture production systems.

Unshaded monocultures do not use shade at all. Therefore the carbon sequestration in this production system is limited to coffee plants. The overall amount of sequestration in coffee plants is also very limited and for this reason the unshaded monoculture shows the lowest amount of on-farm carbon sequestration out of all the researched systems.

When only the carbon sequestered in coffee plants is taken into account (Fig. 43.6) the picture is completely different: on-farm carbon stocks in coffee plants decrease from a mean 10.4 t C ha^{-1} in unshaded monocultures, to a mean 3.1 t C ha^{-1} in traditional polycultures.

This phenomenon is a result of the nature of the four different production systems. Traditional and commercial polycultures contain three different stratums of shade trees with canopy heights that can exceed 30 m. Consequently on the "floor" of these systems there is less space and light available for coffee plants.

Fig. 43.2 Commercial polyculture

Therefore, much lower amounts of coffee plants per hectare are observed resulting in a direct reduction in the total amount of carbon stored in the coffee plants compared to monocultures.

So far we have evaluated carbon stocks that can be found in different coffee production systems. These stocks are built up over a long period of time. When looking at the amounts of carbon sequestered in shade trees per coffee crop cycle (Fig. 43.7), interesting dynamics can be observed. It is found that the mean annual amount of sequestered carbon in shade trees is: 0.32 (shaded monoculture), 0.37 (commercial polyculture), and 0.35 t C ha^{-1} yr^{-1} (traditional monoculture).

This means that although the existing on-farm carbon stocks in shade trees is up to four times higher in traditional polycultures compared to shaded monocultures, the annual carbon sequestration is not overall significantly higher. The observation that is presented in the results can be explained by looking at the shade tree growing dynamics in different coffee production systems. Carvalho et al. (2004) found that the Periodic Annual diameter Increment (PAI) of trees in dense systems

Fig. 43.3 Shaded monoculture

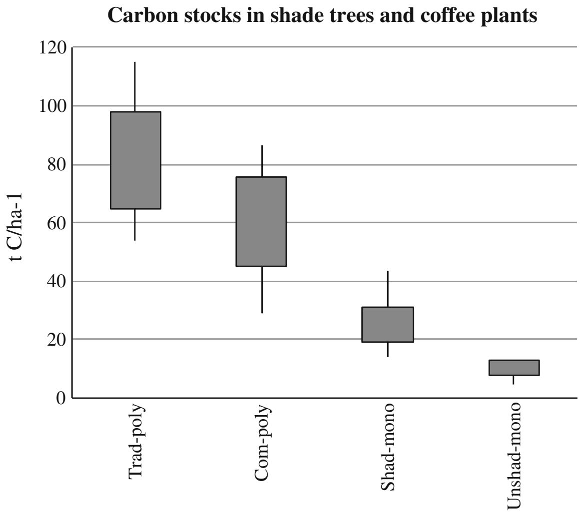
such as traditional polycultures is 0.4 cm^{-1} yr^{-1}. However, Somarriba (1990) reports a 0.6 cm^{-1} yr^{-1} PAI value for systems that can be compared with commercial polycultures and a 0.8 cm^{-1} yr^{-1} PAI value for systems that can be compared with shaded monocultures. Thus other researchers found that shade trees in shaded monocultures grow twice as fast compared to traditional polycultures. This is the reason that shaded monocultures can (in terms of annual carbon sequestration) still keep up with their traditional polyculture counterparts.

Differences in the Carbon Footprints

Calculating the carbon footprint of Latin American coffee production per unit product basis (PCF) is highly relevant, because PCF's are used internationally to communicate the performance of different products regarding their effects on

Fig. 43.4 Unshaded monoculture

Fig. 43.5 Mean on-farm carbon stocks in shade trees and coffee plants



climate change. Figure 43.8 shows that traditional polycultures perform best by emitting the lowest amount of GHG of all production systems.

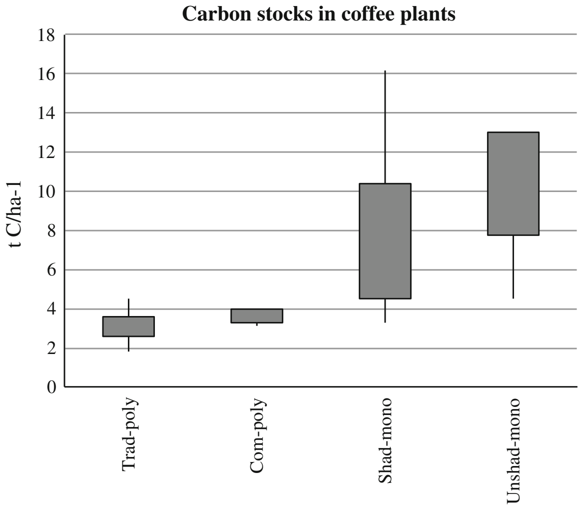


Fig. 43.6 Mean on-farm carbon stocks in coffee plants

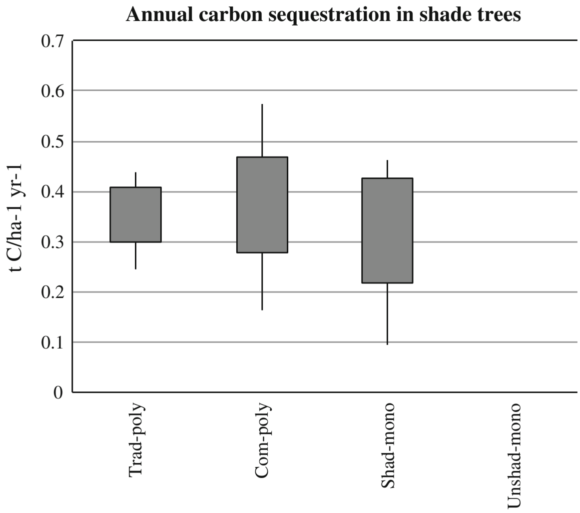
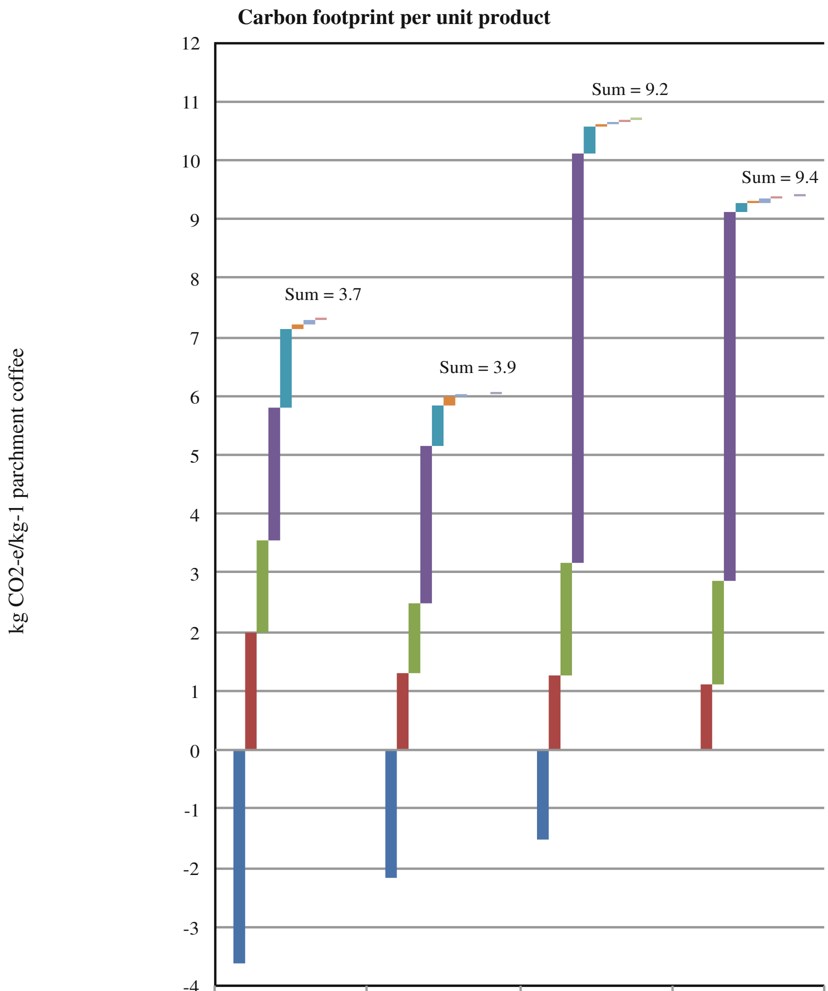


Fig. 43.7 Mean annual sequestered carbon in shade trees

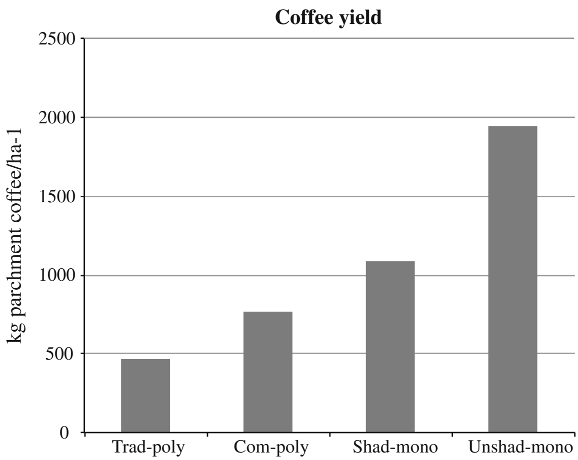
Traditional polycultures (often organic farming systems) show a high amount of emissions arising from fertiliser production and application. This is the case as the emissions are allocated to the amount of produce coming from this system, which is very low (Fig. 43.9). One can thus conclude that a PCF applied in agriculture gives insight into the optimal "input output" balance of production systems in terms of climate change. In this light it can be concluded that traditional and commercial polycultures show the best input–output levels of all the systems researched. This is definitely the case when one takes into account that besides coffee, a commercial polyculture system can deliver, among other things, banana, plantain, avocado, mango, orange, mandarin, lemon, and vanilla.



	Trad-poly	Com-poly	Shad-mono	Unshad-mono
Pesticide production	0.0	0.0	0.0	0.0
Gas use	0.0	0.0	0.0	0.0
Diesel use	0.0	0.0	0.0	0.0
Electricity use	0.1	0.1	0.0	0.1
Off-farm transport	0.1	0.2	0.0	0.0
Crop residue managment	1.3	0.7	0.5	0.2
Waste water production	2.3	2.7	7.0	6.2
Fertiliser induced N2O	1.5	1.2	1.9	1.8
Fertiliser production	2.0	1.3	1.3	1.1
C sequestration in trees	-3.6	-2.2	-1.5	0.0

Fig. 43.8 Mean carbon footprint measured on a per unit product basis

Fig. 43.9 Mean yield for four different coffee production systems



Framework for Effective Mitigation

The framework presented here is based on the following proposition developed by :In ‘t Veld 2002

$$\text{Effectiveness} = \text{Content} * \text{Acceptance}$$

The proposition by In ‘t Veld 2002 has been adapted into the following proposition that defines the effectiveness of the climate change mitigation framework introduced below:

$$\text{MIT}_x = \text{PRC}_y * \text{FSB}_z$$

where
MIT = mitigation, kg CO_2-e
PRC = correct practices
FSB = implementation feasibility

Thus the amount of climate change mitigation in a coffee farming system at location *x* is determined by using the correct agricultural practices at location *y*, times the level of implementation feasibility of these practices for farmers at location *z*. To make this analytical mitigation framework function, the correct agricultural practices for climate change mitigation need to be defined. As well the feasibility of implementation of those practices needs to be ensured. Both issues are addressed in this chapter.

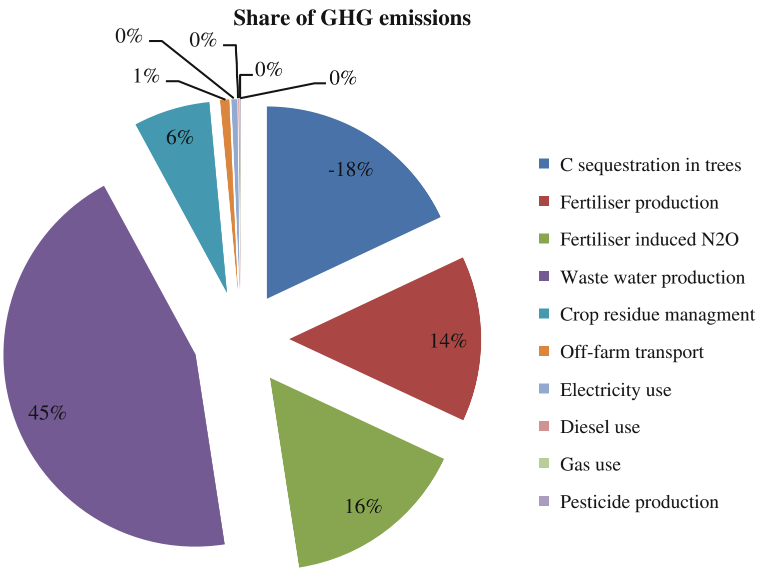


Fig. 43.10 Mean share of GHG emissions for all coffee farms researched

Most Effective Mitigation Practices

In defining climate change mitigation strategies one should focus on those factors that show the highest contribution to the total amount of GHG emissions emitted in coffee production. An overview of all the emission factors and their mean share of Latin American coffee production is shown in Fig. 43.10.

In this figure it is claimed that the factors contributing most to the mean PCF of all Latin American coffee production systems researched are:

1. Carbon sequestration in on-farm shade tree biomass (−18 %).
2. The production and application of organic and synthetic fertilizers (30 %).
3. The generation and discharge of waste water (45 %).

From this comparison it is derived that mitigation strategies in Latin American coffee production should centre around: (i) conserving on-farm carbon stocks in biomass, (ii) reducing the emissions arising from fertiliser production and application, and (iii) reducing the emissions arising from the generation and discharge of waste water.

Fig. 43.11 Different shading systems in coffee farms

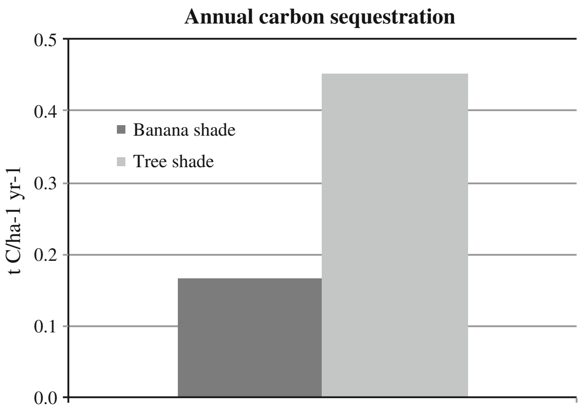


Fig. 43.12 Carbon sequestration in differently shaded coffee farms

Site Specific Mitigation Framework

Coffee production systems vary a great deal depending on a variety of factors such as; input levels, processing methodologies, geographical location and the organisational level of the cooperative or farmer. In this paragraph the need for mitigation strategies that are tailored to the nature of the respective coffee production system is illustrated by means of several examples.

Banana plants used for shading in a coffee plot (left), versus a coffee farm that makes use of different stratum of shade trees (right).

The graph presents two cases from the data collection: a farm using a banana shade system and a farm with a tree shade system.

The difference between different shading systems in coffee farms is visually illustrated in Fig. 43.11. By comparing the effect of these different shading systems on the carbon sequestration per hectare (Fig. 43.12), it is shown that shade systems which are dominated by banana plants store less carbon than those systems with trees.

Fig. 43.13 Different ways of fertilising coffee plants

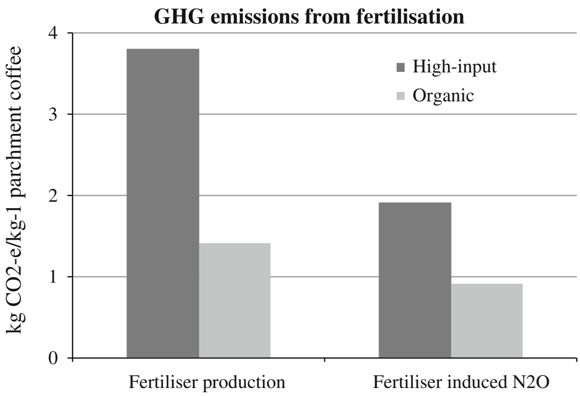


Fig. 43.14 GHG emissions for differently fertilised coffee farms

Urea fertiliser used in high-input coffee production systems (left), versus composted coffee cherry pulp used as fertilisation in organic systems (right).

The graph presents two cases from the data collection; a high-input farm and an organic farm.

The nature of fertilisation (Fig. 43.13) has a high impact on the amount of GHG emissions emitted from farming systems. Figure 43.14 compares a high-input coffee farming system against an organic farming system. The comparison illustrates that high-input systems emit more than twice the amount of GHG compared to organic coffee farming.

Fermentation basins part of the wet coffee processing method (left), combined with an artificial mechanical drying installation (right).

Ecological coffee processing installation making use of a manual de-pulper (left), combined with a patio for sun-drying parchment coffee (right).

The graph presents two cases from the data collection; a farm using the wet process and a farm using the dry process.

Finally the effect of different coffee processing methods is illustrated. Figures 43.15 and 43.16 show the differences between the wet and dry processing

Fig. 43.15 Processing coffee using the wet process

Fig. 43.16 Processing coffee using the dry process

machinery used. Figure 43.17 shows that the wet process emits a higher amount of GHG emissions compared to the dry process.

It is thus illustrated by means of various examples that GHG emissions arising from coffee production are site specific. For this reason, to most effectively mitigate the effects of climate change from coffee production, the framework "site-specific mitigation" is introduced. This means that mitigation strategies should, on the whole, be based on the three most relevant factors found; increasing and conserving on-farm biomass, reduction of synthetic fertiliser use and generation of waste water. Producer organisations and individual farms can subsequently, according to their own performance within these factors, identify their "site-specific" focus area for climate change mitigation.

Site-specific mitigation practices are further desirable as often not all the three focus points for mitigation are within the reach of producer organisations or individual farmers. The methods used to process coffee are embedded in the culture and history of cooperatives and are often connected to several

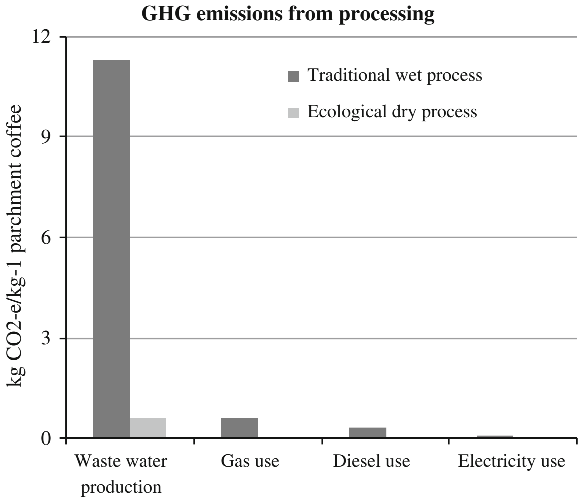


Fig. 43.17 GHG emissions for coffee processed in the wet and in the dry process

environmental attributes. A Mexican coffee farmer explains for example that, "*Due to the high humidity at this altitude we are unable to completely sundry our parchment and make partly use of mechanical dryers to speed up the process*". Some cooperatives produce for high-quality niche markets and make use of fermentation basins (washed *Arabica* coffee) which contribute to the final quality of their product (Calvert 1998) but show high GHG emissions. Furthermore, smallholder coffee farmers in Guatemala explain that they use high quantities of banana and plantain plants to both shade their coffee and at the same time to decrease the dependency on one crop by diversification. One cannot simply expect these cooperatives and farmers to abolish their processing and farming systems for the sake of climate change mitigation. Instead, in line with the site-specific mitigation framework, these farmers can choose one or two mitigation focus points tailored to their own coffee production systems.

Mitigation Practices

Within each mitigation focus point the following mitigation practices are defined:

Practices that increase and conserve on-farm carbon stocks in biomass:

1. Avoidance of changes in land use and deforestation. Especially land use changes whereby annual crops replace forests or perennial crops.
2. Implementation of forest and agroforestry management systems that ensure extracted timber is replaced.
3. Planting additional shade trees in coffee plots that lack shade to build up carbon stock.

Practices that reduce the emissions arising from fertiliser production and application:

1. Implementation of soil and leaf sampling system, whereby cooperatives can use one sample for various farms due to the small plot size and similar practices.
2. Soil and leaf sample results are used as points for departure in defining synthetic and organic fertiliser types and amount.
3. Application of fertiliser according to coffee-growing cycle; "just in time application" to ensure rapid fertiliser uptake and to avoid nutrient leaching.

Practices that reduce the emissions arising from the generation and discharge of waste water:

1. De-pulping of coffee cherries in ecological de-pulping installations where the generation of waste water is reduced to a minimum.
2. Recycling water during coffee cherry processing activities. Pulping water can be re-used during the de-pulping of another day's harvest (Grendelman 2006).
3. Recycling waste waters in bio ethanol distillation plants whereby a part of the waste water can be reused as a fossil fuel.

Conclusions and Recommendations for Policy Makers

This study reveals that traditional polycultures play an invaluable role in maintaining mean carbon stocks of 81.5 t C ha^{-1} in shade trees and coffee plants. Conservation of these traditional coffee polyculture ecosystems is required in order to prevent environmental degradation on a very large scale.

Commercial polycultures present a low PCF and still conserve a mean 60.2 t C ha^{-1} in shade trees and coffee plants. The high degree of crop diversification in this farming system reduces the negative impacts on farmer's livelihoods resulting from extreme weather events to a minimum. Therefore, it is concluded that diversified commercial polycultures will be paramount in producing coffee with the least amount of pressure on our climate and the lowest risk of disaster risk for smallholder coffee farmers in the future.

Finally the study shows that mitigation strategies in Latin American coffee production should concentrate around: (i) conserving on-farm carbon stocks in biomass, (ii) reducing the emissions arising from fertiliser production and application, and (iii) reducing the emissions arising from the generation and discharge of waste water. A site-specific mitigation framework is presented in the study to reduce the risks for farmers that occur due to climate change, accelerate mitigation and build up resilience in Latin American coffee production systems.

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Author Biographies

Henk van Rikxoort is an MSc student in Development and Rural Innovation at Wageningen University. In 2010 Henk worked as an intern with Kenyan coffee farmers on climate change adaptation for the german international cooperation (GIZ). More recently he has provided consulting support to a joint GIZ and international social and environmental accreditation and labelling alliance (ISEAL) research project that aims to increase the efforts of voluntary standards in order to mitigate climate change. Currently Henk is implementing a research project in several countries in Latin America on behalf of CIAT. This research aims at revealing the opportunities of different coffee production systems in the region in order to mitigate climate change.

Peter Läderach holds an MSc in Geography and a PhD in Tropical Agriculture. Since 2005 he has lead a team at the international centre for tropical agriculture (CIAT) that has developed and implemented spatial analyses and supply chain tools for coffee and cocoa that allow the spatial identification and prediction of product attributes; the control and management of product quality; the information flow along the supply chain; and the quantification of the impact of climate change. Peter and his team are currently implementing several coffee and cocoa projects in Latin America and Africa that deploy these methodologies.

Jos van Hal is course coordinator and project leader at the Van Hall Larenstein University of Applied Sciences (VHL). In this position Jos designed the courses Agri-Systems Management and Fair Trade Management and coordinates the educational team of these courses. He also contributes as a lecturer to the Professional Master's Programme: Agri-Production Chain Management. Jos is currently involved in coordinating the role of VHL in several international projects such as: Geo Fair Trade, the Sustainable Trade Academy for the ESNEC University in Mozambique, the TSPN workgroup and Business Minds for Africa.

Chapter 44
Waterlogging Through Soil-Less Agriculture as a Climate Resilient Adaptation Option

Papon Kumar Dev

Abstract Under the coastal embankment project (CEP) in the 1960s, a large number of cross-dams or polders have been constructed for irrigation purposes throughout Bangladesh, especially in coastal areas. But these have wreaked far-reaching changes in the ecosystems in those areas. The rivers have become silted up and natural drainage conditions have been disrupted. The main objective was to practise agriculture in wetlands all year round, but the projected areas have become waterlogged and this is worsening day by day. The effect of climate change has made this situation more complex, with devastating results. Soil-less agriculture is an effective means of dealing with the adverse impacts of climate change, especially waterlogging. Soil-less agriculture is an ancient method of agriculture in Bangladesh. As an environmentally friendly farming system, it minimises the reduction in the quality of soil, the deterioration of the natural environment and water pollution; it also saves energy and helps with carbon sequestration. Its products are fully organic, containing high nutritional value, and can be produced in the off-season. The productivity of this farming system is 3–7 times higher in some cases than traditional land-based agricultural production. This paper will present the potential of a soil-less agriculture farming system as a tool for adapting to climate change, detailing its construction and production mechanisms, maintenance, advantages and disadvantages, and replication; a cost-benefit analysis will also be carried out and the target market segmentation will be examined. Some case studies will also be included to portray the efficiency of this disaster-resilient farming practice.

P. K. Dev (✉)
Monitoring Officer, Adapting Natural Resource Management to Climate Change and Increasing Salinity Project (Ukaid-Shiree funded) Shushilan, Plot No. G#3, kDa Jalil Sarani Muzgunni R/A Boyra, Khulna, 9000 Khulna, Bangladesh
e-mail: papon_urp05@yahoo.com

W. Leal Filho (ed.), *Climate Change and Disaster Risk Management*, Climate Change Management, DOI: 10.1007/978-3-642-31110-9_44,

Fig. 44.1 Soil-less agriculture

Keywords Soil-less agriculture · Adaptation · Waterlogging · Floating bed · Wetland

Introduction

Coastal wetlands are complex and highly biologically productive ecosystems. Without appreciating these ecological significances, several types of embankment construction projects have been undertaken to convert the major wetlands into terrestrial agricultural land. These projects have been exacerbating siltation of rivers, drainage congestion, and waterlogging. More than one million people in the Jessore, Khulna and Satkhira regions of Bangladesh suffer severe food and income insecurity caused by exposure to multiple hazards, of which waterlogging is the most severe and intense in nature. These environmental hazards, including flooding caused by waterlogging, first became visible at the beginning of the 1980s. Presently, the problem is extending towards the southern and south-eastern regions, engulfing up to 0.2 million hectares of land (Neelopal and Islam 2010). The present agricultural farming system does not permit retention of flood water for long periods. After flooding, in most cases, some low-lying areas remain underwater for extensive periods. In this situation, soil-less agriculture is a climate resilient smart adaptation option to waterlogging, which provides multidimensional advantages. This paper will outline those aspects of soil-less agriculture as an adaptation tool (Fig. 44.1).

Table 44.1 Emerging waterlogging trend trend in Jessore-Khulna-Sathkhira regions of Bangladesh from 1980 to 2009

Pathway of river	Area (ha)					
	1980–1985	1986–1990	1991–1995	1996–2000	2001–2005	2006–2009
Apar shoulmari River	1500	3600	3600	4300	4300	4300
Hamkura River	2200	5100	7300	8100	8100	8100
Horinadi	3100	10,400	11,600	11,600	11,600	11,600
Apar bodranadi River	2600	9400	16900	16900	16900	20400
Salta River	–	1200	2600	3400	4100	5300
Gangrail River	–	–	2300	2300	2300	4800
Joykhali River	–	–	–	1300	2300	3500
Jhopjhopia River	–	–	–	–	2200	3500
Kapothakkho River	–	2300	9700	18,700	23,700	47,200
Bathona River	–	1400	6200	8500	11,000	14,000
Morichhap River	–	–	1300	3800	7300	9800
Total	9400	33,400	61,500	78,900	93,800	132,500

Expanding waterlogged area per year is 5070 ha

Statement of Problem and Soil-Less Agriculture as a Smart Adaptation Option

Millions of people in Bangladesh are economically disadvantaged by waterlogging, and these scenarios are worsening gradually due to climatic phenomena, as portrayed in Table 44.1:

The topographical situation in Bangladesh shows higher elevation on river banks due to silt deposits, sloping gradually away from the banks. In addition, there is the presence of several clusters of natural depressions, known locally as *beels*, which are gradually becoming disconnected from the rivers, thereby creating a favourable situation for waterlogging. In the recent waterlogging in late July 2011, approximately 722,132 people were marooned. More than 68,000 people are reported to have taken temporary shelter in school buildings, roadside and other buildings. 2,776 km of roads were damaged in the south-western districts of Shatkhira, Jessore and Khulna. About 90 % of rural connection roads went underwater. The grown vegetables and seed beds were underwater and destroyed within a short time. Shrimps in over 2,000 shrimp enclosures were washed away in Jessore, Satkhira and Khulna. Agricultural land is still under stagnant water in many of the sub-districts (n. d. [2011]).

In this situation, the fertiliser-free floating agriculture mechanism is a smart technique for adapting to the situation: this climate resilient farming practice doubles production at less than half the cost of comparable methods; it is 100 % organic, with an extraordinary potential for carbon sequestration, thereby making better use of waterlogged and wetland areas than any existing land-based farming practices, etc. The base (bed) in this type of farming practice is highly dependent on invasive aquatic plants (e.g. water hyacinth). As a result, two benefits are ensured

- control of invasive aquatic plants in wetlands and waterlogged areas
- higher production at least cost.

Again, ultimately this farming practice generates a large amount of compost which has multi-sectoral use.

Practice of Soil-Less Agriculture

An Indigenous Farming System Practice

The indigenous soil-less agricultural system in Bangladesh can be called "hydroponics". But the system also fulfills the criteria of "organoponics", as semi-decomposed plant materials are used for nutrient solution. Therefore, indigenous floating agriculture is a combination of hydroponics and organoponics, and can be defined as "organo-hydroponics". (Haq et al., 2002, pp 3–5).

Rural Bangladesh is rarely portrayed positively in Western academic literature, despite there being a large number of silent successes that deserve attention. Local self-help activities, facilitated by traditional social structures and solidarity in village communities, demonstrate people's resilience. All over the country, villagers are reproducing environmental, social, and economic sustainability by looking after the basic prerequisites of their livelihoods. This article discusses one example: how people with indigenous traditional knowledge have been raising plants and vegetables successfully for centuries in a remote marshy area in Bangladesh, using technologies that have recently caught the attention of Western scientists.

Farming Procedure of Soil-Less Cultivation System

The soil-less cultivation system originated in the Gopalgonj, Pirojpur and Barisal districts in Bangladesh. Cultivation procedures are not identical in all areas. Farmers developed their own techniques according to their experience, choice, demand and supply of crops in season. (Haq et al. 2005, pp 8–12)

Site Selection

Floating cultivation is possible in any wetland, such as lakes, large ponds, disused canals or rivers, and also in waterlogged areas. The site is best selected where raw materials are available in abundance; otherwise cultivation becomes costly,

Fig. 44.2 Preparation of floating beds

requiring extra labour for the collection of raw materials and carrying those materials to the desired spot. Non-flowing water bodies where aquatic weeds (especially water hyacinth) grow profusely are preferable as production sites, regardless of the depth of the water.

Raw Materials and Sources

The people living within the wetland ecosystem utilise locally available paddy stubs, water hyacinths and various other aquatic plants for making the floating mat or organic bed. The supply of water hyacinth for soil-less cultivation is not sufficient in all areas. Farmers collect water hyacinths from nearby wetlands where it grows profusely. The other important component is semi-decomposed aquatic weeds—*Pistia stratiotes*, *Najas graminea*, *Salvinia spp*., *Potamogeton alpinus*, etc.—which are also used on top of the floating bed to grow vegetables and saplings. Normally these plants are found in local wetlands, but sometimes farmers purchase these aquatic plants from nearby markets. (Wolverton and McDonald 1976, pp 21–25) (Fig. 44.2).

Other ingredients commonly used for this cultivation are collected from local sources. Bamboo and coconut husks are available everywhere. Farmers purchase seeds from the market but sometimes farmers retain seeds for the next season. Farmers grow saplings on seedbed around their homestead areas for planting in the floating beds.

Shape and Size of the Floating Bed

The size and shape of the bed is not fixed. Farmers make the bed as they feel appropriate. Generally, the dimension of the bed is 30–40 ft long, 3–5 ft wide and 3–4 ft high.

Floating Bed Preparation

Water hyacinth is the major ingredient of soil-less cultivation and is collected from May to July from nearby rivers, canals, ditches, and lagoons, and from any other wetland where it grows profusely. The depth of the water bodies is not so significant for bed preparation, which is possible in any depth of water. First of all, farmers place a long bamboo pole on the mass of fully matured water hyacinths (immature hyacinths decompose faster); then a man stands on the bamboo over the mass of water hyacinths and balances himself. He starts to pull the water hyacinths from both sides of the bamboo and flatten them underfoot. Using this process he proceeds towards the end of the bamboo.

This process is continued until the desired height and length of the bed is attained. Farmers dump water hyacinths again 7–10 days after the first dumping and then the bed is allowed to decompose before commencing sowing or planting. Farmers move the bed by rowing it to their own field. The floating bed, whether made from paddy stub or water hyacinths, can be used to cultivate different kinds of vegetables and saplings. Sometimes farmers use semi-decomposed aquatic plants and immature small water hyacinths on the top of the bed to

- d the top of the bed quickly
- make available nutrient for seedlings
- make an ideal ground for settling germinated seeds and different crops.

Maintenance

Farmers chop the decomposed parts of the bed, the roots of water hyacinth, and put them either underneath the seedlings or on the floating bed, one foot away from the edge of the bed. Thus, the seedlings receive the required nutrients, become healthy and grow. After planting saplings onto the floating bed, de-weeding is the regular job of farmers. Bamboos are used for anchorage of floating beds to prevent the beds floating away as a result of wind or water current (Fig. 44.3).

Production of Crops

Seedling Production: Cultivated Varieties, Sequence and Constraints

Seedling production in soil-less agriculture is very attractive and profitable for the farmer, as in this system seedlings are not damaged by heavy rain or droughts. There are two methods of producing seedlings in floating beds:

- making *Tema* with compost

Fig. 44.3 Completion of floating beds

- preparing seed beds with *koyar* dust from coconuts.

Generally, the top of the floating bed needs 15–20 days to be totally decomposed for sowing seeds or planting seedlings. It is remarkable that the newly constructed floating bed can be cultivated from the first day by spreading compost (natural decomposing material) thickly on the bed. Then seeds or *Tema* (a ball made of compost manure and aquatic creepers in which seeds are inserted for safety of germination) are placed on the bed.

From June-July to September–October—in total 3 months—seedlings can be raised in floating beds. During these 3 months, seedlings can be harvested five times from a bed, each time yielding about 1,500–3,500 seedlings depending on species.

Production of Vegetables: Cultivated Varieties, Sequence and Constraints

Vegetables are the main crops usually cultivated in this system. More than 20 different vegetables and five different spices are cultivated by soil-less agriculture (Podder 2002, pp 45). Cucumber, spone gourd, ladies' fingers, turmeric, radish, tomato, spinach, red amarnath, string bean, turnip, bitter gourd, gourd, aubergine, snake gourd, and others, are usually cultivated on floating beds.

Constraints in Production Process

- Infestation by rats, predominant in most of the areas
- Scarcity of matured water hyacinth and aquatic plants
- Unavailability of quality seeds

Table 44.2 Cost estimation of five floating beds (size 30 ft × 4 ft × 3 ft)

Sl.	Cost heading	Unit	Unit cost (amount in BDT)	Total cost (amount in BDT)
1	Construction of floating beds	5 days labour for 1 bed	750.00	3750.00
2	Raw materials (straw, boat, bamboo, coconut husk, etc.)	For 1 bed	50.00	250.00
3	Seed, seedlings and *Tema*, etc.	For 1 bed	50.00	250.00
4	Nursing/maintenance & harvesting	For 1 bed	50.00	250.00
Total cost				4500.00

- Frogs and birds eating seedlings, greatly damaging production.
- Floods or strong currents, which can wash the beds away.

Cost-Benefit Analysis of Soil-Less Agriculture

BDT = Bangladeshi Taka

Gross income of the farmer = 15,280 BDT—4500.00 BDT = 10780.00 BDT. Therefore, a farmer can earn 2156.00 BDT from one floating bed in 4 months. (Tables 44.2, 44.3)

Benefits of Soil-Less Agriculture

Economic and Livelihood Benefits

- Soil-less agriculture introduced in flooded, waterlogged and non-productive areas;
- Production from soil-less agriculture is much higher than from land-based agriculture;
- With vertical utilisation of land and water bodies, every inch of space could be used for production purposes without affecting nature or soil;
- Women could participate in different phases of soil-less agricultural production without hampering household activities;
- Huge compost materials generated at the end of the production cycle are a source of additional income for farmers;
- Vegetables from soil-less agriculture are organic. Their taste and nutritional value are much higher compared to intensive agriculture.

Table 44.3 Income estimation of five floating beds (size 30 ft × 4 ft × 3 ft)

Sl.	Income heading	Quantity	Unit income (amount in BDT*)	Total income (amount in BDT)
1	Red amarnath	100 kg	10.00/kg	1000.00
2	Ladies' finger	220 kg	20.00/kg	4400.00
3	Seedlings of gourd (× 2)	800 pieces	2.00/piece	1600.00
4	Seedlings of pumpkin (× 2)	400 pieces	2.00/piece	800.00
6	Spinach	200 kg	6.00/kg	1200.00
7	Radish	40 kg	7.00/kg	280.00
8	Compost	4000 kg	1.50/kg	6000.00
Total income				15280.00

Disaster Resilience Farming System

- Soil-less agriculture does not require seasonal considerations; most vegetables can be produced off-season;
- Tornado, excessive rainfall, drought, etc., have little impact on production performance;
- There is little requirement for irrigation facilities in soil-less agriculture (soil-less agriculture has been called "de-irrigation agriculture");
- During floods, floating beds protect homesteads from waves; in extreme situations, when a house goes underwater, essential household belongings may also be kept on floating beds to minimise loss and damage.

Environment and Climate Change Adaptation

- Expansion of input intensive land-based agriculture through flood control and drainage projects destroys wetlands in Bangladesh and is the main contributor (80 %) towards global warming. On the other hand, soil-less agriculture needs no irrigation and does not require land to be transformed into dry land; it also saves energy, conserves wetlands and wetland biodiversity, and helps with carbon sequestration instead of emitting CO^2.
- Invasive aquatic plants, which cover most wetlands in Bangladesh, obstructing navigation, hampering shelter and breeding of fish, would be cost-effectively managed through soil-less agriculture.
- Since there is no use of chemical fertilisers or pesticides in soil-less agriculture, CFC gas emission and hence environmental pollution is minimised.
- Modern agriculture depends on irrigation, pesticides and fertilisers that reduce organic content in the soil and adversely affect the natural environment. But soil-less agriculture does not use fertilisers, pesticides or irrigation; rather it produces a huge amount of compost.
- Soil-less farming is energy-saving agriculture, even if labour intensive.

Social Benefits

- Flooded land treated as common property, so poor communities can set up their floating beds in the flooded and waterlogged areas;
- This farming system is labour intensive but not extremely so; women can easily participate in this farming system;
- Soil-less agriculture gives greater working flexibility, so women can participate in soil-less farming after household work;
- There is some conflict between fishermen and the agricultural community, but soil-less agriculture resolves this conflict as a win–win solution;
- Soil-less agriculture areas would be excellent recreation sites and also eye-catching tourist attractions;
- Soil-less agriculture would be a smart tool for generating employment during the period of waterlogging.

Soil-less agriculture is well-suited to our age-old culture of rivers, wetlands, etc.

Target Market Statement

Globally, more than 51 million poor and lower middle class farmers are associated with this farming practice, compared to more than 48 million poor farmers in developing countries. In Bangladesh, 1 m to 2 m people are now engaged with floating gardens seasonally; 2 million poor farmers, however, could engage with floating gardens immediately. (Khan et al. 1994) Wetlands are estimated to occupy nearly 6.4 % of the Earth's land surface. Nearly 30 % is made up of bogs, 26 % fens, 20 % swamps and 15 % flood plains (Limgis 2001). The amount of fresh water on earth is very small (comprising only 2.53 % of the Earth's water) compared to sea water. Presently, more than 1310 wetlands have been designated Wetlands of International Importance, a total area of 111 million hectares where soil-less agriculture can be promoted (European Space Agency 2003).

Initiatives to Begin the Process

The asset base of 600 extremely poor households will be expanded by 2012, using funds from *UKaid-Shiree*, by scaling up the floating gardens in waterlogged areas in the Jessore-Satkhira region in Bangladesh. This project, entitled "Adapting Natural Resource Management to Climate Change and Increasing Salinity" is currently being implemented by *Shushilan.* Some other organisations, such as the *Action Aid, Practical Action, Wetland Resource Development Society (WRDS)*, are also attempting to promote floating gardens in different waterlogged and flood-prone areas. For substantial community involvement, initiatives by farmers' organisations, the Dept. of Agriculture and non-governmental organisations are necessary. Again, the marketing network of these organic products should be developed immediately for the benefit of those farmers. Different organic product exporting agencies, hotels, shopping centres and other interested marketing institutions can easily be involved in these organic product promotion services by communicating with these organisations (project implementation NGOs) or the farmers themselves. Therefore, finally, it can be said that there is potential for enormous productivity from floating gardens if wetland resources can be developed through different private and public sector initiatives working together with small farmers.

Conclusion

Waterlogging is an increasingly serious problem for Bangladeshis. This problem is gradually getting worse due to unusual rainfall and increasing salinity. Estimates from the government's Water Development Board report that 4,000 hectares become permanently waterlogged every year. The Jessore, Khulna and Satkhira districts have seen their total waterlogged area rise from 28,000 hectares in 2004 to more than 200,000 hectares today. This is having serious consequences, as human settlements and crop fields are all inundated. In this context, soil-less agriculture is a smart resilient adaptation tool, as it is free from fertilisers, pesticides and irrigation. It is, both in form and essence, an eco-agriculture, sensitive to the environment and based on a community approach. It is also a unique example of "Reducing, Reusing and Recycling" resources in the climate change hot spot in Bangladesh. The success of soil-less agriculture as a low cost, less technical, sustainable and environmentally friendly farming system, lies in organising small and poor farmers at grass-roots level, building up their capacities as micro and small entrepreneurs and their integration in Government's mainstream agricultural planning process.

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Author Biography

Papon Kumar Dev graduated in Urban and Rural Planning from Khulna University. He has been working as a research assistant and contractual reporter at different research organisations and NGOs for more than 3 years. He has also conducted several studies as Research Officer on climate change adaptation techniques. In addition, he has attended several training courses, seminars and workshops on climate change and disaster adaptation techniques. Currently, he is working as Monitoring Officer in *Shushilan* (a non-governmental voluntary organisation) with the "Adapting Natural Resource Management to Climate Change and Increasing Salinity" project