Climate Change Management

Walter Leal Filho
Daniela Jacob *Editors*

Handbook of Climate Services

Springer

Climate Change Management

Series Editor

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Handbook of Climate Services

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Preface

The provision of climate services, by means of customised tools, products and information based on climate data, is a growing trend. There are, however, some problems associated with it. One of them is the fact that even though climate services are important, they are not as widely used as they could—or should—be. In addition, information on climate services is often not widely available. Moreover, there are many modalities of climate services which are not duly documented or disseminated. Finally, the quality of some quality services is sometimes not as good as it should be. This state of affairs means that many good opportunities to use climate services in support of projects, investments or in future policies and decision-making, are being lost.

Based on the perceived need to promote and disseminate information on climate services, the *Handbook of Climate Services* has been produced. This volume presents information, experiences, practical initiatives and projects around the subject matter of climate services, making it available to a wide audience. It is expected that this publication will make the many benefits of climate services clearer and, inter alia, lead to an increase in the demand for such important services.

This volume contains contributions from across various areas related to climate services. These include:

i. Theory and practice of climate services
ii. Provisions of climate services
iii. IT-based approaches and methods to deliver climate services
iv. Case studies in climate services
v. Community-based climate services
vi. Using climate services in support of policies and decision-making
vii. Collaboration and co-delivery of climate services
viii. Raising demand for climate services
ix. Market for climate services
x. Using climate services to meet mitigation and adaptation needs.

Structurally, the book consists of two parts. Part I presents an overview of the principles, philosophy and applications of climate services. Part II presents a set of case studies, which illustrate how climate services may be deployed in practice.

Thanks to its scope, this book will not only provide essential scientific information, but also describes facts, trends and case studies from various geographical regions.

We would like to thank the authors for their willingness to share their experiences and the reviewers for supporting us with the development of the manuscripts.
We hope this book will foster a broader understanding of the subject matter of climate services and will support their promotion and dissemination across the world.

Hamburg, Germany

Walter Leal Filho
Daniela Jacob

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Part I
Principles, Philisophy and Applications of Climate Services

Chapter 1
Introducing Climate Services and Their Applications

Walter Leal Filho

Abstract This introductory chapter defines climate services and outlines their nature, as processes which deliver climate information to a wide range of users. It also describes some application and the barriers experienced in the dissemination of climate services, and introduces the chapters of this book.

Introduction

Knowledge about climate change plays a crucial role in guiding both, mitigation and adaptation processed. The pressures posed by climate change on the one hand, and the advancement in climate science on the other, have led to the prioritizing the development and provision of Global Climate Services by public and private organisations and specialist institutions (Jancloes et al. 2014). Climate services are defined as those related to the generation, interpretation, transmission and application of climate knowledge and information for the decision making and further planning. Climate services provide the most recent knowledge about climate science, in support of adaptation strategies for agriculture, water, health and other sectors (Climate Services Partnership 2015). The difference between climate service from climate research is that it focuses at serving user requirements which later helps in the understanding of climate systems. Apart from helping to prepare to manage the effects of climate change, one of the mains aim of climate services is to provide up to date climate-related knowledge and information which can be further used to reduce climate related disaster risks, and to improve welfare (Vaughan and Dessai 2014; WMO 2012, 2019).

One of the features of climate services is that the climate information processed is provided in a suitable format which allow it to be used by a variety of groups. These include:

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(a) policy-makers,
(b) planners,
(c) investors,
(d) other user groups (e.g. farmers).

The data required, be it in respect of temperature, rainfall, wind or soil moisture, among others, is provided in the ways required by the users. If needed, long-term historical averages of these parameters, with vulnerability maps and risk analysis may also be provided. Climate data may also be combined with non-climate data i.e. health trends, agriculture production, population distribution in high-risk areas, and other socio-economic variables, depending on users´ requirement (GFCS 2012).

The list of climate service providers, which act in the nexus climate science, policy and process. Include a variety of organisations (Vaughan and Dessai 2014) such as:

- International Service Structures—World Meteorological Organization Climate Service
- National Climate Service Providers—NOAA Climate Services, Climate Service Center, Germany
- Regional Climate Services—Australia National Climate Center
- Research Institutes—The Climate Impacts Group (CIG) of the University of Washington
- Private Sector Services—Climate Risk Analysis, Predictia, and Climpact
- Climate Services across Scales.

There are also organisations, such as meteorological services, which offer climate services. Table 1.1 shows a list of climate services around the world.

Figure 1.1 provides a framework of climate services. It shows that it consists of information provision based on the availability of good quality data, which may allow an interpretation of trends. All these elements interact. Combined, they may ultimately lead to improved decision-making.

There are many factors which speak for the use of climate services. These include:

(a) The pressures posed by a changing climate which leads to a greater demand for timely, reliable and technically sound information
(b) The multiple uses of data, from support to mitigation efforts, to a concrete use in adaptation efforts
(c) The multi-stakeholder dimension, which enables the mobilisation of a variety of users
(d) The concrete support to cope with extreme events
(e) The provision of support to administrations, enterprises and other organisations which need climate information.

One further characteristic of climate services is the existence of various modalities of applications. Figure 1.2 illustrates some of them.

Unlikely widely believed, the provision of climate services is not solely related to the availability of information on weather and climate. Rather, climate services encompass also support to the identification of possible (or likely) risks, proving

Table 1.1 Some existing climate services providers

Climate services	Country	Website
World Meteorological Organization Climate Services	International	http://www.wmo.int/pages/themes/climate/climate_services.php
Food and Agriculture Organization of United Nations—climate change resources	International	http://www.fao.org/climatechange/59898/en/
Red Cross Climate Center	International	http://climatelab.org/Red_Cross_Red_Crescent_Climate_Centre
NOAA (National Oceanic and Atmospheric Administration) Climate Services Portal	USA	http://www.ncdc.noaa.gov/oa/climate/regionalclimatecenters.html
Australia National Climate Centre	Australia	http://www.bom.gov.au/climate/
China Meteorological Administration (CMA) Climate	China	http://www.cma.gov.cn/en2014/
Caribbean Community Climate Change Centre (CCCCC)	Caribbean Community	http://www.caribbeanclimate.bz
Fiji Meteorological Services—Climate Services	Fiji	http://www.met.gov.fj/
Southern African Development Community—Climate Services Centre (SADC CSC)	South Africa	https://www.sadc.int
Climate Service Center, Germany	Germany	https://www.climate-service-center.de/
UK MET Office—Climate Services	UK	https://www.metoffice.gov.uk/services/research-consulting/climate-service
KNMI Climate Services	Netherlands	https://www.knmi.nl/research/climate_services/
Météo-France Climate Section	France	http://www.meteofrance.com/accueil

Source Modified from Medri et al. (2012)

valuable information which may be deployed in support of investment decisions or policies.

But despite the relevance of and the need for climate services, there are some barriers which hinder their deployment. These are described in Table 1.2.

This list is by no means exhaustive. Other barriers which may be added include possible problems related to the lack of quality regarding the information offered by the scientific community, as cross-checked against the needs of diverse potential users (Brasseur and Gallardo 2018). In some developing countries, up to date weather information may not be available, which would make it difficult to deploy climate

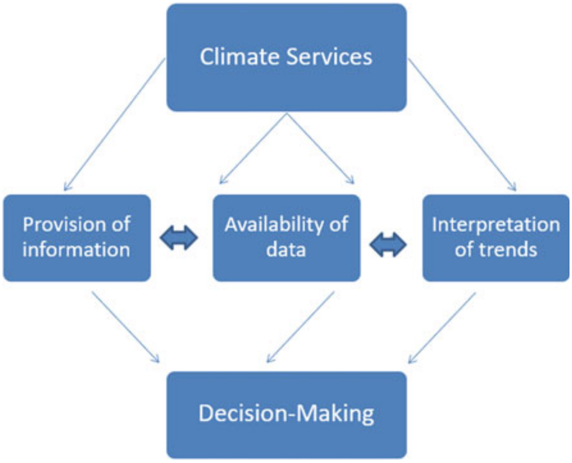

Fig. 1.1 Framework of climate services

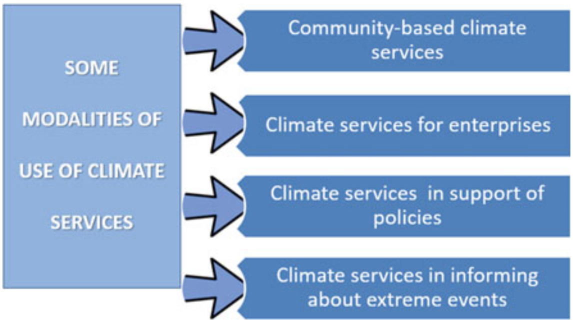

Fig. 1.2 Some modalities of climate services

Table 1.2 Some of the barriers to the dissemination of climate services

Barrier	Impact
Limited access to technology	Limits the options and access to up to date information in some contexts (e.g. developing countries)
Low levels of awareness	Limited information about the benefits of climate services
Restricted data availability	Reduces the scope of use of climate services
Need for multi-stakeholder engagement	Adds complexity to the design and use of climate services
Lack of frameworks	Unsystematic use of climate services

services. Moreover, the key issue in integrating climate services is budgeting should be mentioned, since government budgets are usually assigned sectorally (Bettencourt 2015), which may make inhibit the allocation of specific funding for climate services.

But despite the barriers, climate services do offer various benefits at the community level, at the individual level, and to the environment as well. For instance, in agriculture, climate services can enhance awareness regarding the possible climate risks and help farmers in deciding on particular crops, plantation timing, and fertilizers' application to mitigate the impact of climate risk on agriculture (Vaughan and Dessai 2014). Moreover, disaster risk reduction can be pursued, by prior information obtained from climate services. The broadcasting of warnings related to hazards can help appropriate preparedness measures, and ultimately protect lives. In addition, data observation on extreme weather events can help increase livelihood's security (Dutton 2002; WMO 2012). Moreover, climate services may be used to raise awareness regarding the patterns and burdens of many diseases related to the environment, which may prevent the population from getting infected (Global Framework for Climate Services 2012). Indeed, the inclusion of climate information in health planning is one of the promising areas of climate services, which may assist the health community (Shafer 2008).

Another advantage of climate services is the support of sustainable tourism development, and adaptation to climate change as a whole. The use of historical climate information can be beneficial for infrastructure planning for tourism, location analysis for new resorts, architectural and landscape designs (Scott et al. 2011). Overall, climate services may be helpful tools to climate change resilience (Leal Filho 2019) and may contribute towards achieving it.

Experiences from This Book

This book encompasses a set of papers, which explore the different dimensions of climate services. Saleem Khan and Amsad Ibrahim Khan for instance, introduce "BASIEC", a coastal climate service framework for community-based adaptation to rising sea-levels. Abbadi Girmay Reda describes some methods for geospatial climate change detection and resilience through nature conservation in Ethiopia. Jahir Anicama Diaz discusses a state of the art socio-economic valuation tools for climate services.

Haile Arefayne Shishaye provides an overview of nitrous oxide emissions from agricultural farms and how this contributes to global warming.

Markus Groth outlines some business strategies and climate change, with a prototype development, as well as testing of a user specific climate service product for companies, whereas Steffen Bender describes why there is more to adaptation than creating a strategy.

Saleem Khan tackles, with the paper "COREDAR: A coastal climate service framework on sea-level rise risk communication for adaptation policy planning", issues related to climate change services focusing on sea-level rise.

Esther Hoffmann provides an overview of what users expect from climate adaptation services, whereas Karianne de Bruin outlines the links between physical climate risks and the financial sector. Åshild Hauge discusses the role of public-private cooperation for climate adaptation, providing insurance loss data to the municipalities. The need to assess climate services was analysed by Maida Zahid, who looked at how to enable users to assess the quality of multi-model climate projections and derived products. Marcela Scarpellini outlines the need for science-based information, describing a requirement for top-down and bottom-up decision-making processes, whereas Hannah Helmke describes the provision of climate services and the XDC Model.

At a case study level, Busuttil and Galdies describes a climatological global solar UV index, with a measurement and link with health issues in Malta, whereas Michael Addaney outlines climate change risk and insurance as an adaptation strategy, with an inquiry into the regulatory framework of Ghana and South Africa.

Sajal Roy writes on the impacts of climatic disasters in the coastal area of Bangladesh, using 'Climate Services' as a way-forward. Andrea Rossa, in turn, outlines trends towards more resilient food systems for smallholder farmers in the Peruvian Altiplano. Perdinan, on the other hand, outlines how weather services are used for forecast based early actions in Indonesia. Other case studies are from:

(a) Uganda: appraising climate services and impacts on adaptation and mitigation to climate change (Mwangu Alex Ronald)
(b) Bangladesh: climate information services and their potential on adaptation and mitigation (Muhammad Abdur Rahaman)
(c) Nigeria: communicating Climate Change impacts as manifested in extreme weather (Ayansina Ayanlae)
(d) Sri Lanka: climate-indexed insurance as a climate service to drought-prone farmers (Pahan Prasada)
(e) Ethiopia: Geospatial Climate Change Detection and Resilience through Nature Conservation in Ethiopia (Abbadi Girmay Reda) and Food security in the face of a climate change at Kafa Biosphere Reserve (Teowdroes Kassahun)
(f) Zimbabwe: A participatory approach to developing community based climate services (Juliet Gwenzi)
(g) Serbia: Climate services for climate resilient planning of natural and cultural heritage (Tijana Crnčević).

Both, individually and combined, the experiences from the authors illustrate the fact that engagement and collaboration are very useful on how to best prepare for and provide climate services.

Conclusions

Climate services offer reliable support in efforts towards climate change mitigation and adaptation. As the subsequent chapters of this book show, climate services can offer effective support to decisions which can increase the resilience of sites, cities or regions, making them better prepared to manage the effects of climate change and extreme events.

But in order to yield maximum benefits, climate services should ideally follow the principle of co-production, meaning that apart from weather and climate data, they need to also take into account traditional and local knowledge, hence providing a basis for climate smart practices, from agriculture to pastoralism, especially in the developing world.

Apart from the key role they can play in decision-making, one of the major advantages of climate services is their proven support in the better understanding—and often anticipation—of disaster and risks, helping to reduce the uncertainties related to climate change.

References

Bettencourt S (2015) Making climate services more effective. World Meteorological Organization. https://public.wmo.int/en/bulletin/making-climate-services-more-effective. Accessed 9 Sept 2019

Brasseur GP, Gallardo L (2018) Climate services: lessons learned and future prospects. Rev Geophys 79–89. https://doi.org/10.1002/2015EF000338@10.1002/(ISSN)1944-9208.COMOC1

Climate Services Partnership (2015) What are climate services? Climate Services Partnership. http://www.climate-services.org/about-us/what-are-climate-services/. Accessed 9 Sept 2019

Dutton JA (2002) Opportunities and priorities in a new era for weather and climate services. Bull Am Meteorol Soc 83:1303–1312. https://doi.org/10.1175/1520-0477-83.9.1303

Jancloes M, Thomson M, Costa MM, Hewitt C, Corvalan C, Dinku T, Lowe R, Hayden M (2014) Climate services to improve public health. Int J Environ Res Public Health 11:4555–4559. https://doi.org/10.3390/ijerph110504555

Leal Filho W (ed) (2019) Handbook of climate change resilience. Springer, Cham

Medri S, Banos de Guisasola E, Gualdi S (2012) Overview of the main international climate services (SSRN Scholarly Paper No. ID 2194841). Social Science Research Network, Rochester, NY

Scott D, Lemieux C, Malone, L (2011) Climate services to support sustainable tourism development and adaptation to climate change. Clim Res 47:111–122. https://doi.org/10.3354/cr00952

Shafer MA (2008) Climate literacy and a national climate service. Phys Geogr 29(6):561–574. https://doi.org/10.2747/0272-3646.29.6.561

Vaughan C, Dessai S (2014) Climate services for society: origins, institutional arrangements, and design elements for an evaluation framework. Wiley Interdiscip Rev Clim Change 5:587–603. https://doi.org/10.1002/wcc.290

World Meteorological Organization (WMO) (2012) Guidelines on frameworks for climate services at the national level, 2012. World Meteorological Organization, Geneva. https://gfcs.wmo.int/sites/default/files/events/Regional%20Workshop%20on%20Climate%20Services%20at%20the%20National%20Level%20for%20the%20LDCs%20in%20Asia/GuidetoClimateServicesattheNationalLevelFinalOctober2012.pdf. Accessed 9 Sept 2019

World Meteorological Organization (WMO) (2019) What is the Global Framework for Climate Services and what will it accomplish? GFCS. https://gfcs.wmo.int/node/219. Accessed 9 Sept 2019

Chapter 2
BASIEC: A Coastal Climate Service Framework for Community-Based Adaptation to Rising Sea-Levels

A. Saleem Khan, M. Sabuj Kumar, R. Sudhir Chella and B. Devdyuti

Abstract Climate change induced sea-level rise poses serious threats to coastal regions across the world and the communities in the low-lying coastal regions are at high risk. Building capacities of coastal communities to adapt to sea-level rise are increasingly high priorities for low-lying coastal regions. Climate services are believed to be a powerful mechanism to build capacities of communities, particularly at the local level. It focuses on the connection between climate science and public demand for information and services. In this context, this chapter emphasizes the importance of community-based climate services that build the capacities of local communities to prepare, manage and adapt to rising sea-levels. This study has put forth three research questions such as (1) what services do the coastal communities require; (2) how these services need to be delivered; (3) what are all the roles of climate services that can help in building capacities of coastal communities and involve them in the community-based adaptation decision-making process? This study has adopted the methodology following the recommendations and guidelines of the UNFCCC, the Global Framework for Climate Services (GFCS) and Fifth Assessment Report of IPCC, on climate information and services. As a result, this study has introduced BASIEC (Building capacities for Adaptation to Sea-level rise through Information, Education and Communication for coastal communities), a coastal climate service framework for community-based adaptation to rising sea-levels. The framework emerges from theoretical and empirical knowledge of community-based climate services and offers a holistic approach for integrating information, communication and education through the lens of climate change and sea-level rise. Thus, it provides a systematic starting point and guidance for local level coastal climate policy planners, decision-makers, researchers, local communities and others who hold a stake on coastal climate services for community-based adaptation to changing climate in general and sea-level rise in particular.

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Introduction

The Paris Agreement sets a long-term temperature goal of holding the global average temperature increase to well below 2 °C, and pursuing efforts to limit this to 1.5 °C above pre-industrial levels (Schleussner et al. 2016). Even if greenhouse gas emissions were stabilized in the near future, thermal expansion and melting of glaciers would continue to raise the sea level for many decades (Natesan and Parthasarathy 2010). Sea-Level Rise (SLR) in this case has been defined as the combination of climate induced rising sea-levels, intensified storm surges, frequent cyclones, extreme flood events etc. The Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) has projected SLR for all four Representative Concentration Pathways (RCPs), based on CMIP5 climate projections. Global mean SLR for 2081–2100 relative to 1986–2005 will likely be in the range of 0.26–0.55 m for RCP 2.6, 0.32–0.63 m for RCP 4.5, 0.33–0.63 m for RCP 6.0, and 0.45–0.82 m for RCP 8.5 (Church et al. 2013; IPCC 2013; Ramachandran et al. 2017; Khan et al. 2018). It is virtually certain that in the coming decades, the expected acceleration of SLR in response to continuing global warming will exacerbate the vulnerability of many low-lying, densely populated coastal regions of the world, and very likely will become a major threat in the near future for a significant fraction of human beings (Cazenave and Cozannet 2013). Globally, each year, millions of people experience coastal flooding, often leading to inequalities for vulnerable populations. It is in these communities that the adverse effects will be the most prominent (Moth 2008). However, SLR poses an ominous threat because 10% of the world's population (634 million people) lives in low-lying coastal regions within 10 m elevation of sea level (McGranahan et al. 2007; Fitz Gerald et al. 2008). This threatened population is growing significantly (McGranahan et al. 2007), and it will almost certainly increase in the coming decades, especially if the strong tendency for coastward migration continues (Nicholls 2011). However, the vulnerability of coastal communities to SLR depends on their exposure to climatic hazards such as storms, floods and cyclones, erosion, ecosystem changes, and saltwater intrusion. These types of events are likely to become more frequent and intense as sea level rises (Tol et al. 2008).

Adaptation is one of the significant measures that reduce vulnerability to actual or expected climate-change effects (Khan et al. 2012). It enables coastal communities to limit their vulnerability by averting or reducing potentially negative consequences of SLR while benefiting from potentially positive consequences (Tol et al. 2008). IPCC in its Fifth Assessment Report defines adaptation as "the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects" (IPCC 2014). However, until recently, most adaptation efforts have been top-down, and little attention has been paid to communities' experiences of climate change and their efforts to cope with their changing environments (Reid et al. 2009). Emphasis was placed on applying 'bottom-up' participatory processes to identify the climate change problem and appropriate local responses to this problem (Ayers and Forsyth

2009). Also, providing a means to overcome uncertainties relating to climate vulnerability and impacts, Community-based adaptation (CBA) has increasingly gained traction among national governments and international non-government organization (Reid and Huq 2014; Jamero et al. 2018). It is defined as ‘a community-led process, based on communities’ priorities, needs, knowledge, and capacities, which should empower people to plan for and cope with the impacts of climate change’ (Reid and Huq 2014). It focuses attention on empowering and promoting the adaptive capacity of communities. It is an approach that takes context, culture, knowledge, agency, and preferences of communities as strengths (IPCC 2014).

Capacity building has long been accepted as a critical element for improving responses to climate change (both mitigation and adaptation) at the local, urban and national level (Archer and Dodman 2015). It is a key issue for climate adaptation measures (Hartmann and Spit 2014) and it is one of the most urgent requirements for addressing climate risk, such as SLR, particularly at the local level (IFRC 2009; Khan 2017). It is defined as the practice of enhancing the strengths and attributes of, and resources available to, an individual, community, society, or organization to respond to change (IPCC 2014). Thus, it is important to engage in community mobilization and awareness raising through designing activities that are tailored to local practices and establish strong relationships with the communities to enable sustainable actions to involve the key stakeholders in adaptation action and enhance capacity building (Khan 2017). However, not all stakeholders are aware and informed about their vulnerability and the measures they can take to pro-actively adapt to climate change. Awareness raising is therefore an important component of the adaptation process to manage the impacts of climate change, enhance adaptive capacity, and reduce overall vulnerability (EEA 2015). Thus, understanding the challenges and raising awareness of the action required is key to improving the region’s resilience and capacity to take advantage of the opportunities (South West 2008).

Climate services are an influential mechanism to build capacity to different stakeholders in general and local communities in particular by creating awareness about the changing climate and enhance their capacity to respond to the challenges. Climate services may be defined as scientifically based information and products that enhance users’ knowledge and understanding about the impacts of climate on their decisions and actions (AMS 2012). In other words, it is a decision aide derived from climate information that assists individuals and organizations in society to make improved ex-ante decision-making. It requires appropriate and iterative engagement to produce a timely advisory that end-users can comprehend and which can aid their decision-making and enable early action and preparedness (WMO 2013). Thus, touted as an important part of the adaptation agenda, climate services have received a great deal of attention in recent years. Improving our understanding of the role and relative contribution of climate services is thus a critical step in enhancing our ability to manage climate-related risk (Vaughan and Dessai 2014), in this case risk due to rising sea-level. Unfortunately, the relation between climate services and potential stakeholders remains weak or ad hoc in many cases and the reason could be the insufficient awareness by some societal actors of their vulnerability to future climate change (Brasseur and Gallardo 2016). However, there are a number of climate services available across the globe and some of them are (i) NOAA Climate Services (USA): It is a source of timely and authoritative scientific data and information about climate. The main goal is to promote public understanding of climate science and climate-related events, to make data products and services easy to access and to serve people making climate-related decisions with tools and resources that help them answer specific questions (NOAA 2019); (ii) Climate Service Centre (Germany): It functions as a think tank for climate services and develops prototype products in the area of climate services, it also offers advisory services and decision-relevant information in order to support government, administration and business in their efforts to adapt to climate change (GERICS 2019); IMD Climatological Services (India): Indian Meteorological Department provides climate products that include real-time climate monitoring and publication of Climate Diagnostics Bulletins for the Indian region and reporting of major anomalous climate events were generated and supplied to researchers (MoES 2019) and likewise many other examples of climate services are available.

In this purview, this chapter explores community-based coastal climate services through the lens of an SLR and put forth three research questions such as (1) what services do the coastal communities require; (2) how these services need to be delivered; (3) what are all the roles of climate services that can help in building capacities of coastal communities and involve them in community-based adaptation decision-making process?. Thus, the aim of this chapter is to address the importance of community-based climate services that build the capacities of local communities to prepare, manage and adapt to rising sea-levels. The chapter sets its objective to create climate awareness by evolving a framework that outlines as (1) to collect coastal climate (SLR) information, (2) to communicate the impact and vulnerability of changing climate (SLR) and (3) to educate coastal communities to respond to changing climate (adaptation to SLR) following the guiding principles of the UNFCCC (United Nations Framework Convention on Climate Change) and GFCS (Global Framework for Climate Services) to build the capacity of coastal communities.

Rationale and Guiding Principle

UNFCCC emphasizes the need to educate people about climate change. Improving awareness and understanding of climate change, and creating solutions to facilitate access to information on climate change is key to winning public support for climate-related policies (UNFCCC 2018). The New Delhi Work Programme on Article 6 of the UNFCCC stipulates the promotion of education, training and public awareness on climate change (REC 2008). Similarly, Article 10 of the Kyoto Protocol provides for strengthening of research capacity, education and training of personnel and institutional strengthening in developing countries. Article 11 of the Paris Agreement creates the Paris Committee on Capacity Building (PCCB), to oversee a work plan for the period 2016–2020; Article 12 on the promotion of education, training, and public awareness and Article 13 on the Capacity Building Initiative on Transparency (ECBI

2018). However, the Paris Agreement has elevated capacity building and education to new heights as important avenues toward climate action. It creates an opportunity to foster enhanced, strategic and sustained approaches supporting transformational change and enabling all parties and stakeholders to build the capacities needed to mitigate and adapt to climate change. Indeed, the premise is the participation of all, and capacity building is a fundamental precondition for this goal (Dagnet and Northrop 2015).

Climate services play a major role in building capacities at different levels and for different stakeholders. It may contribute to the reduction of risks and maximize opportunities associated with a variable and changing climate, and provide substantial social and economic benefits (Rosas et al. 2016). The GFCS has been established by the United Nations and spearheaded by the World Meteorological Organization (WMO) to support the development and application of science-based climate information and services for effective decision-making (Giuliani et al. 2017). GFCS represents a major, concerted and coordinated global effort to improve the wellbeing of all parts of society vulnerable to climate variability and climate change (Hewitt et al. 2012). The ultimate objective of GFCS is to ensure that the best available climate science is effectively used and communicated to various sectors that may benefit from climate knowledge (Lucio and Grasso 2016; Giuliani et al. 2017). GFCS recommends the establishment of Climate Services on a regional and national scale (Rosas et al. 2016). It is a user need driven, as a process and includes five major components: (i) observations; (ii) climate research, modeling and prediction; (iii) a climate services information system (CSIS); (iv) a climate user interface programme (CUIP); and (v) capacity building/development. Importantly, the fifth pillar, i.e. Capacity building supports the systematic development of the institutions, infrastructure and human resources needed for effective climate services. It refers to investment in people, practices, policies and institutions to stimulate and systematically develop capacities such as human resource capacity, infrastructural, capacity, and institutional capacity in the Pillars of the GFCS (WMO 2014). The scope of this chapter is on human resource capacity and it deals with equipping individuals with the knowledge, skills and training to enable them to generate, communicate and use decision-relevant indigenous climate information together with the scientific climate information. Though GFCS as a whole, address capacity development at the national level, this chapter inspires the goals and objectives of GFCS capacity development and adhere the recommendation of UNFCCC to apply at the local level, in particular for the low-lying coastal communities to the risk of rising sea-levels (Fig. 2.1). Figure 2.1 outlines the stepwise rationale and guiding principle based on UNFCCC and GFCS recommendations. As a result, this chapter introduces a coastal climate service awareness framework (BASIEC) for community-based adaptation to rising sea-levels at the local level.

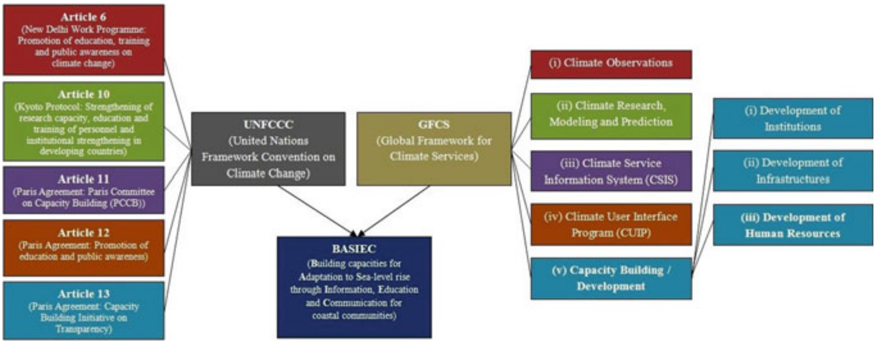

Fig. 2.1 Rationale and guiding principle of BASIEC framework

BASIEC Framework

Climate services draw on a variety of sources from scientific research, meteorological and climate models, to practical experience and local and indigenous knowledge. They also involve the process of co-producing knowledge and building the necessary skills and capacity of different user groups, both to guide the production and tailoring of climate information (to meet context-specific needs) and to be able to apply that information (Davis et al. 2016). GFCS can be used as one model among many for information sharing and knowledge co-production. However, more specific framework and tools are required to address different challenges of climate change (in this case SLR), particularly at the local level and to create awareness among the local stakeholders. Awareness raising includes establishing an overview of climate change (SLR), communicating its risk and to build capacities through education. Raising awareness is essential to facilitate identification of above mentioned opportunities and pave the way for the scaling-up and replication of identified opportunities (Trærup and Olhof 2011). Nevertheless, a framework is needed at the local level to address this and thus the "framework" is defined as "a set of ideas that provide support" or "skeletal structure designed to support", Framing theory and research seek to understand the ways in which related sets of ideas of SLR and CBA in the public sphere are organized, presented and debated, and is increasingly being used to understand a range of problems and issues (Miller 2010; Spence and Pidgeon 2010). A frame allows complex issues to be pared down and for some aspects of that issue to be given greater emphasis than others in order that particular audiences can rapidly identify why an issue may be relevant to them (Nisbet and Mooney 2007; Spence and Pidgeon 2010). In this context, this chapter introduces a framework BASIEC (Building capacities for Adaptation to Sea-level rise through Information, Education and Communication for coastal communities), a coastal climate service framework for community-based adaptation to rising sea-levels. The framework proposed as a fundamental means to describe relations between SLR and its socio-ecological interactions. The framework presented here provides the much-needed conceptual clarity and facilitates bridging the various approaches (Fussel 2007) to address SLR risk awareness through capacity building at the community level. It targets the different dimensions of SLR and CBA, and focuses on collecting SLR risk information, communicating SLR risk information and educating to build capacity to adapt to SLR risk. Thus three pillars of the BASIEC framework are (i) SLR risk information, (ii) SLR risk communication and, (iii) SLR risk education, build the architecture of the framework (Fig. 2.2). Figure 2.2 constructs the architecture of the BASIEC framework with SLR risk information, education and communication as its three pillars that has been constructed based on the guiding principles of UNFCCC and GFCS. The framework is generally applicable on the local scale as a community-based or bottom up approach and utilizes community level perceptions and experiences to identify the characteristics that influence response, recovery and adaptation, focusing on locally relevant outcomes that promote more effective planning (Chadwick et al. 2011). The framework will enhance local capacity building through improved access to both the global and local climate data and products. Suitable use of this framework provides a means of capturing the complexity of SLR and coastal system at multiple scales, and therefore a better representation of response to change (Eliot

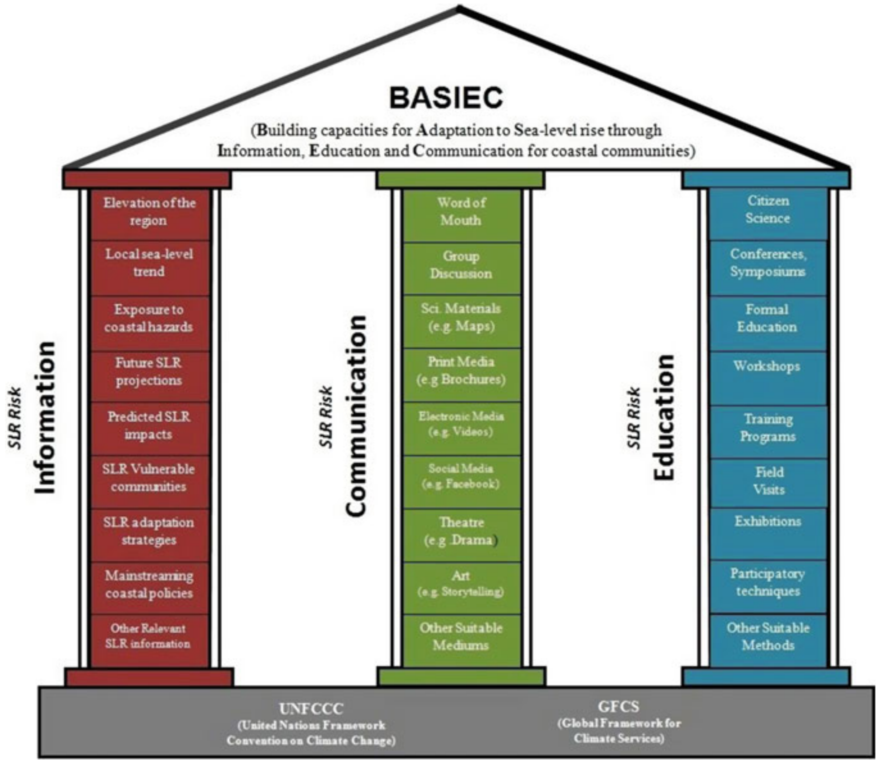

Fig. 2.2 Architecture of the BASIEC framework

2013) and in this case communicating the risk of SLR and to educate local communities. Thus, as a framework, it lays out an approach to address SLR risk awareness as coastal climate services and facilitates the process of information, communication and education in SLR risk research. This framework has been developed to explain how the emerging GFCS and recommendation of UNFCCCs might be reflected in the implementation and operation of climate services at the local level. An outline of each component of the framework is explained as follows.

SLR Risk Information

The demand for tailored climate information by the public and a variety of specific users has recently grown worldwide together with the awareness of the challenges posed to society and environment by climate variability and change (Medri et al. 2012). Climate information services and evidence from climate science can provide data to inform preparedness strategies and tools in the short and longer term. Such information would be the basis of positive coping strategies and it provides opportunities for risk reduction (ICHA 2017). Users expect climate services to provide authoritative and objective information rather than being guided by ideological motivations (Brasseur and Gallardo 2016). People require climate information over wide ranges of time and space scales for planning and operational purposes. It is imperative, therefore, to ensure that they have the highest quality and the widest possible range of products, information (including about uncertainties), and guidance on how the information can be used to provide optimal results and ensure appropriate decisions are made (Martínez et al. 2012). In many cases, the vulnerabilities identified through the "bottom up-top down" process extended beyond the generalized impacts to engage with indirect and location specific impacts—a key component in increasing the usability of scientific information (Dilling and Lemos 2011; Cash et al. 2003; Kettle et al. 2014). There are three types of climate information such as historical data (which help elucidate trends, provide climate statistics, set a context for current data, and allow, variability and the occurrence of extremes to be quantified); real-time data (i.e. current climate observations); climate forecasts (i.e. predictions of the climate, ranging from long-term weather forecasts, through seasonal forecasts, to medium- (10–30 year) and long-term climate change projections). Advances in climate science are improving the availability and quality of all three information types (Hellmuth et al. 2007). Furthermore, the climate information is often required at local scale, sometimes site-specific, and at daily or sub-daily time step. In most cases, climate data at this level of details are not readily available hence additional work is often required (NCSP 2009). Nevertheless, challenges remain for making this information readily usable and relevant to stakeholders, including downscaling results of large-scale computer models to the community level, incorporating local changes in coastline morphology, and understanding potential responses of coastal vegetation (DeLorme et al. 2018a). Moreover, stakeholders require not just access to information, but support in incorporating it into their planning procedures and communication (Tribbia and Moser 2008) as well as tools to help understand immediate risks and underlying physical, biological, and social processes (Stephens et al. 2016; DeLorme et al. 2018a). In addition to these insights, this framework details how the process of synthesizing SLR risk information as it builds context specific understanding of the SLR risk of the coastal region. Thus, this framework has jot down following major SLR risk information are required for the chosen study area to initiate address the challenges of SLR. It includes (1) elevation of the study region from the mean sea-level; (2) regional and local sea-level trend; (3) exposure and vulnerability of the region to coastal disasters; (4) future projections of local sea level; (5) predicted impacts of SLR risk; (6) identifying vulnerable ecosystems, communities/population, infrastructures etc. SLR risk; (7) list of SLR risk response strategies such as an adaptation; (8) list of existing coastal management policies and interventions and, others. The information such as changing surge and wave heights etc., in additional to SLR is required and a more pragmatic way to examine the need for climate information to support adaptation (NCSP 2009). Thus, one of the three purposes of this component of the framework is to propose ways to make climate services more effective in providing relevant and usable information of SLR to the coastal communities and stakeholders.

SLR Risk Communication

Making scientific research on SLR accessible and useful to diverse audiences is a crucial, yet complex endeavor (Moser 2010; DeLorme et al. 2018b). The transition from useful to readily-usable information can be complex and requires careful communication efforts that are customized to specific audiences (Lemos et al. 2012; Sheppard et al. 2011; DeLorme et al. 2018a). Therefore, the information to be provided to stakeholders must be credible (of high technical quality), legitimate (fair and impartial, with the interests of users in mind), and salient (relevant to users and capturing their attention) (NRC 2009). Also, timely communication of climate change risk has been found globally to be very beneficial and known to promote local ownership of adaptation planning in some cases (Dovie 2017). The term 'risk communication' as used here, refers to intentional efforts on the part of one or more sources (e.g. international agencies, local government, communities) to provide information about hazards and hazard adjustments through a variety of channels among themselves or to different audiences (e.g. the general public, specific at-risk communities), for the purpose of influencing the recipients to apply the information and take appropriate action. It also includes efforts of local communities to characterize and communicate their risk-based experiences (Martínez et al. 2012). The dissemination of such information requires, therefore, that the climate services establish a communication strategy that addresses these requirements (Brasseur and Gallardo 2016). However, communicating and disseminating risk information can be very challenging. One of the first steps for effective communication is to ensure two-way communication channels, where information providers and users can interact equally and explain misunderstandings (Martínez et al. 2012). SLR communication focuses on the interaction between scientists, policymakers, and other stakeholders for the purposes of planning, and the wider inclusion of the public in outreach and environmental decision making (Akerlof et al. 2017). SLR communication shares many of the same challenges as climate change communication, including difficulties with translating the science because of the abstract nature of the phenomena, the invisible causes, temporally distant impacts, and uncertainty surrounding the timing and probability of impacts. In addition, SLR communicators have the challenge of creating texts and images for people with a variety of worldviews and political outlooks that could result in unexpected interpretations of the information (Weber and Stern 2011; Covi 2014). Thus, transformation of climate-related data—together with other relevant information—into customized products such as projections, forecasts, information, trends, economic analysis, assessments (including technology assessments), counseling on best practices, development and evaluation of solution, and other services in relation to climate that may be of use for society at large (European Commission 2015; Brasseur and Gallardo 2016). Therefore, for effective SLR risk communication, SLR risk information must be appropriately framed, visually compelling and take into account prevailing risk perceptions and diverse viewpoints. There are various methods and medium to communicate SLR risk, some of them are (1) Word of mouth (e.g. one to one communication, public speaking, etc.); (2) Group discussion; (3) Scientific materials (e.g. maps, graphs, charts, tables, posters etc.); (4) Print media (e.g. brochures, posters, magazines, newspapers, etc.); (5) Electronic media (e.g. power point presentations, videos, television, community radios, etc.); (6) Social media (Website, blogs, facebook, twitter, etc.); (7) Theatre (e.g. drama, street play, movies, puppet show, etc.); (8) Art (e.g. paintings, storytelling, cartoons, etc.) and others. Thus, one of the three purposes of this component of the framework is to propose ways to make climate services more effective in communicating SLR risk information through various mediums and create awareness about SLR risk to the coastal communities and stakeholders.

SLR Risk Education

Education is an essential element of the global response to climate change. It helps people understand and address the impact of changing climate, increases “climate literacy” among people, encourage changes in their attitudes and behavior and helps them adapt to climate change-related trends (UNESCO 2018). Conceptualizing risk as a communication process involving public participation led us to consider the stages the public moves from awareness of a risk to the knowledge of specific solutions (Clark et al. 1999). Climate change education demands a focus on the kind of learning, critical and creative thinking and capacity buildings that will enable to engage with the information, inquire, understand, ask critical questions and take what they determine are appropriate actions to respond to climate change (Stevenson et al. 2017). However, the need is to engage all stakeholders, to facilitate awareness and education, and to support dialog so that users can help shape the services they receive (Hellmuth et al. 2007). Informal learning institutions along with formal education systems must work together to engage audiences, share new information and promote behavior change to better manage climate change risk (Caribbean Community 2018). Coastal communities do not have many communication and engagement tools/frameworks available to help their residents understand the threat of SLR and often find that public audiences are uncertain and apathetic when they lack personal experience of SLR associated impacts (Akerlof et al. 2017). Observation of how people understand and perceive SLR risk, comprehend information about their risk, and enter into processes to manage risk can provide us with a better understanding of how risk can be socially amplified or attenuated, and strategies to overcome barriers to adaptation planning (Covi 2014). Thus, educational responses to SLR best take the form of active social learning that develops the capacity for personal and societal transformative practice (Stevenson et al. 2017). If climate information and services are to support the stakeholders and local communities, their involvement is crucial. Yet much of the climate discourse so far has been at the national and international levels. This mismatch needs to be addressed if successful practices—and policies—are to be developed that make the best possible use of climate information (Hellmuth et al. 2007). There is an emerging consensus on processes useful for integrating local and scientific knowledge. These approaches often share the use of participatory methods, employment of iterative strategies to support learning and feedback, attention to temporal and spatial scales, and incorporation of values into decision processes (Raymond et al. 2010; Dietz 2013; Kloprogge and Van Der Sulijs 2006; Kettle et al. 2014). They also share an increasing focus on active engagement, deliberation, and process (rather than product alone) to enhance individual and social learning experiences (Moser and Dilling 2007; NRC 1996, 2009, 2010; Jones et al. 2009; Berkhout et al. 2002; Kettle et al. 2014). Participatory action research offers one valuable route through which academics and professional researchers can work with stakeholders to build local capacity to adapt. Academics and researchers can advance local climate change adaptation efforts through collaborative, action-oriented research that enhances the capacity of local communities. Such "participatory action research," also can help researchers produce knowledge that is more salient, legitimate, and credible to local stakeholders and directly useful for decision-making (Rumore 2014). This framework recommends various learning techniques such as (1) Citizen science; (2) Conferences and symposiums; (3) Formal education; (4) Workshops; (5) Training programs; (6) Field visits; (7) Exhibitions; (8) Participatory techniques and others. Thus, this component of the framework is to foster an atmosphere of dialogue that helps all stakeholders in general and communities, in particular, to understand the risk of rising SLR and build capacity at the local level.

SWOT Analysis of the BASIEC Framework

The effectiveness of the emerging frameworks like this can be assessed initially through a SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis. It is used to provide a descriptive assessment and provide a comparison of the factors affecting the effectiveness of the tool/framework. It is an assessment of internal strengths, weaknesses, external opportunities, and threats used in the preliminary stage of strategic decision-making (Johnson et al. 1989; Berte and Panagopoulos 2014). There are several interesting observations that can be useful for anyone considers the application of a tool/framework or the development of new approaches, particularly when it comes to weaknesses, opportunities and threats (MRC 2010; Khan 2017). In this study, SWOT analysis was carried out theoretically based on the secondary literature with specific reference to BASIEC framework. SWOT exercise aimed at maximizing the potential of the strengths and opportunities while minimizing the impact of the weaknesses and threats in order to achieve the best results on the application of the BASIEC framework. Some of the key findings of the SWOT analysis of BASIEC framework are: (i) *Strength*: (1) Many of the climate change frameworks and tools are generic in nature, whereas BASIEC framework exclusively address SLR and coastal climate; (2) It integrates different dimensions of SLR risk information from observed and past local SLR data to future predicted impact and adaptation planning; (3) The three pillars of the framework are distinctive from each other yet plays a collective role in building the framework; (4) This framework is exclusively designed for SLR risk awareness and CBA at the local level; (5) The framework with a worksheet is simple and user friendly and it is applicable to any part of the global coastal region that are at risk to SLR; (ii) *Weakness*: (1) Difficulties in delineating SLR and coastal issues from the rest of the other issues such as developmental issues; (2) Lack of availability of expertise in SLR risk to handle SLR risk information to communicate and educate stakeholders and communities locally; (3) Lack of unavailability of SLR in formation at the local level, which includes future SLR projection, predicted impacts, etc.; (4) Obscurity on availability and accessibility of communication and educational aids to communicate SLR risk information and to educate; (5) Challenges in working with local communities such as gathering local communities, communicating the risk in local language etc., (iii) *Opportunities*: (1) To upscale the application of BASIEC to wider and various stakeholders and geographical locations; (2) To develop formal SLR risk communication and education curriculum for schools and colleges; (3) To develop web-based online platform to get digitized; (4) To develop a smart phone based apps for BASIEC to reach wider audiences; (5) To make BASIEC interventions in SLR policy planning; (iv) *Threats*: (1) Need of scientific information on SLR risk may lead to manipulation of SLR risk information and data; (2) Many technical information on SLR may increase complexity and leads to confusion; (3) Chances of wrong or miscommunication of SLR information and its translation into local languages; (4) The evaluation of the application o BASIEC i.e. SLR risk communication and education is majorly qualitative and is based on the expertise of an individual and group who handle BASIEC, is

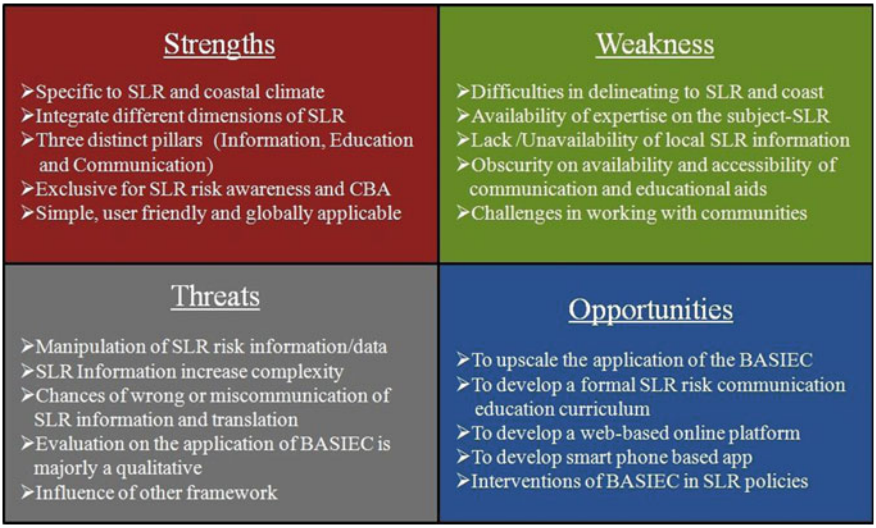

Fig. 2.3 An outline of SWOT analysis of the BASIEC framework

uncertain; (5) Frameworks and tools other than non-climate change and SLR frameworks may influence the quality of BASIEC framework that is subject to climate change, SLR and CBA. Thus the analytical structure of SWOT is used to generate strategies with the aim of increasing the level of information and reducing uncertainty (Karppi et al. 2001; Berte and Panagopoulos 2014). However, the key utility in the SWOT analysis presented here is thus to review and capture, in a structured way, a variety of considerations relevant to the strategic development of the BASIEC framework. Another important aspect of conducting such a SWOT analysis is the process itself (Pickton and Wright 1998; Bull et al. 2016). An outline of a SWOT analysis of BASIEC framework is given in Fig. 2.3. It lists out the key points on strength, weakness, opportunities and threats of BASIEC framework.

Application of the BASIEC Framework

The application of the SLR risk framework (BASIEC) developed in this chapter provides more nuanced and more actionable insights into the SLR risk information that are required, need for communicating the SLR risk and methods and approach to educate about the SLR risk and build capacity to respond to the risk. Thus, the BASIEC framework has three major applications in the arena of climate change adaptation in general and SLR in particular as (i) SLR awareness creation; (ii) SLR Capacity building; and (iii) SLR Policy implications. (i) *SLR awareness creation*: BASIEC plays a key role in creating awareness of the SLR risk to coastal communities. SLR Awareness is the ability to directly know, perceive, to feel or to be cognizant of SLR and coastal events. In other words, it is the state of being conscious of SLR. Information and communication perspectives of BASIEC make a platform to create awareness by gathering location specific and evidence based SLR risk information, and communicating it to the local communities and stakeholders through various communication mediums such as print media, electronic media, social media, etc. It is important to note and it is aimed that the improvements in the level of climate change (SLR) awareness can lead to better adaptation outcomes (Shahid and Piracha 2016). (ii) *SLR capacity building*: BASIEC also plays a significant role in SLR building capacity for coastal communities. The SLR capacity building is the process by which coastal communities and other coastal stakeholders obtain information, improve knowledge, identifying tools and methods, and retain the skills and other resources needed to respond to SLR such as adapting to SLR risk competently or to a greater capacity. BASIEC provides a platform to build the capacity of the local communities to address the risk of SLR through SLR education, such as workshops, training programs, formal education etc. It is important to note that SLR education is positively associated with SLR awareness and capacity building through education is aimed to cope with the impacts, including the possibilities to prevent or reduce impacts via adaptation measures (NCAP 2005); (iii) *SLR policy implications*: BASIEC makes an intervention in SLR policies. BASIEC responds to UNFCCC call on climate action and GFCS climate services—to inform, to educate, to improve awareness, to develop an understanding of people about climate change (SLR). This contextualization served an important role in educating stakeholders about the importance of considering climate in place-based policy decisions (McNie 2013). Thus, it gives an opportunity for both National/Federal governments and also State/Local Governments to take climate action at the community-level using climate services like this to build the capacity of the local communities to changing climate and rising sea-levels. This framework is applicable to any part of the world that has low-lying coastal regions and that are vulnerable to the risk of rising sea-levels.

Limitation and Scope of the BASIEC Framework

The framework is based on theoretical perspective and it requires testing and enhancement before it aid for awareness creation and capacity-building. The framework with suitable case study application and its possibilities to upscale is need and it will gain more attention. However, the scope of the framework provides promising opportunities to develop it as a potential climate service tool. Furthermore, the evolving template of this prospective tool opens a gateway to develop a "Climate Service App" (BASIEC app) and a "Web-based climate service application". This framework can be developed further as a guiding protocol/manual for climate services with specific reference to sea-level rise risk awareness and capacity building through information, education and communication.

Conclusion

Climate change induced SLR confronts serious challenges to low-lying coastal regions across the world. Coastal communities, resources and infrastructures are in the frontline to experience the impact of changing coastal climate and rising sea levels. Adaptation is one of the response strategies to address climate change and SLR. Adaptation enables coastal communities to limit their vulnerability by averting or reducing potentially negative consequences of SLR while benefiting from potential positive consequences (Tol et al. 2008). SLR awareness creation and building capacity of communities is one of the adaptation measures at the local level to develop and enhance CBA. By understanding, planning for and adapting to a changing climate, individuals and societies can take advantage of opportunities and reduce risks. To fulfill these requirements, climate change communication and education play a crucial role in information dissemination, especially in translating technical information to increase public understanding and incorporating indigenous knowledge into climate change adaptation for policy planners (Sharples 2010; Khan et al. 2012). Easily accessible and timely scientific information can help societies not only limit the economic and social damage caused by climate-related disasters, but also take advantage of opportunities provided by favorable conditions (Medri et al. 2012). Climate services play a key role in building capacities of people and local communities to address the challenges of climate change and SLR. It has gained a great deal of attention in recent years; this is reflected in the implementation of the GFCS and in the rise of climate service providers in both public and private sectors and on international, national, and regional scales (Vaughan and Dessai 2014). Climate services involve the timely production, translation, and delivery of useful climate data, information, and knowledge for societal decision-making. They rely on a range of expertise and are underpinned by research in climate and related sciences, sectoral applications (e.g., coasts), and a number of social science fields. Climate services that are built on the best available science and providing researchers with guidance regarding priority challenges in the development of climate services warrant attention (Vaughan et al. 2016). In this context, this chapter has introduced BASIEC (Building capacities for Adaptation to Sea-level rise through Information, Education and Communication for coastal communities) a coastal climate service framework. It builds upon three different dimensions to create awareness and build the capacity of communities at the local level to address SLR; it includes (i) *SLR risk Information*: SLR risk information is crucial and it is in high demand to provide a science and evidence-based information at the local level to create awareness to the coastal communities. The framework outlines the information related to SLR such as past and present sea-level trend, projected future SLR, predicted impact of SLR, identifying vulnerable communities, resources and infrastructures, framing suitable adaptation strategies, SLR policy planning and mainstreaming etc. (ii) *SLR risk Communication*: Communicating complex climate science, such as SLR science is a daunting task, yet it is the need of the hour. The framework recommends some of the communication strategies such as one to one communication, group discussion, print media, electronic media, social media etc.; (iii) *SLR risk Education*: Understanding how people perceive the threat and potential response measures are important for public and stakeholder communication to reduce exposure to coastal risks (Akerlof et al. 2017). SLR education plays a major role in making communities to understand the risk and to build capacity to adapt to rising sea-levels. The framework proposes various learning techniques such as citizen science, conferences, and symposiums; formal education, workshops; training programs, participatory techniques etc. Thus, the framework aimed to foster effective application of climate knowledge and information for the benefit of society and thus the scope of BASIEC spans across three interrelated perspectives such as Information, Communication, and Education. It provides some basic climate science background, guidance for understanding and using climate data, insights for effectively communicating climate change, research and examples of how climate information can be integrated across levels, and knowledge for the design, implementation, and evaluation of effective climate services (We Adapt 2018). It is hoped that the BASIEC framework provides a systematic starting point and guidance for local level coastal climate policy planners, decision-makers, researchers, local communities and others who hold a stake on coastal climate services for CBA to changing climate in general and SLR in particular.

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References

Akerlof K, Covi M, Rohring E (2017) Communicating sea level rise. Climate change communication. Oxford research encyclopedia of climate science. Oxford University Press, USA, p 50. https://sci-hub.tw/10.1093/acrefore/9780190228620.013.417

AMS (2012) Climate services. A policy statement of the American Meteorological Society. https://www.ametsoc.org/index.cfm/ams/about-ams/ams-statements/archive-statements-of-the-ams/climate-services/. Accessed 15 Feb 2019

Archer D, Dodman D (2015) Making capacity building critical: power and justice in building urban climate resilience in Indonesia and Thailand. Urban Clim 14(1):68–78

Ayers J, Forsyth T (2009) Community-based adaptation to climate change: strengthening resilience through development. Environment 51(4):22–31

Berkhout F, Hertina J, Jordan A (2002) Socio-economic futures in climate change impact assessment: using scenarios as ‘learning machines’. Global Environ Change 12:83–95

Berte E, Panagopoulos T (2014) Enhancing city resilience to climate change by means of ecosystem services improvement: a SWOT analysis for the city of Faro, Portugal. Int J Urban Sust Dev 6(2):241–253

Brasseur GP, Gallardo L (2016) Climate services: lessons learned and future prospects. Earth’s Future 4:79–89

Bull JW, Jobstvogt N, Böhnke-Henrichs A, Mascarenhas A, Sitas N, Baulcomb C, Lambini CK, Rawlins M, Baral H, Zähringer J, Carter-Silk E, Balzan MV, Kenter JO, Häyhä T, Petz K, Koss R (2016) Strengths, weaknesses, opportunities and threats: A SWOT analysis of the ecosystem services framework. Ecosyst Serv 17:99–111

Caribbean Community (2018) The role of education in climate change risk management. https://www.caribbeanclimate.bz/the-role-of-education-in-climate-change-risk-management/. Accessed 26 May 2019

Cash DW, Clark WC, Alcock F, Dickson NM, Eckley N, Guston DH (2003) Knowledge systems for sustainable development. Proc Natl Acad Sci 100(14):8086–8091

Cazenave A, Cozannet G (2013) Sea level rise and its coastal impacts. Earth's Future 2:15–34

Chadwick B, Flick F, Helly J, Nishikawa T, Fang Wang P, O'Reilly W, Guza R (2011) A framework for sea level rise vulnerability assessment for southwest U.S. military installations. OCEANS'11 MTS/IEEE KONA. https://sci-hub.tw/10.23919/oceans.2011.6107212

Church JA, Clark PU, Cazenave A, Gregory JM, Jevrejeva S, Levermann A, Merrifield MA, Milne GA, Nerem RS, Nunn PD, Payne AJ, Pfeffer WT, Stammer D, Unnikrishnan AS (2013) Sea level change. In. Stocker TF, Qin D, Plattner GK, Tignor M, Allen SK, Boschung J, Nauels A, Xia Y, Bex V, Midgley PM (eds) Climate change 2013: the physical science basis. Contribution of working group I to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp 1137–1216

Clark F, Stamm KR, Eblacas PR (1999) A process model of risk communication: the case of global climate change. RISK: Health Saf Environ 10:197. https://scholars.unh.edu/cgi/viewcontent.cgi?article=1400&context=risk. Accessed 15 Feb 2019

Covi MP (2014) Water's gonna rise: sea-level rise risk perception, communication and policy-making in North Carolina. Doctoral Dissertation, East Carolina University, USA, p 195. http://hdl.handle.net/10342/4389. Accessed 26 May 2019

Dagnet Y, Northrop E (2015) 3 reasons why capacity building is critical for implementing the Paris Agreement. World Resources Institute. https://www.wri.org/blog/2015/12/3-reasons-why-capacity-building-critical-implementing-paris-agreement. Accessed 15 Feb 2019

Davis M, Barrott J, Bharwani S, Gerger Swartling Å, Coll Besa M, Vulturius G, Johnson O (2016) The SEI initiative on climate services. SEI initiative information sheet, p 4. https://mediamanager.sei.org/documents/Publications/SEI-FS-2016-Climate-Services-Initiative.pdf. Accessed 28 May 2019

DeLorme DE, Stephens SE, Hagen SC, Bilskie MV (2018a) Communicating with coastal decision-makers and environmental educators via sea level rise decision-support tools. J Sci Commun 17(03):1–18

DeLorme DE, Stephens SH, Hagen SC (2018b) Transdisciplinary sea level rise risk communication and outreach strategies from stakeholder focus groups. J Environ Stud Sci 8(1):13–21

Dietz T (2013) Bringing values and deliberation to science communication. Proc Natl Acad Sci 110:14081–14087

Dilling L, Lemos MC (2011) Creating usable science: opportunities and constrains for climate knowledge use and their implications for science policy. Global Environ Change 21:680–689

Dovie DBK (2017) A communication framework for climatic risk and enhanced green growth in the eastern coast of Ghana. Land Use Policy 62:326–336

ECBI (2018) Pocket guide to capacity building. European Capacity Building Initiative, p 42. http://pubs.iied.org/pdfs/G04165.pdf. Accessed 15 Feb 2019

EEA (2015) Awareness campaigns for behavioral change. European Environment Agency, Copenhagen, Denmark. https://climate-adapt.eea.europa.eu/metadata/adaptation-options/awareness-campaigns-for-behavioural-change. Accessed 15 Feb 2019

Eliot M (2013) Application of geomorphic frameworks to sea-level rise impact assessment. Report 193-01-Rev0. Prepared for Geoscience Australia. Damara WA Pty Ltd, Innaloo, Western Australia, p 80. https://www.environment.gov.au/system/files/resources/a510cc11-aa53-4be6-b0e0-9b9e4d459d31/files/geomorphic-frameworks.pdf. Accessed 28 May 2019

European Commission (2015) A European Research and Innovation Road map for Climate Services, Directorate-General for Research and Innovation, European Commission, Brussels, p 51
Fitz Gerald DM, Fenster MS, Argow BA, Buynevich IV (2008) Coastal impacts due to sea-level rise. Annu Rev Earth Planet Sci 36:601–647
Fussel HM (2007) Vulnerability: a generally applicable conceptual framework for climate change research. Global Environ Change 7(2):155–167
GERICS (2019) The Climate Service Centre Germany-GERICS, Hamburg, Germany. https://www.climate-service-center.de/about/index.php.en. Accessed 24 May 2019
Giuliani G, Nativi S, Obregon A, Beniston M, Lehmann A (2017) Spatially enabling the Global Framework for Climate Services: reviewing geospatial solutions to efficiently share and integrate climate data & information. Clim Serv 8:44–58
Hartmann T, Spit T (2014) Capacity building for the integration of climate adaptation into urban planning processes: the Dutch experience. Am J Clim Change 3:245–252
Hellmuth ME, Moorhead A, Thomson MC, Williams J (2007) Climate risk management in Africa: Learning from practice. International Research Institute for Climate and Society (IRI), Columbia University, New York, USA, p 104
Hewitt C, Mason S, Walland D (2012) The Global Framework for Climate Services. Nat Clim Change 2:831–832
ICHA (2017) Raising risk awareness: using climate science for disaster risk management. International Centre for Humanitarian Affairs (ICHA), Nairobi, p 5. https://cdkn.org/wp-content/uploads/2017/08/2016-2017-Kenya-drought-policy-brief-1.pdf. Accessed 29 May 2019
IFRC (2009) Climate change adaptation strategies for local impact key messages for UNFCCC negotiators. Prepared by the, technical paper for the Inter Agency Steering Committee. Task force on climate change, international federation of red cross and red crescent societies, p 11. http://unfccc.int/resource/docs/2009/smsn/igo/054.pdf. Accessed 15 Feb 2019
IPCC (2013) Chapter 5. Coastal systems and low-lying areas. In: Poh Poh W, Iñigo JL (eds) Impacts, adaptation and vulnerability. Contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, UK, pp 1–28
IPCC (2014) Glossary. In: Climate change 2014: impacts, adaptation and vulnerability. Contribution of working group I to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press, NY, pp 1757–1776
Jamero ML, Onuki M, Esteban M, Tan N (2018) Community-based adaptation in low-lying islands in the Philippines: challenges and lessons learned. Reg Environ Change. https://sci-hub.tw/10.1007/s10113-018-1332-8
Johnson G, Scholes GK, Sexty RW (1989) Exploring strategic management. Prentice Hall, Scarborough, Ontario, Canada, p 387
Jones N, Perez P, Measham TG, Kelly GJ, D'Aquino P, Daniell KA, Dray A, Ferrand N (2009) Evaluating participatory modeling: developing a framework for cross-case analysis. Environ Manag 44(6):1180–1195
Karppi I, Kokonen M, Latheenmaki-Smith K (2001) SWOT analysis as a basis for regional strategies. Stockholm, Nordregio, p 80
Kettle NP, Dow K, Tuler S, Webler T, Whitehead J, Miller KM (2014) Integrating scientific and local knowledge to inform risk-based management approaches for climate adaptation. Clim Risk Manag 4–5:17–31
Khan AS, Ramachandran A, Usha N, Arul Aram I, Selvam V (2012) Rising sea and threatened mangroves: a case study on stakeholders' engagement in climate change communication and non-formal education. Int J Sustain Dev World Ecol 19(4):330–338
Khan AS (2017) COREDAR for cities: developing a capacity building tool for sea-level rise risk communication and urban community-based adaptation. In: Leal Filho W, Keenan JM (eds) Climate change adaptation in North America: fostering resilience and the regional capacity to adapt. Climate change management. Springer, Berlin, pp 137–157

Khan AS, MacManus K, Mills J, Madajewicz M, Ramasubramanian L (2018) Building resilience of urban ecosystems and communities to sea-level rise: Jamaica Bay, New York City. In: Leal Filho W (ed) Handbook of climate change resilience. Springer, Cham, Germany, pp 1–21
Kloprogge P, Van Der Sulijs JP (2006) The inclusion of stakeholder knowledge and perspectives in integrated assessment of climate change. Clim Change 75:359–389
Lemos MC, Kirchhoff CJ, Ramprasad V (2012) Narrowing the climate information usability gap. Nat Clim Change 2(11):789–794
Lucio FD, Grasso VF (2016) The global framework for climate services (GFCS). Clim Serv 2–3:52–53
Martínez R, Hemming D, Malone L, Bermudez N, Cockfield G, Diongue A, Hansen J, Hildebrand A, Ingram K, Jakeman G, Kadi M, McGregor GR, Mushtaq S, Rao P, Pulwarty R, Ndiaye O, Srinivasan G, Seck E, White N, Zougmoré R (2012) Improving climate risk management at local level—techniques, case studies, good practices and guidelines for world meteorological organization members. In: Risk management—current issues and challenges, pp 477–532. http://cdn.intechopen.com/pdfs/38972/InTech-Improving_climate_risk_management_at_local_level_techniques_case_studies_goodpractices_and_guidelines_for_world_meteorological_organization_members.pdf. Accessed 15 Feb 2019
McGranahan DA, Balk D, Anderson B (2007) The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones. Environ Urban 19:17–39
McNie CE (2013) Delivering climate services: organizational strategies and approaches for producing useful climate-science information. Weather Clim Soc 5:14–16. https://sci-hub.tw/10.1175/WCAS-D-11-00034.1. Accessed 15 Feb 2019
Medri S, de Guisasola EB, Gualdi S (2012) Overview of the main international climate services. Centro Euro-Mediterraneo sui Cambiamenti Climatici, Italy, p 109. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2194841. Accessed 29 May 2019
Miller T (2010) North Carolina Division of Coastal Management sea level rise scoping survey. N.C. Division of Coastal Management, N.C. Department of Environment and Natural Resources, Morehead City, NC, p 87. http://digital.ncdcr.gov/cdm/ref/collection/p249901coll22/id/395199. Accessed 29 May 2019
MoES (2019) Climate services and climate data centre. Ministry of Earth Science, Government of India, New Delhi, India. https://www.moes.gov.in/programmes/climate-services-and-climate-data-centre. Accessed 24 May 2019
Moser SC (2010) Communicating climate change: history, challenges, process and future directions. WIREs Clim Change 1:31–53
Moser SC, Dilling L (2007) Creating a climate for change: communicating climate change and facilitating social change. Cambridge University Press, Cambridge, p 549
Moth P (2008) Examining the environmental justice of sea level rise and storm tides in New Zealand. A thesis submitted in partial fulfillment of the requirements for the Degree of Master of Science in Geography in the University of Canterbury, New Zealand, p 2
MRC (2010) Review of climate change adaptation methods and tools. MRC technical paper 34, Mekong River Commission, Office of the Secretariat in Vientiane (OSV), Vientiane, Lao PDR, p 76
Natesan U, Parthasarathy A (2010) The potential impacts of sea level rise along the coastal zone of Kanyakumari District in Tamilnadu, India. J Coast Conserv 14(3):207–214
NCAP (2005) Capacity building to improve adaptability to sea level rise in two vulnerable points of the Colombian coastal areas (Tumaco-Pacific coast and Cartagena-Caribbean coast) with special emphasis on human populations under poverty conditions. Netherlands Climate Assistance Programme, p 26. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.499.6571&rep=rep1&type=pdf. Accessed 29 May 2019
NCSP (2009) Applying climate information for adaptation decision-making a guidance and resource document. National Communications Support Programme. http://www.climate-services.org/wp-content/uploads/2015/05/ncsp2009_applying_climate_information.pdf. Accessed 29 May 2019
Nicholls RJ (2011) Planning for the impacts of sea level rise. Oceanography 24(2):144–157

Nisbet MC, Mooney C (2007) Framing science. Science 316:56
NOAA (2019) About NOAA Climate.gov. https://www.climate.gov/about. Accessed 24 May 2019
NRC (1996) Understanding risk: informing decisions in a democratic society. National Academy Press, Washington, DC, p 241
NRC (2009) Informing decisions in a changing climate. National Academies Press, Washington, DC, p 200
NRC (2010) America's climate choices: informing an effective response to climate change. National Academy Press, Washington, DC, p 346
Pickton DW, Wright S (1998) What's SWOT in strategic analysis? Strateg Change 7(2):101–109
Ramachandran A, Khan AS, Prasnnahvenkatesh R, Palanivelu K, Jayanthi N (2017) Projection of climate change induced sea level rise for the coasts of Tamil Nadu and Puducherry, India using SimCLIM: a first step towards planning adaptation policies. J Coast Conserv 21:731–742
Raymond CM, Fazey I, Reed M, Stringer LC, Robinson GM, Evely AC (2010) Integrating local and scientific knowledge for environmental management. J Environ Manag 91:1766–1777
REC (2008) Regional focal point for Article 6 of the United Nations Framework Convention on Climate Change. Regional Environmental Center for Central and Eastern Europe and Turkey, Szentendre, Hungary, p 14. http://article6.rec.org/documents/action_plan_2008.pdf. Accessed 29 May 2019
Reid H, Huq S (2014) Mainstreaming community-based adaptation into national and local planning. Clim Dev 6:291–292
Reid H, Alam M, Berger R, Cannon T, Huq S, Milligan A (2009) Community-based adaptation to climate change: an overview. In: Participatory learning and actions 60. Community-based adaptation to climate change. The International Institute for Environment and Development (IIED), Russell Press, Nottingham, UK, p 217
Rosas G, Gubler S, Oria C, Acuña D, Avalos G, Begert M, Castillo E, Croci-Maspoli M, Cubas F, Dapozzo M, Díaz A, van Geijtenbeek D, Jacques M, Konzelmann T, Lavado W, Matos A, Mauchle F, Rohrer M, Rossa A, Scherrer SC, Valdez M, Valverde M, Villar G, Villegas E (2016) Towards implementing climate services in Peru—the project CLIMANDES. Clim Serv 4:30–41
Rumore D (2014) Building the capacity of coastal communities to adapt to climate change through participatory action research: Lessons learned from the New England climate adaptation project. Carolina Plan 39:16–23
Schleussner C, Rogelj J, Schaeffer M, Lissner T, Licker R, Fischer EM, Knutti R, Levermann A, Frieler K, Hare W (2016) Science and policy characteristics of the Paris Agreement temperature goal. Nat Clim Change 6:827–835
Shahid Z, Piracha A (2016) Awareness of climate change impacts and adaptation at local level in Punjab, Pakistan. In: Maheshwari B, Singh V, Thoradeniya B (eds) Balanced urban development: options and strategies for liveable cities. Water science and technology library, vol 72. Springer, Cham
Sharples DM (2010) Communicating climate science: evaluating the UK public's attitude to climate change. Earth Environ 5(1):185–205
Sheppard SRJ, Shaw A, Flanders D, Burch S, Wiek A, Carmichael J, Robinson J, Cohen S (2011) Future visioning of local climate change: a framework for community engagement and planning with scenarios and visualization. Futures 43(4):400–412. https://sci-hub.tw/10.1016/j.futures.2011.01.009. Accessed 15 Feb 2019
South West (2008) The South West climate change action plan for the South West 2008–2010. http://www.swcouncils.gov.uk/media/SWRA/Climate%20Change/Climate_Change_ActionPlan.pdf. Accessed 15 Feb 2019
Spence A, Pidgeon N (2010) Framing and communicating climate change: the effects of distance and outcome frame manipulations. Global Environ Change 20:656–667
Stephens SH, DeLorme DE, Hagen SC (2016) Evaluation of the design features of interactive sea-level rise viewers for risk communication. Environ Commun 11(2):248–262
Stevenson RB, Nicholls J, Whitehouse H (2017) What is climate change education? Curric Perspect. https://sci-hub.tw/10.1007/s41297-017-0015-9

Tol RSJ, Klein RJT, Nicholls RJ (2008) Towards successful adaptation to sea-level rise along Europe's coasts. J Coast Res 24(2):432–442

Trærup SLM, Olhoff A (2011) Climate risk screening tools: a guide to the guidance. Danmarks Tekniske Universitet, Risø Nationallaboratoriet for Bæredygtig Energi, Roskilde. http://orbit.dtu.dk/files/6238714/Climate%20Risk%20Screening%20Tools.pdf. Accessed 29 May 2019

Tribbia J, Moser SC (2008) More than information: what coastal managers need to plan for climate change. Environ Sci Policy 11(4):315–328

UNESCO (2018) Climate change education and awareness. https://en.unesco.org/themes/addressing-climate-change/climate-change-education-and-awareness. Accessed 15 Feb 2019

UNFCCC (2018) Understanding capacity-building, education and outreach. https://bigpicture.unfccc.int/content/capacity-building.html. Accessed 15 Feb 2019

Vaughan C, Dessai S (2014) Climate services for society: origins, institutional arrangements, and design elements for an evaluation framework. WIREs Clim Change 5:587–603

Vaughan C, Buja L, Kruczkiewicz A, Goddard L (2016) Identifying research priorities to advance climate services. Clim Serv 4:65–67

We Adapt (2018) Using climate information. https://www.weadapt.org/knowledge-base/climate-services. Accessed 15 Feb 2019

Weber EU, Stern PC (2011) Public understanding of climate change in the United States. Am Psychol 66(4):315–328

WMO (2013) What do we mean by climate services? Bulletin 62(Special Issue). https://public.wmo.int/en/bulletin/what-do-we-mean-climate-services. Accessed 29 May 201

WMO (2014) Capacity development. Annex to the implementation plan of the Global Framework for Climate Services. World Meteorological Organization, Geneva, Switzerland, p 58

Chapter 3
Nitrous Oxide Emissions from Agricultural Farms and Its Contribution to Global Warming

Haile Arefayne Shishaye

Abstract Global warming is a universal issue caused by increasing atmospheric greenhouse gases such as nitrous oxide (N_2O), carbon dioxide (CO_2) and methane (CH_4). N_2O is produced from natural and anthropogenic sources. Microbial processes of nitrification and denitrification produce N_2O which is then released into the atmosphere. This research aims to estimate the emission rate of N_2O through denitrification processes in a mechanized sugarcane farm in Metahara, Ethiopia. The LEACHN/LEACHM model was used to estimate the rate of denitrification and emission of N_2O. The model was calibrated by groundwater nitrate concentrations estimated from laboratory measurements using the APHA 4500-NO_3-B, Ultraviolet Spectrophotometric screening method. The results show that the amount of atmospheric nitrogen (N_2O and N_2) produced due to denitrification processes in the farm was 230.4 kg/ha/year. The share of N_2O from this estimate was 1/41th, as the soil in the farm was alkaline (pH = 9.0). As a result, the annual N_2O emission from the farm was estimated to be 5.62 kg/ha/year. This implies that the current farm management and nutrient and water application scenario in the area is causing a significant amount of N_2O emissions to the atmosphere, which in turn has a collective impact on global warming.

Introduction

Global temperature has increased by an average of 1 °C since the industrial revolution in a process known as global warming (Fig. 3.1; Signor et al. 2013a; IPCC 2013; Iqbal et al. 2014). Global warming has resulted from increasing concentrations of the greenhouse gases: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) (Shishaye 2015a; Ahmed et al. 2013). These greenhouse gasses in the atmosphere absorb sunlight and solar radiation that have bounced off the earth's surface (Snyder et al. 2009). This radiation would escape into space, but the pollutants, which can last for years to centuries in the atmosphere, trap the heat and cause the planet to get

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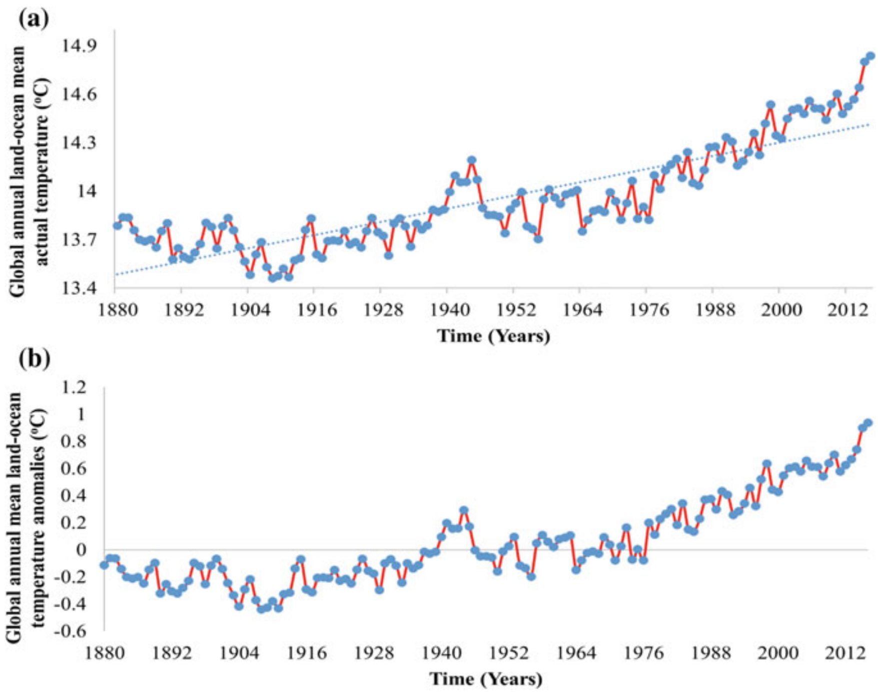

Fig. 3.1 Global annual land-ocean mean **a** actual temperature and **b** temperature anomalies from 1880–2016. The base period was 1901–2000. The data for these graphic representations were collected from NASA, Jet Propulsion Laboratory website https://www.jpl.nasa.gov/edu/teach/activity/graphing-global-temperature-trends/

hotter (i.e. greenhouse effect; Hartmann et al. 2013). Without the greenhouse gases, the average temperature of the earth's surface would be about −18 °C rather than the present average of 15 °C (NASA 2016; Ma and Tipping 1998; Le Treut et al. 2007; Karl and Trenberth 2003).

Global warming is caused both by natural and anthropogenic effects (Ahmed et al. 2013; Denman et al. 2007). However, according to the IPCC (2013), human influences have been the dominant cause of the observed warming since the mid-20th century (Fig. 3.1). Many scientists agree with the fact that the world will host environmental, economic, and health consequences of global warming if current trends continue (Ma and Tipping 1998; Le Treut et al. 2007; Karl and Trenberth 2003). The major consequences of global warming include rising sea levels, changing precipitation patterns, and expansion of deserts in the subtropics (Lu et al. 2007; Le Treut et al. 2007). Other likely changes include more frequent extreme weather events such as heat waves, droughts, heavy rainfall with floods and heavy snowfall, ocean acidification, and species extinctions due to shifting temperature regimes (Vitousek 1994; Ma and Tipping 1998; Welch et al. 1998; Hughes 2000, Shishaye 2015a).

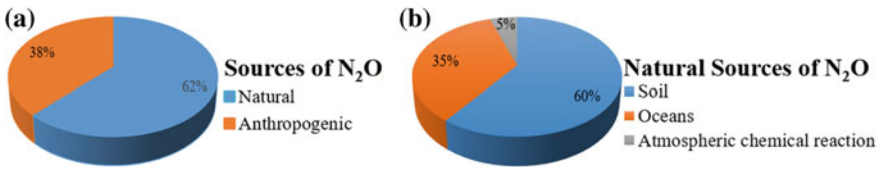

Fig. 3.2 **a** The contributions of natural and anthropogenic factors and **b** natural sources of N_2O (the data for these charts were collected from IPCC (2007))

Nowadays, there are different pieces of evidence supporting the facts revealed and predicted by scientists. The world is facing the impacts of climate change in its every corner differently, i.e., different regions are facing the challenges of climate change differently (Ma and Tipping 1998; Signor et al. 2013a; Shishaye 2015a; Australian Academy of Science 2015). Moreover, future climate change and its impacts are also predicted to vary from region to region (IPCC 2013). Significant regional differences exist even within the Americans and Chinese, whose economies are responsible for the greatest annual CO_2 emissions, but among the least concerned (Stokes et al. 2015; Shishaye 2015a). Nevertheless, the projected surface temperature is always set as an average; i.e., the regions that are expected to suffer the most and those expected to suffer less are not reported separately. In this case, even though the IPCC reported that long-term prediction of future climate state is impossible (IPCC 2007), the ranges of the lowest and highest emission scenarios of global surface temperature projections made for the 21st century are 0.3–1.7 °C and 2.6–4.8 °C, respectively (IPCC 2013; DiMento et al. 2007). This implies that even the low emission standards will cause an increase in global temperature.

Nitrous oxide is produced by natural (62%) and anthropogenic (38%) factors (Fig. 3.2a; IPCC 2007). Natural sources of N_2O emissions include soil, oceans and atmospheric chemical reactions (Fig. 3.2b). Soils are the largest N_2O source to the atmosphere, accounting for 12 Tg/year of the current annual budget (20 Tg/year) (Syakila and Kroeze 2011), followed by oceans and atmospheric chemical reactions (Fig. 3.2b). Nitrous oxide produced by microbes that break down nitrogen in uncultivated soils, which make up the majority of the earth's land surface, are considered as natural sources. Riparian and tropical rainforest soils that have higher nutrient availability and moisture levels are important contributors to this source (IPCC 2007). N_2O producing microbes living in the ocean also create N_2O emissions. Microbial activities in and around sinking particles, such as faecal pellets provide the anaerobic conditions necessary for denitrification which in turn produces N_2O. Chemical reactions in the atmosphere also produce a significant amount of N_2O emissions. The oceans, manure from wild animals as well as decomposed plants form the most important natural sources of ammonia in the air. The oxidization of ammonia from these natural sources then creates 600,000 tons of N_2O per year (IPCC 2007).

Anthropogenic sources of N_2O have caused a dramatic increase in N_2O emissions since the Industrial Revolution (Signor et al. 2013a; IPCC 2007). Agricultural farms using inorganic fertilizers are believed to be the major contributors to the anthropogenic N_2O budget that also includes forest fuel combustion, industrial processes and biomass burning (Fig. 3.3; Signor et al. 2013b; Beaulieu et al. 2011; Dalal et al. 2003). In this case, the miss-managed agriculture is expected to have the highest share (Shishaye 2015b; Easton and Lassite 2013; Signor et al. 2013a; Cerri et al. 2009; Forster et al. 2007; Dalal et al. 2003; Barton and Atwater 2002). For instance, unbalanced nitrogen fertilizer applications with the crop uptake capacity may cause an increase in the level of denitrification. An increased extent of denitrification in return increases the emission of N_2O to the atmosphere.

N_2O in the atmosphere constitutes 7% of the anthropogenic greenhouse effect (IPCC 2013). The global warming potential of N_2O in a 100-year period is 300 and 16 times higher than that of CO_2 and CH_4, respectively (Signor et al. 2013a; Barton and Atwater, 2002). The total estimated annual N_2O emission is 20 Tg (Syakila and Kroeze 2011), but there are large uncertainty ranges in each of the individual sources (Zaman et al. 2012). N_2O emissions from agricultural farms can also vary from farm to farm based on the soil type, rate of water application, type and extent of nutrient application and crop type. In general, N_2O emission and estimation across the different agricultural landscapes (arable, pasture, and wetland) is extremely variable (both spatially and temporally), thus posing the greatest challenge to researchers, modellers and policy makers to accurately predict N_2O emissions. According to IPCC (2007), N losses as N_2O across agricultural landscapes are extremely variable and range from about 1% to more than 20% of the applied N. These large uncertainties highlight the need for N_2O to be quantified at farm level, then cumulated to national, regional and global levels.

Therefore, the objective of this study was to estimate the rate of N_2O emissions from denitrification processes in the Metahara Sugarcane Farm, Ethiopia. N_2O is produced in soils during nitrification (the aerobic conversion of ammonium (NH_4^+) to nitrate (NO_3)) and denitrification (the anaerobic conversion of NO_3 to N_2O and dinitrogen (N_2) gases) processes (Hayatsu et al. 2008). However, this work only considers the production of N_2O from denitrification processes. Due to a lack of robust, easy and less expensive measurements and analytical methods used to separately measure the emissions of N_2 and N_2O from denitrification processes, the extents of

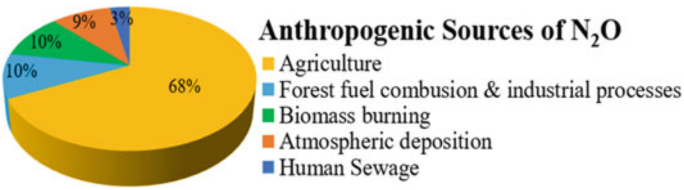

Fig. 3.3 Anthropogenic sources of N_2O emissions (data was collected from IPCC (2007)). Fertilized agricultural soils and livestock manure are considered as the direct sources (42%) of the total emission that agriculture is responsible for, while the indirect emissions (25%) come from runoff and leaching of fertilizers

N_2 and N_2O were estimated simultaneously. The one-dimensional LEACHN model (Hutson 2003) was applied to estimate the N_2O emission rate from the farm.

Materials and Methods

Description of the Study Area

Metahara sugarcane farm is one of the largest sugarcane farms in Ethiopia (Fig. 3.4). It is located in the East Shewa Zone, 200 km east of Addis Ababa, in Oromiya Regional State, at the geographical coordinates of 8°54′0″ N and 39°55′0″ E with an average altitude of 940 m.a.s.l. It was established in an agreement between the Dutch company Handels Vereniging Amsterdam and the Ethiopian government in 1965 to meet an increasing domestic sugar demand and started production in 1966. It produces around 120,000 tons of sugar per year (Shishaye 2015b). The area has a semi-arid climatic condition, with mean maximum and minimum temperatures of

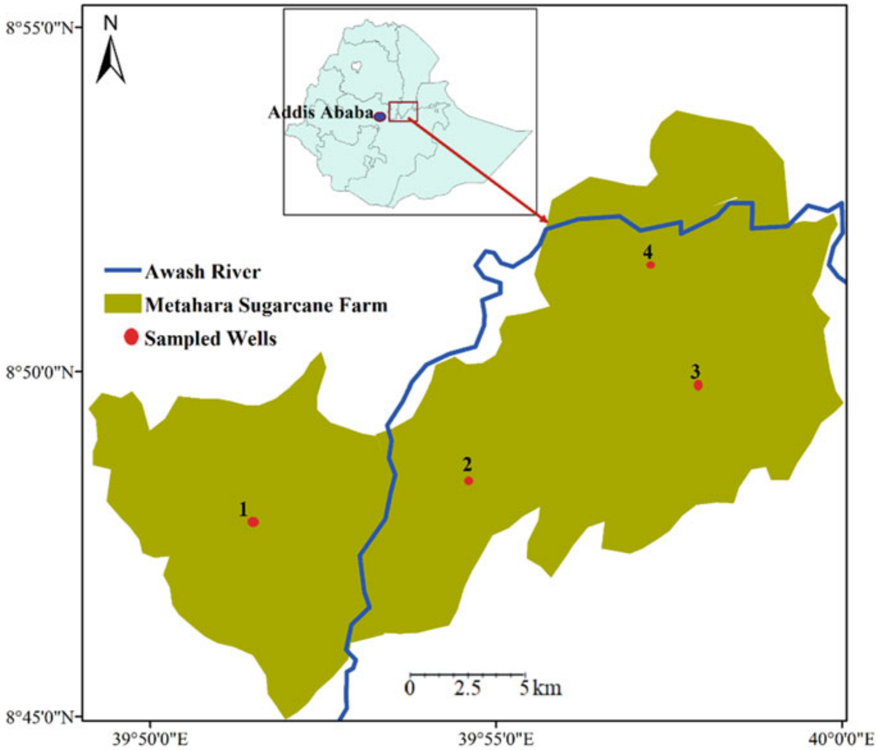

Fig. 3.4 Location map of the Metahara Sugarcane farm and the sampling boreholes

32.8 and 17.5 °C, respectively, and an average annual rainfall of about 600 mm. Most of the region's rain falls from June to September and the rest of the months are dry. The farm covers 10,230 ha of land with the majority (>98%) of it covered by sugarcane plantation and the remaining 2% covered by orchard crops.

The Nitrogen Cycle and the LEACHN Model

Nutrient loss from agricultural farms is an increasing concern worldwide. Nitrate leaching is one side of the nutrient loss problems in many agricultural areas (Oenema et al. 2003; Shishaye 2015b). On the other hand, denitrification is also the other phase of the losses. However, the level of nitrate leaching and the rate of denitrification may vary based on the crop type, soil type, soil water content, and other factors. For instance, the loss of nitrate from sugarcane production is very high, in comparison with other crop productions, because its nutrient uptake capacity is low (Biggs 2003). The rate of denitrification is high in oxygen-limited situations than oxygen-rich conditions. Therefore, the increase in denitrification rates contributes to the increase in global warming by producing N_2O greenhouse gas. Nitrogen cycle passes through four major spheres: the atmosphere, hydrosphere, biosphere, and the lithosphere (Fig. 3.5). Organic nutrients from plant residues, animal manure or compost, and inorganic nitrogen fertilizers pass through different microbial processes in the root zone then ends up either as plant uptake or leaching to the groundwater or denitrified to the atmosphere in the form of nitrogen gases. The gas forms, especially N_2O, then end up as a greenhouse gas and partially comes back to the earth in the form of acid rain. Acid break-up processes convert nitric acid (acid rain) to $2H^+$ and nitrate. Then, it follows the same trend in the spheres of the nitrogen cycle (Fig. 3.5).

Direct measurement/quantification of the rates of nitrogen transformation processes including nitrification and denitrification is difficult. However, with the advent of computer modelling, the rates of nitrogen transformation processes (Fig. 3.5) can be predicted. There has been a large growth in the number of computer simulation codes and their use to predict nitrate-leaching and denitrification losses in the last 2–3 decades. One of the widely used codes for such a work is the LEACHN/LEACHM (Leaching Estimation and Chemistry Model) model (Hutson and Wagenet 1992; Hutson 2003). The LEACHN model was originally designed to simulate vertical nitrogen movements within the unsaturated soil profile (Hutson and Wagenet 1992). However, with the series of modifications, the model is able to estimate the loss of gaseous nitrogen to the atmosphere (Hutson 2003).

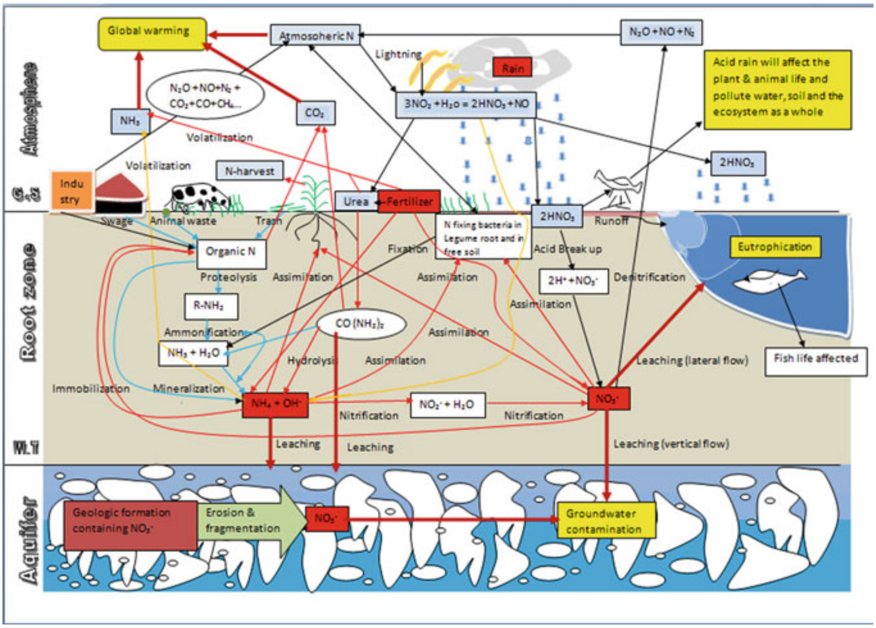

Fig. 3.5 The nitrogen cycle. The diagram shows that the nitrogen cycle is a natural phenomenon, but the rates of each of the components of the cycle may vary from place to place due to spatial variations of the natural and anthropogenic factors. The diagram was developed in AutoCAD-2007

Model Input Data Collection and Analysis

Farm Irrigation Practice

The type of irrigation practice used in the study area is surface irrigation (furrow irrigation for sugarcane and basin irrigation system for orchard crops). The dimensions of the furrow are 100 m in length, 60 cm in width and 30 cm in depth. During irrigation times, the farm is irrigated for 9 h. Because the source of irrigation water is river water, it has a continuous flow. The diverted water from the main course of the Awash River is stored in the night storage reservoirs for 15 h. The irrigation water application is 40 L/s/ha. According to the information obtained from the head office of the enterprise, the field irrigation efficiency is 60% and the conveyance efficiency is 85%. The irrigation interval, even though it varies based on the soil types, was taken as an average of 15 days. The total irrigated land coverage of the Metahara sugarcane farm is 10,130 ha. Of the total area, 10,000 ha is covered by sugarcane and the remaining 130 ha is covered by orchard fruits. The farm is divided into different irrigation units. One irrigation unit covers 64 ha of land.

Fertilizer Application

The N fertilizers in the area are applied as Ammonium Sulfate Nitrate (ASN). ASN is a nitrogen fertilizer, formed by the mixture of ammonium sulphate $(NH_4)_2SO_4$ and ammonium nitrate (NH_4NO_3). It contains 26% N and 13% Sulfur in a sulfate form (Aurepio 2012). Even though nitrogen fertilizer application varies based on the soil types, the average rates of fertilizer applications in the farm are 400 kg/ha of ASN for sugarcane plant, 500 kg/ha of ASN for the first and second-ratoon crops, and 600 kg/ha of ASN for the third ratoon crops (Booker Tate Limited 2009). This implies that the fertilizer application in terms of nitrogen is 104 kgN/ha for sugarcane plant, 130 kgN/ha for the first and second-ratoon crops and 156 kgN/ha for the third ratoon crops. The method of calculating the amount of nitrogen from the ASN fertilizer was by upscaling the fertilizer application rates by 26%, as 26% of the ASN fertilizer is nitrogen. Thus, these three fertilizer application values were used as inputs for the model in the simulation processes. The carbon to nitrogen ratio (C:N) in the study area was 20:1 (Booker Tate Limited 2009).

Soil Property and Meteorological Data

The soil physical property data are also other major inputs for the LEACHN model. Booker Tate Limited conducted a detailed soil survey in the study area in 2009. The soil property data used as input for the model (Table 3.1) were then taken from the Metahara sugarcane farm main soil re-evaluation report (Booker Tate Limited 2009).

The important meteorological data for the LEACHN model are precipitation, temperature, evaporation, and evapotranspiration. The long-term monthly meteorological data of the site were obtained from the head office of the Metahara Sugarcane Farm. The average monthly rainfall was fairly distributed into the number of rainy days, as the numbers of rainy days were known. This was done because of the daily

Table 3.1 Soil property parameters and their corresponding values used as inputs for the LEACHN model

Soil physical properties	Values used
Particle density (kg/dm^3)	2.65
Bulk density (kg/dm^3)	1.3
Organic carbon (mass%)	1.5
Hydraulic conductivity (mm/d) (only for the simulations based on land use)	200
Profile thickness (mm)	1600
Segment thickness (mm)	100
Dispersivity (mm) = between 0.5 and 2 times of the segment thickness	100
Clay (%) (only for the simulations based on land use)	55
Silt (%) (only for the simulations based on land use)	25

meteorological data was not fully documented. Similarly, the other necessary meteorological information including rainfall and relative humidity were also taken from the monthly average data. Furthermore, evapotranspiration was estimated from the class "A" pan evaporation value using the following relationship:

$$ET_0 = K_{pan} * E_{pan}$$

where ET_0 is the reference crop evapotranspiration (mm day^{-1}), E_{pan} is the measured class A pan evaporation (mm day^{-1}) and K_{pan} is the pan coefficient (Snyder 1992). The pan coefficient value varies due to different conditions, i.e., it is highly dependent on the surrounding conditions. However, the average K_{pan} value was taken as 0.7 (Snyder 1992).

Crop Data

Crop data is also another input data for the LEACHN model. The main crop type grown in the study area is sugarcane, with an average production of 120,000 tons of sugar per year. This implies that the production is 12 tons/year/ha of irrigated land, which in turn shows that the rate of N application on the farm is 8.667 kgN t^{-1} cane for sugarcane plant, 10.83 kgN t^{-1} cane for the first and second-ratoon crops and 13 kgN t^{-1} canes for the third ratoon crops. However, according to different studies (Shishaye 2015b; Biggs 2003), the nutrient uptake capacity of sugarcane is low, 2.8 kgN t^{-1} cane. Therefore, the target nitrogen uptake for sugarcane was set in the model as (12 ton cane ha^{-1} * 2.8 kgN t^{-1} cane) 33.6 kgN/ha.

Laboratory Measurements

Groundwater samples were taken from four wells for nitrate and ammonium end-member concentration. Samples were sent to "JIJE LABOGLASS P.L.C", Addis Ababa, Ethiopia for analysis. APHA 4500-NO_3-B, Ultraviolet Spectrophotometric screening method was used to determine nitrate concentration. Finally, nitrate concentration from each well was averaged and the average value was used for model calibration purposes.

Modelling N_2O Emissions

The model input data describes soil properties for each layer, crop growth and phonological data, soil management information, meteorological data, N transformation and their rate constants, and boundary conditions. Some of the important rate constants used in the model such as the NH_4^+–N partition coefficient, NO_3^-–N partition coefficient, and other model input parameters including the *b* parameter in Campbell equation, Q10, air-entry value in the Campbell equation and molecular diffusion coefficient were obtained from published sources as well as direct suggestions from model developers.

The organic nitrogen pool within a soil profile is significantly influenced by the initial conditions that are estimated for organic carbon content in the soil (Johnson et al. 1993; Toride and Chen 2011). Estimating the initial nitrogen and carbon content in the soil profile was one of the most important activities in this simulation. In order to get the starting values of nitrogen and carbon from residue and hummus, the model was run for 47 years (1966–2014) simulation period, because of the availability of recorded data, with 20 numbers of repetitions until the value of nitrogen and carbon become constant. Then, those values of nitrogen and carbon were taken as initial values from residues and hummus. Finally, after filling the necessary input data, the simulation was conducted for 47 years and the model results were analyzed accordingly.

Model Calibration

The average groundwater nitrate-nitrogen concentration found from the laboratory measurements was used to calibrate the LEACHN model. The model input parameters were modified until the simulated nitrate-nitrogen concentration matches the average experimental result. The other data used for calibration purposes was the nitrogen stress data of the crop. There was a study conducted in the area by Booker Tate Limited in 2009 regarding leaf N%. They took 164 samples from the study area; of the 164 samples taken, 22% were found to be below the accepted lower limit for leaf N% within any season (1.6%), whilst the remainder (78%) showed satisfactory levels of N. Requirements for the leaf N levels are, however, related to crop type and cropping season. In South Africa, for example, the threshold value has been determined to vary between up to 1.6% (for late season ratoon cane) to 1.9% (for early season plant cane) (Booker Tate Limited 2009). The lowest of these figures (1.6%) was used during the analysis. Therefore, 78% of the N level was used as the lowest plant nitrogen uptake to target. The model was repeatedly run and the input parameters were modified until the nitrogen uptake to target values along the whole simulation periods became above 78%.

Results and Discussion

Laboratory Results

The concentrations of groundwater nitrate from the laboratory results were found lower in wells 1 and 4 (Fig. 3.4), while it was relatively higher in wells 2 and 3 (Table 3.2). The average groundwater nitrate concentration in the area was found to be 3.6 $mgNO_3\_N/L$ (Table 3.2). Groundwater nitrate concentration in the farm

Table 3.2 Experimental results. Groundwater nitrate concentrations measured from 4 different wells in the Metahara sugarcane farm

Well No.	Laboratory No.	NO_3-N (mg/L)
1	J-W-0024/14	1.5
2	J-W-0023/14	5.4
3	J-W-0025/14	5.4
4	J-W-0022/14	2.0
Average	–	3.6

was therefore small compared to groundwater nitrate concentrations of other farms elsewhere such as south of the city of Ashkelon, Israel (724 mg/L; Dahan et al. 2014) and the corn and wheat farm in southwestern Ontario (22.4 mg/L; Barry et al. 1993). The main reason for this could be the excess application of irrigation water and low nutrient uptake capacity of sugarcane. High soil water content (water logged area) creates favorable condition for denitrification processes, as it limits the availability of oxygen in the soil (Hutson 2003).

Modelling Results: N_2O Emissions Through Denitrification

A separate estimation of the extents of N_2O and N_2 emitted from the area was the challenge of this research. In fact, the extent of N that actually lost from an agricultural farm in the form of N_2O during denitrification depends on soil pH. According to Schwenke et al. (n.d), the amount of N_2O lost from high pH (alkaline) soils is very low in proportion to N_2; for example, there is about 40 times more N_2 produced from denitrification as there is N_2O in soils with a pH > 8. In contrary, the N lost in the form of N_2O from low pH (acidic) soils can be greater than or equal to half of the total N lost (Schwenke et al., n.d). Therefore, even though it has some biases, using this fact was helpful to estimate the rate of N_2O emission separately. Otherwise, estimating the extents of N_2O and N_2 separately may demand isotopic analysis and some other economically intensive experimentations.

The soil in the study area was alkaline (pH > 8), averagely 9.0 (Shishaye 2015b). Accordingly, the N_2O emission from the farm was set to 1/41th of the total nitrogen lost to the atmosphere through denitrification. This is according to the above-mentioned fact of the N_2O to N_2 ratio of alkaline soils. Therefore, the amount of atmospheric nitrogen produced from the denitrification process was found to be 230.4 kg/ha/year (Fig. 3.6). Hence, N_2O emission from the farm due to denitrification processes was estimated to be 5.62 kg/ha/year. This estimation is comparable with the denitrification-driven N_2O emissions estimated in the Bornhoved Lake region, northern Germany (5.3 kg/ha/year; Mogge et al. 1999).

As discussed in the methodology section, the target nitrogen uptake capacity of sugarcane was set to 33.6 kgN/ha. However, the rate of N fertilizer application on the farm was 104 kgN/ha for sugarcane plant, 130 kgN/ha for first and second-ratoon crops and 156 kgN/ha for the third ratoon crops (Shishaye 2015b). This shows that

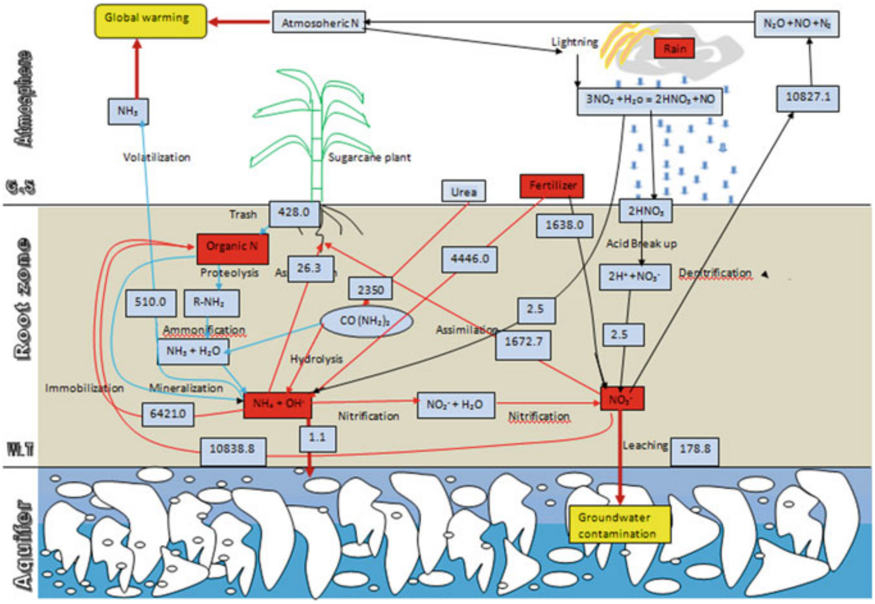

Fig. 3.6 Simulation results. Nitrogen gas emission as a result of denitrification was found to be 10,827.1 kg/ha/47 years, while the amount of nitrate leaching was 178.8 kg/ha/47 years. The model also estimated the extents of the different forms of nitrogen from the different sources at different stages of the nitrogen cycle

the application rate was not balanced with the standard crop uptake capacity. It, therefore, has led to a loss of nitrogen in the form of gas to the atmosphere and leaching down to the aquifer underneath (Fig. 3.6). However, the amount nitrogen loss from the system due to denitrification was around 61 times higher than the nitrate leaching loss (Fig. 3.6). This was typically caused by the excess water and nitrogen application rates, and the low nutrient uptake capacity of sugarcane. Gaseous (N_2O and N_2) nitrogen loss was also 6.5 times higher than the nutrient uptake capacity of sugarcane (Fig. 3.6).

Thus, a 10,000 ha sugarcane farm with the above-mentioned nitrogen application scenario was found to contribute 5.62 kg-N_2O/ha/year to the atmosphere. This amount seems to be small. However, it only represents 10,000 ha of sugarcane farm. Furthermore, the global estimation of N_2O emission from nitrogen fertilizers applied to the soil is around 1% (Arne et al. 1997) of the applied nitrogen, which also seems very small, while agriculture is believed to create a global sum of around 4.5 million tons of N_2O per annum (IPCC 2013; Denman et al. 2007). Therefore, even the small number of estimates imply dangerous risks in terms of the contribution of global agricultural farms to global warming and the warming potential of N_2O. On the other hand, the impact of the estimated N_2O emission from this study (5.62 kg-N_2O/ha/year) on global warming is equivalent to 1686 kg-CO_2/ha/year.

In fact, projecting the amount of N_2O emission estimated from this site to the global mechanized agricultural farms seems to yield a huge amount of N_2O emission. However, projecting an estimate from a small area to global scale will yield high uncertainty as well. Hence, to reduce the levels of uncertainties and to attain the global goals of greenhouse gas emission reduction through designing appropriate management strategies, site-specific studies are very important, as management strategies may vary spatially and temporally. The results from this study show how important appropriate agricultural management, including the balanced fertilizer and water application with the crop uptake capacity, is to tackle against the changing climate and to achieve the goals of decreasing the rates of N_2O emissions. However, the important causes of increased N_2O emissions may vary spatially (Ma and Tipping 1998; Signor et al. 2013a). Therefore, this suggests that the estimation of N_2O emissions at farm levels can solve the uncertainty states in the estimation processes and help to suggest/design appropriate site-specific management strategies to reduce greenhouse gas emissions.

There are different management practices that can help to decrease the emission rates of N_2O from agricultural farms. Even though this work was mainly about N_2O emissions through denitrification, N_2O can also be emitted from nitrification processes. Therefore, factors influencing the nitrification and denitrification processes, such as soil moisture, temperature, oxygen concentration, amount of available organic carbon and nitrogen and soil C:N ratio can affect the emission rates of N_2O from agricultural farms. Among these factors, those related to the soil could be easily altered by management practices. Therefore, understanding the processes of N_2O formation in soils and the factors influencing the emission process is fundamental to develop efficient strategies to reduce N_2O emissions from agricultural soils.

Looking at the denitrification processes separately, the amount of water filled in the soil pore spaces is the main factor influencing the emissions of N_2O from a system (Snyder et al. 2009; Brentrup et al. 2000; Bremner et al. 1980; Davidson and Swank 1986). Denitrification is the anaerobic conversion of nitrate nitrogen to the gases, N_2O and N_2. The last step in microbial denitrification is the reduction of N_2O to N_2. The intermediate in the anoxic reduction of NO_3^- to N_2 follows the following procedure: $NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$ (Lewicka-Szczebak et al. 2017; Barbarick 2014; Zhu et al. 2013; Easton and Lassite 2013; Thomson et al. 2012; Hofstra and Bowman 2005; Andrew and Erin 2002; Johnson et al. 1993). Therefore, the process of denitrification occurs in waterlogged soils and it requires an energy source (carbon) and warm soil temperatures. Unlike N_2O, N_2 is not a greenhouse gas. However, the loss of N_2 from the soil means less N fertilizer uptake by plants (Arne et al. 1997). On the other hand, the loss of N_2O from cropping areas is environmentally significant. Thus, in addition to the balanced application of nitrogen fertilizers with the crop uptake capacities, balanced application of water based on the crop demand is also very important to reduce N_2O emissions from agricultural farms through denitrification processes.

Conclusion

In this work, the LEACHN model was used to predict N_2O emissions from the Metahara Sugarcane Farm due to denitrification processes. A significant amount of N_2O emission was predicted from the farm. The main cause of the considerable N_2O emission from the farm was an unbalanced application of nitrogen fertilizer with the nutrient uptake capacity of sugarcane. The other likely cause was related to excess irrigation water application on the farm. However, these causes may not be important in other places with different nutrient and water application scenarios. This suggests that farm scale estimation of N_2O emissions is very important to use the information generated under specific climate, soil conditions, and fertilizer and water application scenarios so that to reduce uncertainties associated with global projections and design site-specific management strategies to achieve the emission reduction goals. The limitation of this work is that it only considers N_2O emissions from denitrification processes, while N_2O can also be emitted from nitrification processes. Therefore, this should be considered in future research in the area for a comprehensive understanding of N_2O emissions from the farm.

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References

Ahmed M, Anchukaitis K, Asrat A et al (2013) Continental-scale temperature variability during the past two millennia. Nat Geosci 6:339–346
Andrew O, Erin B (2002) Chemistry and the nitrogen cycle. Alaska agriculture in the classroom, pp 1–6
Arne S, William L, James S (1997) Denitrification as a component of the nitrogen budget for a large plains river. Biogeochemistry 39:327–342
Aurepio A (2012) Ammonium sulfate nitrate. http://www.aurepio.pl/en/nitrogen-fertilizers/ammonium-sulphate-nitrate-s250. Accessed 12 Dec 2015
Australian Academy of Science (2015) The science of climate change: questions and answers. Australian Academy of Science, Canberra, www.science.org.au/climatechange. Accessed 3 April 2019
Barbarick KA (2014) Nitrogen sources and transformation. Fact Sheet No. 0.550, Colorado State University Extension, Colorado, USA
Barry AJD, Goorahoo D, Goss M (1993) Estimation of nitrate concentrations in groundwater using a whole farm nitrogen budget. J Environ Qual 22:1–10
Barton PK, Atwater JW (2002) Nitrous oxide emissions and the anthropogenic nitrogen in wastewater and solid waste. J Environ Eng 1–12
Beaulieu et al (2011) Nitrous oxide emission from denitrification in stream and river networks. PNAS Environ Sci 108(1):214–219

Biggs I (2003) An investigation of sugarcane nitrogen physiology: sources, uptake and metabolism. Ph.D. Thesis, The Queensland University, School of Integrative Biology

Booker Tate Limited (2009) Re-evaluation of plantation soils at Metahara sugar factory. Masters Court, Church Road Thame, Oxon, UK

Bremner JM et al (1980) Formation of nitrous oxide and dinitrogen by chemical decomposition of hydroxylamine in soils. Soil Biol Biochem 12(3):263–269

Brentrup F et al (2000) Methods to estimate on-field nitrogen emissions from crop production as an input to LCA studies in the agricultural sector. Int J Lifecycle Assess 5(6):349–357

Cerri CC et al (2009) Brazilian greenhouse gas emissions: the importance of agriculture and livestock. Sci Agric 66(6):831–843

Dahan O, Babad A, Lazarovitch N, Russak EE, Kurtzman D (2014) Nitrate leaching from intensive organic farms to groundwater. Hydrol Earth Syst Sci 18:333–341

Dalal R, Wang W, Robertson GP, Parton WJ, Myer CM, Raison RJ (2003) Emission sources of nitrous oxide from Australian agricultural and forest lands and mitigation options. National Carbon Accounting System Technical Report No. 35, Australian Government, Australian Greenhouse Office, pp 3–64

Davidson EA, Swank WT (1986) Environmental parameters regulating gaseous nitrogen losses from 2 forested ecosystems via nitrification and denitrification. Appl Environ Microbiol 52(6):1287–1292

Denman KL, Brasseur G, Chidthaisong A, Ciais P, Cox PM, Dickinson RE, Hauglustaine D, Heinze C, Holland E, Jacob D, Lohmann U, Ramachandran S, da Silva Dias PL, Wofsy SC, Zhang X (2007) Couplings between changes in the climate system and biogeochemistry. In: Climate change: the physical science basis. Contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

DiMento J, Doughman FC, Pamela M (2007) Climate change: what it means for us, our children, and our grandchildren. The MIT Press, p 68

Easton ZM, Lassite E (2013) Denitrification management. Virginia Tech: invent the future, Virginia cooperative extension. Publication BSE, p 54

Forster P et al (2007) Changes in atmospheric constituents and in radiative forcing. In: Solomon S et al (eds) Climate change, the physical science basis. Cambridge University Press, Cambridge, pp 129–234

Hartmann D, Klein T, Rusticucci M (2013) Observations: atmosphere & surface. IPCC WGI AR5 (Report), p 198

Hayatsu M, Tago K, Saito M (2008) Various players in the nitrogen cycle: diversity and functions of the microorganisms involved in nitrification and denitrification. Soil Sci Plant Nutr 54(1):33–45

Hofstra N, Bowman AF (2005) Denitrification in agricultural soils: summarizing published data and estimating global annual rates. Nutr Cycl Agroecosyst 72:267–278

Hughes L (2000) Biological consequences of global warming: is the signal already. TREE 15(2):56–61

Hutson JL (2003) Leaching Estimation and Chemistry Model: a process-based model of water and solute movement, transformations, plant uptake, and chemical reactions in the unsaturated zone, version 4. Department of Crop and Soil Sciences, Research Series No. R03-1, Cornell University, Ithaca, NY, USA

Hutson J, Wagenet R (1992) LEACHM (Leaching Estimation and Chemistry Model): a process-based model of water and solute movement, transformations, plant uptake and chemical reactions in the unsaturated zone, Vers. 3.0. Department of Soil, Crop and Atmospheric Sciences, Cornell University, Ithaca, NY

IPCC (2007) Climate change, mitigation of climate change, contribution of working group III to the intergovernmental panel on climate change, fourth assessment report, Cambridge

IPCC (2013) The physical science basis—summary for policymakers, observed changes in the climate system. http://www.climatechange2013.org/images/report. Accessed June 2014

Iqbal J, Parkin TB, Helmers MJ, Zhou X, Castellano MJ (2014) Denitrification and nitrous oxide emissions in annual croplands, perennial grass buffers, and restored perennial grasslands. Soil Sci Soc Am J 52:1–15

Johnson A, Cabrera M, Hargrove W, McCracken D, Harbers G (1993) Estimating nitrate leaching and soil water dynamics with LEACHM. Institute of Natural Resources, The University of Georgia, Athens, Georgia, p 371

Karl TR, Trenberth KE (2003) Modern global climate change. Science 302:1719–1723

Le Treut H, Somerville R, Cubasch U, Ding Y, Mauritzen C, Mokssit A, Peterson T, Prather M (2007) Historical overview of climate change science. In: Climate change. Cambridge University Press. Accessed 14 Dec 2008

Lewicka-Szczebak D, Augustin J, Giesemann A, Well R (2017) Quantifying N_2O reduction to N_2 based on N_2O isotopocules—validation with independent methods (helium incubation and ^{15}N gas flux method). EGU: Biogeosciences 14:711–732

Lu JV, Gabriel A, Reichler T (2007) Expansion of the Hadley cell under global warming. Geophys Res Lett 34(6):1–12

Ma Q, Tipping RH (1998) The distribution of density matrices over potential-energy surfaces: application to the calculation of the far-wing line shapes for CO_2. J Chem Phys 108:3386–3399

Mogge B, Kaiser E, Munch J (1999) Nitrous oxide emissions and denitrification N-losses from agricultural soils in the Bornhöved Lake region: influence of organic fertilizers and land-use. Soil Biol Biochem 31(9):1245–1252

NASA (2016) Science Mission Directorate article: water cycle. http://nasascience.nasa.gov/earth-science/oceanography/ocean-earth-system/ocean-water-cycle. Accessed June 2017

NASA, Jet Propulsion Laboratory website. https://www.jpl.nasa.gov/edu/teach/activity/graphing-global-temperature-trends/. Accessed 5 May 2019

Oenema O, Kros H, De-Vries W (2003) Approaches and uncertainties in nutrient budgets: implications for nutrient management and environmental policies. Eur J Agron 20:3–16

Schwenke G, Haigh B, McMullen G, Brock P (n.d) Nitrous oxide—an indicator of N loss? NSW Department of Primary Industries and David Herridge, University of New England, Primary Industries Innovation Centre, GRDC code: UNE00012

Signor D, Eduardo C, Cerri P (2013a) Nitrous oxide emissions in agricultural soils: a review. Pesq Agropec Trop 43(3):322–338

Signor D, Cerri CEP, Conant R (2013b) N_2O emissions due to nitrogen fertilizer applications in two regions of sugarcane cultivation in Brazil. Environ Res Lett 8:1–5

Shishaye HA (2015a) The negative impacts of climate change in sub-Saharan Africa and their mitigation measures. Br J Appl Sci Technol 11(5):1–18

Shishaye H (2015b) Simulations of nitrate leaching from sugarcane farm in Metahara, Ethiopia, using the LEACHN model. J Water Resource Prot 7:665–688

Snyder RL (1992) Equation for evaporation pan to evapotranspiration conversions. J Irrig Drain Eng 118(6):977–980

Snyder CS et al (2009) Review of greenhouse gas emissions from crop production systems and fertilizer management effects. Agric Ecosyst Environ 133(3–4):247–266

Stokes B, Wike R, Carle J (2015) Global concern about climate change, broad support for limiting emissions: U.S., China less worried; partisan divides in key countries. Pew Research Center. http://www.pewglobal.org/2015/11/05/global-concern-about-climate-change-broad-support-for-limitingemissions/. Accessed 18 June 2016

Syakila A, Kroeze C (2011) The global nitrous oxide budget revisited. Greenh Gas Meas Manag 1(1):17–26

Thomson AJ et al (2012) Biological sources and sinks of nitrous oxide and strategies to mitigate emissions. Philos Trans R Soc Biol Sci 367:1157–1168

Toride N, Chen D (2011) Fate transport modelling of nitrogen and organic matter in soils. Mie University, Tsu, Japan

Vitousek PM (1994) Beyond global warming: ecology and global change. Ecol Soc Am 75(7):1861–1876

Welch DW, Ishida Y, Nagasawa K (1998) Thermal limits and ocean migrations of sockeye salmon (*Oncorhynchus nerka*): long-term consequences of global warming. Can J Fish Aquat Sci 55:937–948

Zaman M, Nguyen ML, Simek M, Nawaz S, Khan MJ, Babar MN, Zaman S (2012) Emissions of nitrous oxide (N_2O) and di-nitrogen (N_2) from the agricultural landscapes, sources, sinks, and factors affecting N_2O and N_2 ratios. Greenhouse gases—emission, measurement and management. Intechopen. ISBN: 978-953-51-0323-3

Zhu X, Burger M, Doane TA, Horwath WR (2013) Ammonia oxidation pathways and nitrifier denitrification are significant sources of N_2O and NO under low oxygen availability. PNAS: Agric Sci 110(16):6328–6333

Chapter 4
Business Strategies and Climate Change—Prototype Development and Testing of a User Specific Climate Service Product for Companies

Markus Groth and Peer Seipold

Abstract Companies are increasingly concerned with current and future climate change risks and opportunities that have the potential to generate a substantial change in their business operations, revenue and/or expenditure. Against this background, the paper presents and discusses the methodology and results from a joint activity carried out by the Climate Service Center Germany (GERICS), the management consultancy CSR Management Services, as well as the German 2° Foundation and eight of its supporting companies in Germany. Based on the practical requirement to develop a novel approach to increase awareness for companies to adapt to climate change, a questionnaire has been co-developed as a novel "Company Analysis Tool", which considers the influence of climate change on key business indicators and planning strategies. Additionally, a first implementation and testing of the "Company Analysis Tool" took place, whereby 35 interviews have been carried out with the top-level management involved. Therefore the main objective was to raise awareness for climate change and the need for adaptation measures. The paper presents and discusses the methodology, practical implementation, results and lessons learned as part of this prototype development and testing of a climate service product for companies. One main outcome of the project was to learn about the crucial importance of closely integrating companies in the development of a climate service product at an early stage and on an equal footing. Besides awareness raising and a company-specific analysis, the detailed reflection of climate change opportunities and risks has also been of great interest and importance for the participating companies. Therefore our approach with a clear focus on companies' specific challenges in different sectors proved to be a useful climate service product, with results of high relevance for adaptation practice and business.

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Introduction

Climate change challenges companies all over the world, forcing them to take action in climate change mitigation and adaptation (Brunsmeier and Groth 2015b; CDP 2015; UN Global Compact 2015; Arent et al. 2014; IPCC 2014; Okereke et al. 2012; Agrawala et al. 2011; UKCIP 2010). Thereby climate change imposes several risks for companies, investors and financial stability in general (Sakhel 2017; Battiston 2016; Carney 2015). The Economist Intelligence Unit (2015) estimated the value at risk as a result of climate change at 4.2–43 trillion US Dollar between now and the end of the century and indicates that a wide range of assets might be affected. In addition, Mark Carney (2015), the governor of the Bank of England, highlighted in a worldwide noted speech that financial stability is threatened by climate change due to the "Tragedy of the Horizon". He referred to the dilemma that the "catastrophic impacts of climate change will be felt beyond the traditional horizons of most [financial] actors—imposing a cost on future generations that the current generation has no direct incentive to fix" (Carney 2015, 3) and stressed that climate change related risks threaten financial stability (Carney 2015). Assessing the impact these climate-related risks have on the financial system is ranked as one of the most crucial societal issues due to the importance of financial stability for the world economy and social well-being (Battiston 2016; ESRB Advisory Scientific Committee 2016; Carney 2015).

The World Economic Forum also reflects on the significance of climate change in its annual "Global Risks Report". Within the "Global Risks Report 2016" (World Economic Forum 2016) the failure of climate change mitigation and adaptation has risen to the top and was perceived as the most impactful risk for the years to come. The "Global Risks Report" (World Economic Forum 2018) shows that environmental risks have even grown in prominence in recent years. This trend has continued this year, with all five risks in the environmental category being ranked higher than average for both likelihood and impact over a 10-year horizon.

The possible negative impacts of climate change for businesses, therefore, range from an increase in production costs or a decrease in demand up to the destruction of entire productions lines and the breakdown of the core business (IPCC 2014; Linnenluecke et al. 2013; Agrawala et al. 2011; Linnenluecke and Griffiths 2010; Aragón-Correa and Sharma 2003). Hence, for companies the aim is both to minimize risks and also to be able to take opportunities from a changing climate (Groth and Brunsmeier 2016; UN Global Compact 2015; IPCC 2014).

Companies are in general affected by climate change on a regulatory level (e.g. by emissions trading systems or environmental impact assessments), on a physical level (e.g. by an increasing temperature or changes in precipitation patterns) as well as on a market level (e.g. through changes in consumer behavior or capital market-related influences) (CDP 2015, 2017; BSR 2016; Groth and Brunsmeier 2016; Brunsmeier and Groth 2015a, b; UN Global Compact 2015; Arent et al. 2014; CDP and Climate Service Center Germany 2013, 2014; Linnenluecke et al. 2012, 2013).

Climate change-related risks and opportunities differ significantly from one company to another, based on the specific companies' activity, location, as well as supply chain (CDP 2018; BSR 2016; Groth and Brunsmeier 2016; CDP 2015; Brunsmeier and Groth 2015b; CDP and Climate Service Center Germany 2013, 2014; Linnenluecke et al. 2013).

Due to specific vulnerabilities and capacities, companies also need company-specific adaptation measures (Linnenluecke et al. 2013; Linnenluecke and Griffiths 2012; Busch 2011). But how should climate change knowledge and information be processed to not only sensitize companies to the need of adapting to climate change, but also to reflect and analyze business strategies?

Addressing this specific challenge, the project "Business Strategies and Climate Change" has been carried out in Germany. The project was a joint effort between the Climate Service Center Germany (GERICS) and the German 2° Foundation, as well as the management consultancy CSR Management Services. The project was structured in two phases. During the first phase, the methodological approach was developed and tested with the support of three member companies of the 2° Foundation. As part of the second phase, an adjustment and further development of the procedure as well as an in-depth practical examination with five other member companies of the 2° Foundation has been carried out. A main part of the project was the development and testing of the so-called "Company Analysis Tool". The "Company Analysis Tool" includes questions regarding the main organizational areas of companies, mainly aiming to raise awareness for adapting to climate change. A major goal was also to stimulate decision makers to critically question and recognize company-specific processes and structures in light of potential interdependencies with climate change.

The paper is structured as follows. Based on an introduction of the framework conditions of the project, the methodological approach is described in the second section. Thereby the focus lies on the development and testing of the "Company Analysis Tool". The third section discusses the results of the project, whereby both the scientific and business perspectives are taken into account. Based on the experiences and results from this project, ten recommendations for action how to integrate climate change into business strategies (section four) will be introduced. Finally, a conclusion summarizes the major findings and briefly highlights further need for research.

Methodological Approach

Development of the "Company Analysis Tool"

The development of the "Company Analysis Tool" was based on preliminary considerations of the effects of climate change on businesses and companies. The starting point was a classical model of economic value chains, additionally placed in the company/community sector and surrounded by suppliers and consumers (Porter 1985,

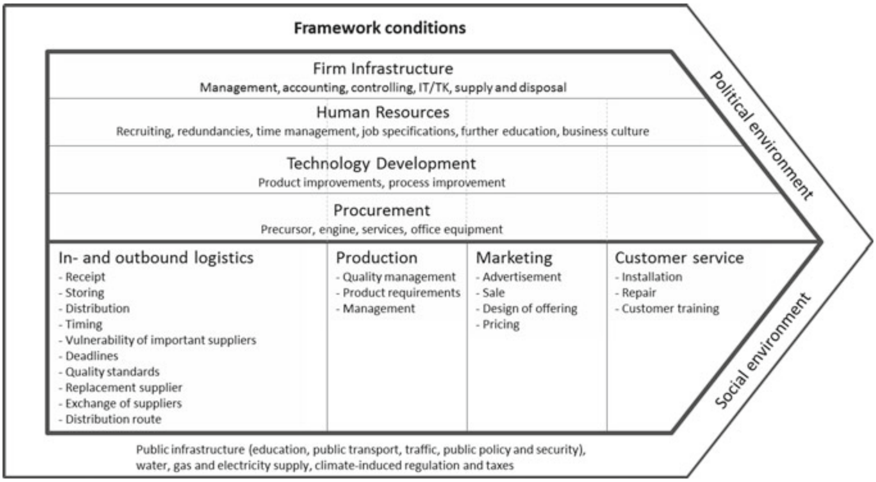

Fig. 4.1 Criteria along the value chain. *Source* Own, based on Porter (1985, 37)

1998, 2010). Three complementary perspectives are addressed to consider the possible influences of climate change on operational activities as comprehensively as possible.

Relevant Areas of Analysis Along the Value Chain

The concept of the value chain by Porter has been used to analyze the operational value-creation based on interrelated factors of production (primary and secondary activities). Various value chains yield a value system, which corresponds to an overall value chain. As a first step, the project team identified value-creating activities within companies relevant with regard to climate change (Fig. 4.1).

Relevant Areas of Analysis Along the Value Levers

As a second step, the extent to which climate change may have an influence on production factors and stakeholders with a leverage effect on revenue and profit was analyzed (value levers). This approach is not based on an established model, hence a specific procedure was established. In total, the following eight areas of analyses (Table 4.1) were discursively deduced by the project team. Included are those production factors not being considered in the value chain concept of Porter.

Table 4.1 Criteria regarding value levers

Management and management systems – Target systems – Incentives – Decision actions at investments – Environment controlling – Support programs for affected communities – Cross industry participation or local industry initiative – Anticipation of political interventions	**Facilities/locations** – Resilience requirements for existing locations – Selecting and planning of locations – IT/TK-Infrastructure (own data centers) – On site utilities (electricity, water, gas etc.) – Stocks, aggregates	**Costumers** – Changed demand – Customer satisfaction – Willingness to repurchase – Recommendations – Customer loyalty – Costumer acquisition	**Employees** – Health and security of employees – Support programs for affected employees – Reputation of employers
Reputation – Credibility – Brand trust – Media feedback	**Innovation** – Impact on technical, social and organizational innovations – Research and development efforts	**Organization and operative efficiency** – Location based emergency plans (authorities, stakeholder, charities) – Risk maps – Disaster-teams	**Investors** – Access to finance – Creditworthiness – Ratings – Insurance category

Source Own

Relevant Areas of Analysis Along the Value Driver

Furthermore, the potential effect of climate change on the financial outcome of business activities has been considered. The driver tree was used for this purpose as a classic economic model (following the “Du-Pont-Scheme”; see for example Horváth 2011 or Bausch and Kaufmann 2000). Potential influence points for climate change related effects are illustrated on the right-hand side of Fig. 4.2. The left-hand side illustrates the measurability of corresponding impacts on economic successes. The different indicators of the “Du-Pont-Scheme”—if and how climate change may influence these, and how this may in turn impact economic success—have been discussed within the project team.

Against this background, the areas of analysis illustrated in Table 4.2—and deemed as fundamentally relevant—were deduced along the value driver. Here the focus lies on monetary indicators, which are relevant for the account balance and company management.

Structure and Content of the “Company Analysis Tool”

The three complementary areas value chain, value levers and value drivers are the main areas of investigation. In order to limit the planned interviews to one and a half hours, the project team prioritized possible subtopics based on their perceived

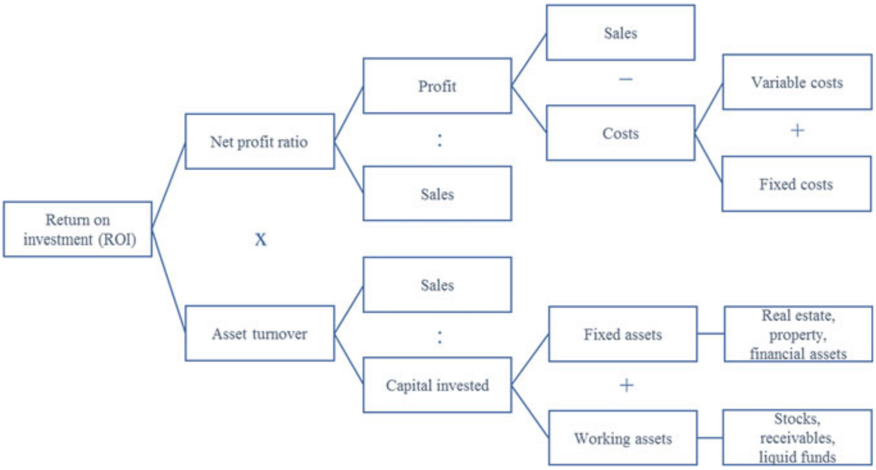

Fig. 4.2 Driver tree based on the “Du-Pont-Scheme”. *Source* Own

Table 4.2 Criteria regarding value driver

Current asset – Stocks – Demands – Liquidity	**Variable costs** – Procurement costs – Production costs – Distribution costs	**Fixed assets** – Property assets – Tangible assets (machines, fleet, equipment)
Additional indicators – Revenue (regions, customer groups, product group) – Cash flow – Contribution margin – Profitability – Sales volumes – Turnover rate – Prices	**Fixes costs** – Procurement overheads – Productions overheads – Distribution overheads – Administration overheads – (Insurance costs)	

Source Own

importance. These estimates were merged during a successive project meeting. All subtopics with different prioritizations were jointly discussed, whereby the essential necessity of their inclusion was reflected. Based on the consensus-oriented discussions, the relevant subtopics were determined, which served as the bases for the “Company Analysis Tool”.

Thereby interview questions were formulated for each subtopic. In summary, the structure of the “Company Analysis Tool” is based on the following main organizational areas of companies (Table 4.3): (i) management and leadership, (ii) market, (iii) finances, (iv) infrastructure, (v) production and logistics and (vi) employees.

Table 4.3 Main organizational areas of companies and subtopics of the "Company Analysis Tool"

Management – Management board – Climate-induced regulation – Time horizon – Risk management – Accounting/controlling – Investors – Decisive action at investments, mergers and choice of location – Resilience of existing locations	**Market** – Changed demand and customer service – Influence on technical, social and organizational innovations – Product improvements and adjustments – Product quality – Costumers communication – New structure of markets due to competitors	**Finances** – Property assets – Participations – Tangible assets (machines, fleet, equipment) – Asset investments – Depreciation – Interest cost – Insurance costs – Stocks
Infrastructure – Emergency plans for failures of public infrastructures – Supply and disposal – Utilities – Risk-/opportunity-maps – IKT – IT/TK infrastructure (own data center) – Selection of data center provider	**Production and logistic** – Precursors – Warehousing – Distribution, transport, inbound and outbound – Termination – Resilience and vulnerability of important suppliers	**Employees** – Qualification requirements (skills, competences) – Trainings

Source Own

Each of the six main organizational areas of companies is divided into different company-relevant subtopics, whereby each subtopic is translated into specific questions. In total, the "Company Analysis Tool" includes 55 questions regarding 36 subtopics. The following questions taken from the "Company Analysis Tool" have been of particular relevance during the interviews and can serve as examples for questions focusing on the different organizational areas of companies:

(i) Management and leadership:

- Is the topic already in the company's strategic planning catalogue or has this been requested?
- Is there a channel or the possibility of feeding the topic "climate change" into the management board?
- What period does the strategic planning of your company encompass?
- Has or will an early warning system been/be set up?
- Do national and international corporate location program/action plans exist in order to increase resilience?

(ii) Market:

- Is the company able to take advantage of opportunities arising from climate-induced changes in demand (e.g. due to changes in lifestyle)?

– Does the company use opportunities for new products and services that may arise from climate change?
– Is the functionality and performance of products or services under changed climatic conditions guaranteed at the same or at least comparable quality?
– Is there a plan for customer communication in climate-related crises?

(iii) Finances:

– Is the company taking into consideration its own location and the risk of devaluation of land, because climatic effects could affect its value?
– Is the company taking into account the opportunities and risks of climate change on investments?
– Is the company taking into account increased depreciation requirements and asset impairments by climate-related impacts?

(iv) Infrastructure:

– Does an emergency or contingency plan exist for the failure of public and technical infrastructure at each of the national and international corporate locations (public transport, traffic, public order and security, water, gas, electricity, schools, etc.) as well as for the cooperation with local authorities, stakeholders and aid organizations?
– Is a self-contained power, fuel (e.g. gas) and water supply available at national and international corporate locations?
– Do geographical risk maps for climate change impacts exist for national and international locations?
– Are in-house IT/telecom infrastructure (networks, data centers, accounts points) designed to be resistant to climate change impacts?

(v) Production and logistic:

– Have you made sure that primary products, semi-finished goods or inputs that are essential for the production process or for the provision of services by the main and spare suppliers, can be supplied in the same quality in order to avoid failures induced by climate change?
– Do warehouse stocks at the company's sites exist in sufficient number in order to overcome supply bottlenecks (e.g. from areas affected by impacts of climate change) and to keep production running?
– Are buffer times in incoming and outgoing logistics scaled in a way that effects related to climate change (e.g. transport delays) are factored in?
– Does information exist that will allow an assessment of the degree of climate-resilience/vulnerability of the most important suppliers?
– Is there a development programme aimed at strengthening the resilience of the main suppliers?

(vi) Employees:

- Do you expect that the skill profile of the workforce will change due to requirements related to climate change?
- Are programs offered for further training or a systematic exchange of knowledge in order to match the required skills profile of employees due to climate change?

Cooperation with Companies

The appointments with the companies included a pre-evening meeting as well as the actual work meeting (interviews). A total of 35 interviews were held at eight different companies. In the second phase of the implementation and testing, two informal interviews with CEOs were carried out. Aims of the pre-evening meetings for the participants were to become familiarized with each other, to introduce the project, to explain the developed approach, as well as to answer general questions. On the following day, the interviews took place. The selection of participating decision makers was the responsibility of the company representative of the 2° Foundation. Each of them received the "Company Analysis Tool" several weeks beforehand, and appointed interview partners within the company based on the interview contents. Generally, the interview partners have been working in the areas of strategy, finances, procurement, logistics, product development, marketing or human resources.

After the first implementation and field testing of the "Company Analysis Tool" with three companies, the findings of the first project phase were used to critically examine and evolve the content. Some questions were reformulated or removed, and additional questions have also been included.

In the second project phase, the updated "Company Analysis Tool" was again implemented and tested in practice. Five additional member companies of the 2° Foundation participated. The involvement of partners in the field intended to give the project team a more detailed implementation knowledge as well as practical experience about how different companies deal with decisions on climate change impacts. At the same time, the participating company representatives were able to receive more information and persuasive argumentation skills in handling the topic of climate change adaptation within their companies.

For the completion of the project, a summarizing feedback meeting for the participating companies was organized in order to present the (anonymized) project results. Additionally, each company received an individual evaluation of the interviews as a confidential document. This evaluation included (i) company-specific recommendations, (ii) anonymous references from the interviews, (iii) an anonymous comparison with other participating companies, (iv) general recommendations for actions, as well as (v) the current version of the "Company Analysis Tool".

Results

In addition to identifying different service and user requirements for individual companies, such as the analysis of climate change-induced risks for production sites and supply chains, the project and associated discussions with companies from different sectors contributed to the generation and solidification of important practical knowledge. Moreover, crucial findings about the existing demand for information about climate change and adaptation were gained. Thereby the interviews made for example clear, that currently companies have a greater need for either past climate data or data analysis for the next one to maximum five years, as they can be more easily integrated into decisions and processes compared to long-term climate predictions. Hence, a lack of relevance was considered due to the fact that longer-term data is too far beyond companies' time horizons. This is in line with the current literature (Soares and Dessai 2016; European Commission 2015).

In general, the results from the interviews showed that companies are already affected by climate change and will continue to be affected in the future. Regarding their primary economic activity, one main impact is a change in the quality and availability of input factors, which also influences their prices. Since some of the main manufacturing facilities and also distribution infrastructures are located in vulnerable regions, climate change has a strong relevance regarding the stability and continuity of supply chains. Furthermore, companies are influenced by climate change regulations, as well as expected changes in the demand for products. These overall results from the interviews are very much in line with the current literature on the influence of climate change on companies (CDP 2017, 2018; World Economic Forum 2018; Sakhel 2017; Groth and Brunsmeier 2016; Brunsmeier and Groth 2015a; UN Global Compact 2015; Arent et al. 2014).

The adaptation to climate change, however, is currently not the most important topic for the companies, as they assume to be able to react in due time and are able to change their suppliers, if needed. Although a general interest in climate services is prevalent, they currently do not see direct physical impacts as an urgent topic, as these are not perceived as an actual threat. On the other hand, climate change as a business opportunity is perceived as important.

What also turned out to be very relevant during the interviews was a differentiation of the assessments regarding the main organizational areas of companies. Regarding management and leadership, there is often no clear answer to the question of the extent to which the issue of climate change is anchored in the executive board, whereby climate change is currently still mainly perceived as a risk. A few companies already perceive climate change as a business opportunity, whereby an early consideration of shifting consumer needs is of great importance. The possibility of looking at opportunities, however, has often not yet been established.

In the organizational area of production and logistics, companies often pointed out that they usually have few alternatives, as trucks are the most important means of transport. For ships, the supply chain can be interrupted, whereby disasters or climatic conditions are currently not sufficiently studied. In general, there is a great awareness that climate change combined with environmental requirements will influence the way in which companies produce in the future. Regarding the need for climate information, for example, it would be of interest for companies to know where suppliers are located and what climatic challenges are relevant for the management of these locations. Such information or data could then be "played through" with climate scenarios in order to identify the most important risks. As such, there is a well-defined need to include background information on climate change. However, often there is still no clear pathway of how to include climate impacts into decision making.

In general, the decision makers interviewed see the potential to use climate services in the future, even though they have so far hardly dealt with the topic. The most important step seems to raise awareness of climate-related threats and opportunities, in order to deal with a significant opportunity to improve their knowledge about how impacts of climate change—especially physical impacts—directly affect them. The main purchase driver for climate services is profit maximization, specifically in the short term. Because companies react on short timescales, decision makers develop strategic orientations for the next one to three years. In order to generate profits, short-term (seasonal to decadal) climate information could be helpful to support companies' decision making—mainly to proactively develop new strategies to adapt to climate change, taking into account the above-mentioned influences.

Potential purchase drivers could also include risk assessments for suppliers or supply chains, governmental regulations, and sales decline or revenue growth. The buying decision of climate services depends upon a company's structure and whether it is easier to sell climate services directly to the management in the company's headquarters, or to a company's branch in another country. In the case that climate services are applied in the future, companies would most likely buy them externally, rather than building their respective capacities internally.

Furthermore, necessary research areas for companies were detected. These included the necessity of scientifically sound and practicable methods for the estimation of the financial impacts of climate change on real estate, investments, properties, and amortization. For the companies' participants the individual evaluations and the derived recommendations for action were considered valuable and relevant in practice. To this end, it was important that the companies' individual situations were considered throughout the duration of the project.

The sensitization to and anchoring of the topic of adaptation to climate change were perceived as especially useful and innovative. Moreover, participation in the project was recognized as an important and effective impulse for an intensive internal reflection on the topic of climate change. Furthermore, the project enabled future process optimizations as well as improved internal topic-related networking.

Additionally, the project proved to be effective in identifying the adequate departments and divisions, and in bringing together the relevant stakeholders within the participating companies. It is important to mention here that the project was purposefully designed in a way that the overarching structures and departments—such as risk management, environment and climate change mitigation or sustainability—were not immediately relevant for the selection of the interview partners. The focus was instead placed on approaching the companies with the project-relevant functions. This facilitates companies in structuring and processing the topic in the future, contributing to minimizing inter-divisional strategical and operational gaps.

Recommendations for Action How to Integrate Climate Change into Business Strategies

Supporting companies with respect to climate change impacts needs a strong focus on business opportunities. A proactive analysis with climate change impacts can also open up possibilities for new business models or products. Still, businesses often struggle with the development and implementation of climate-proof strategies.

Creating awareness and a problem analysis are important starting points towards adaptation. Both need to use state-of-the-art climate change information with a focus on the identification of areas of vulnerability within the value chain. The idea behind this is to find the trigger for thought-provoking impulses. This could range from the planning and implementation of redundant system elements up to the relocation of suppliers and/or industrial facilities away from highly exposed sites. Thereby the role of climate service providers is to act as a catalyst introducing customized scientific knowledge to match a company's internal expertise. Interlinking the two subsequently enables a company to channel adaptation measures fit for its very own specific purposes.

Based on the project described above, we developed the following ten recommendations for actions as a sequence of steps for companies to integrate climate change as changing framework conditions into business strategies:

1. Create awareness for climate mitigation and adaptation on management or board level.
2. Consider climate change impacts in the company's strategic planning cycle by putting the topic on the agenda of a board or management meeting at least once a year, and implementing it as part of the risk management.
3. Use the management report for the communication with different stakeholders as well as for company-internal awareness-raising.
4. Develop criteria to strengthen the resilience of the sites together with the management of the branches.
5. Simulate critical climate events (production disruptions, supply bottlenecks, etc.), along with corporate communications to show how business would be affected and to supplement the crisis communication.
6. Carry out an analysis of the climate change risks of the company locations (climate hot spot maps) in order to be able to develop adaptation measures.
7. Check the contracts of external service providers at the sites regarding guarantees of force majeure (extreme weather events).

8. Check the availability of intermediate products, semi-finished and finished goods, for example for the duration of extreme weather events and the associated impairments until infrastructures have been restored.
9. Consider the impacts of climate change with your most important suppliers. Ask them to provide the relevant information also from their most important suppliers.
10. Use the internal corporate communication to report on implemented measures, so employees can document successes and effectively communicate knowledge.

Conclusion

For companies, the gradual and long-term nature of climate change often still creates a conflict, because corporate strategy planning rarely ever exceeds 3–5 years. Nonetheless, if companies do not start acting now and do not leave the "wait-and-see" mentality behind, it will continuously become more complex and cost-intensive to avoid major repercussions in the future.

Overall, the participating company representatives demonstrated a keen interest in the "Company Analysis Tool" as well as the accompanying implementation and testing. In addition to the thematic sensitization and the company-specific analysis, the strategically important opportunity of a consolidated reflection about opportunities and risks of climate change was of particular interest.

The "Company Analysis Tool" thereby served as an innovative approach for a thematically comparison, learning and improvement of the addressed company divisions. Moreover, often a stimulating and constructive discourse about the impacts of climate change for the company in question was initiated. The project also demonstrated that for the development of innovative and scientifically sound climate service products, it is crucial to work together with companies from the beginning onwards and based on individual company-specific situations. Through the involvement of company representatives from different sectors, a consolidated implementation expertise, as well as experiences about climate change-related decision making processes within companies, was generated. A challenge recognized throughout the overall process was the identification of quantifiable benefits of the adaption to climate change for companies, even if most of the participants recognize the urgent need to manage current and possible future impacts of climate change. Moreover, an important communication task for the project team was to guide the thematic focus of the interviews towards the adaptation to climate change, as the questions posed were sometimes mistaken with climate change mitigation.

In summary, the project showed that no “one-size-fits-all-adaptation” to climate change exists for companies. Even best-practice examples are in most cases not effective, as projecting from one company to another might ignore individual features and structures. However, the “Company Analysis Tool” and the accompanying approach proved to be a specific and scientifically sound climate service product, that is based on requirements from the private sector and helpful for companies to raise awareness and reflect on robust climate strategies.

Based on the project and it’s results additional recommendations for actions have been developed as a sequence of steps for companies to integrate climate change as changing framework conditions into future business strategies.

However, based on the project, additional need for research has been derived regarding the necessary next step of integrating climate information into business operations. As part of this currently ongoing work, it will—jointly together with companies—analysed which weather events and climatic changes can directly or indirectly affect the companies’ workflows and business processes. The identified impacts will then be prioritized with regard to their relevance for the company. The aim is to identify those affected areas that have the highest potential to influence companies. Climate parameters will then be selected for the most important impacts. For this purpose, available regional climate information for the identified climate parameters will be visualized and evaluated.

References

Agrawala S, Carraro M, Kingsmill N, Lanzi E, Mullan M, Prudent-Richard G (2011) Private sector engagement in adaptation to climate change: approaches to managing climate risks. OECD Environment Working Papers, No 39. http://dx.doi.org/10.1787/5kg221jkf1g7-en. Accessed 16 Oct 2018

Aragón-Correa JA, Sharma S (2003) A contingent resource-based view of proactive corporate environmental strategy. Acad Manag Rev 28(1):71–88

Arent DJ, Tol RSJ, Faust E, Hella JP, Kumar S, Strzepek KM, Tóth FL, Yan D, Amjad A, Haroon K, He X, Julius N (2014) Key economic sectors and services. In: Climate change 2014: impacts, adaptation, and vulnerability. Part A: global and sectoral aspects. Contribution of working group II to the fifth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp 659–708

Battiston S (2016) A climate stress-test of the financial system. Nat Clim Change 7(4):283–288

Bausch A, Kaufmann A (2000) Innovationen im Controlling—am Beispiel der Entwicklung monetärer Kennzahlensysteme. Controlling 3:121–128

Brunsmeier A, Groth M (2015a) Hidden climate change related risks for the private sector. University of Lüneburg Working Paper Series in Economics, Working Paper No. 333

Brunsmeier A, Groth M (2015b) Unternehmerische Klimawandelrisiken—Eine Sektor übergreifende Analyse auf der Grundlage von CDP Klima-Berichterstattungen. uwf UmweltWirtschaftsForum 23(3):111–115

BSR (2016) Adapting to climate change: a guide for the energy and utility industry. http://www.bsr.org/reports/BSR_Climate_Adaptation_Issue_Brief_Energy_Utilities.pdf. Accessed 16 Oct 2018

Busch T (2011) Organizational adaptation to disruptions in the natural environment: the case of climate change. Scand J Manag 27(4):389–404

Carney M (2015) Breaking the tragedy of the horizon—climate change and financial stability. Speech at Lloyd's of London, England. https://www.bis.org/review/r151009a.pdf. Accessed 29 Sept 2015

CDP (2015) CDP global climate change report 2015. https://www.cdp.net/CDPResults/CDP-global-climate-change-report-2015.pdf. Accessed 16 Oct 2018

CDP (2017) CDP Climate change report 2017, DACH 350+ Edition

CDP (2018) Closing the gap: scaling up sustainable supply chains. CDP supply chain report 2017/2018

CDP, Climate Service Center Germany (2013) Klimawandelvermeidung und Anpassung im Energiesektor—Deutschland, Österreich und Schweiz. http://www.climate-service-center.de/imperia/md/content/csc/cdp___csc_energiesektorstudie_opt.pdf. Accessed 16 Oct 2018

CDP, Climate Service Center Germany (2014) Klimawandelvermeidung und Anpassung im Transport- und Logistiksektor—Deutschland, Österreich und Schweiz. http://www.climate-service-center.de/imperia/md/content/csc/cdp-csc-climate-change-transport-logistic-2014-german.pdf. Accessed 16 Oct 2018

Economist Intelligence Unit (2015) The cost of inaction: recognising the value at risk from climate change. https://www.eiuperspectives.economist.com/sites/default/files/The%20cost%20of%20inaction_0.pdf. Accessed 16 Oct 2018

ESRB Advisory Scientific Committee (2016) Too late, too sudden: transition to a low-carbon economy and systemic risk. Report of the Advisory Scientific Committee, No. 6. https://www.esrb.europa.eu/pub/pdf/asc/Reports_ASC_6_1602.pdf. Accessed 16 Oct 2018

European Commission (2015) A European research and innovation roadmap for climate services. Directorate-General for Research and Innovation, Publications Office of the European Union, Luxembourg. https://ec.europa.eu/programmes/horizon2020/en/news/european-research-and-innovation-roadmap-climate-services. Accessed 13 May 2019

Groth M, Brunsmeier A (2016) A cross-sectoral analysis of climate change risk drivers based on companies' responses to the CDP's climate change information request. University of Lüneburg Working Paper Series in Economics, Working Paper No. 364

Horváth P (2011) Controlling, 12th edn. Vahlen Verlag, München

IPCC (2014) Climate change 2014: impacts, adaptation, and vulnerability. Part A: global and sectoral aspects. Contribution of working group II to the fifth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge

Linnenluecke MK, Griffiths A (2010) Beyond adaptation: resilience for business in light of climate change and weather extremes. Bus Soc 49(3):477–511

Linnenluecke MK, Griffiths A (2012) Assessing organizational resilience to climate and weather extremes: complexities and methodological pathways. Clim Change 113(3–4):933–947

Linnenluecke MK, Griffiths A, Winn MI (2012) Extreme weather events and the critical importance of anticipatory adaptation and organizational resilience in responding to impacts. Bus Strategy Environ 21(1):17–32

Linnenluecke MK, Griffiths A, Winn MI (2013) Firm and industry adaptation to climate change: a review of climate adaptation studies in the business and management field. Wiley Interdiscip Rev: Clim Change 4(5):397–416

Okereke C, Wittneben B, Bowen F (2012) Climate change: challenging business, transforming politics. Bus Soc 51(1):7–30

Porter ME (1985) Competitive advantage. Free Press, New York

Porter ME (1998) The competitive advantage of nations. Free Press, New York

Porter ME (2010) Wettbewerbsvorteile: Spitzenleistungen erreichen und behaupten. Auflage 7. Campus Verlag, Frankfurt/M

Sakhel A (2017) Corporate climate risk management: are European companies prepared? J Clean Prod 165(103):103–118

Soares MB, Dessai S (2016). Barriers and enablers to the use of seasonal climate forecasts amongst organisations in Europe. Sustainability Research Institute Paper No. 91, Centre for Climate Change Economics and Policy Working Paper No. 249, Sustainability Research Institute, Leeds, United Kingdom

UKCIP (2010) A changing climate for business, 3rd edn. UK Climate Impacts Programme (UKCIP), School of Geography and the Environment (OUCE), Oxford

UN Global Compact (2015) The business case for responsible corporate adaptation. Strengthening private sector and community resilience. A caring for climate report. https://www.cdp.net/CDPResults/C4C-Adaptation-Report-2015.pdf. Accessed 16 Oct 2018

World Economic Forum (2016) The global risks report 2016, 11th edn. Geneva

World Economic Forum (2018) The global risks report 2018, 13th edn. Geneva

Chapter 5
Why There Is More to Adaptation Than Creating a Strategy

Steffen Bender, Jörg Cortekar, Markus Groth and Kevin Sieck

Abstract Decision makers in cities and urban areas are key implementers of policy steps to meet the goal of curbing global warming to 1.5 °C compared to pre-industrial levels. This needs strong political leadership as well as major transitions in how both mitigation and adaptation are undertaken. However, as simple as adaptation to climate impacts can sound at the beginning, as difficult it becomes when working on it. Adaptation to climate change in urban areas is a complex process with mostly small scope for action. It requires the synthesis and integration of different approaches, methods, tools, interests and stakeholder engagement, all inside a rigid administrative and legal framework. The potential for an effective climate risk management including multiple sector-oriented adaptation actions is increased by combining local environmental and social information with regional projected climate impacts as well as different scales of potential risks. To positively influence the quality of life and the resilience of infrastructure in the future, it is necessary to consider first all possible impacts in planning and design processes in a strategy. Furthermore, the theoretical and legal framing needs to be transferred into operational adaptation actions. Thereby, the role of climate services will be further developed in a field currently still characterised by specific need for research.

Introduction

Climate change and urbanization are closely interconnected. Currently, more than a half of the world's population lives in urban areas with an expected increase of this share to approximately 60% by 2050 (United Nations 2018). As cities are important economic hubs, their demand for resources and the account of global CO_2 emissions is high. But, they are not only contributing to climate change, they will also be affected by expected climate change impacts such as urban and river floods after heavy rain events, storm surges or heat stress, which will most likely occur more frequently and

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Climate Change Management, https://doi.org/10.1007/978-3-030-36875-3_5

with increasing intensity in the future (Jacob et al. 2014; Revi et al. 2014; Collins et al. 2013). From the cities perspective, the top-five physical risks reported to the CDP are (i) more intense rainfall, (ii) more frequent heatwaves, (iii) more hot days, (iv) hotter summers, and (v) an increased urban heat island effect (CDP 2014; Groth et al. 2015). Thereby, the concentration of people, assets, critical infrastructure and economic activities exacerbates the potential of natural hazards and extreme weather events. This is why cities are key players with respect to climate change, both in terms of mitigation and adaptation. Hence, it is necessary to consider them jointly and equally when searching for solutions.

The important role of mitigation and adaptation efforts is also highlighted in the Global Risk Report 2018 (World Economic Forum 2018), whereas the risk categories "extreme weather events", "natural disasters" and "failure of climate change mitigation and adaptation" are among in the "top 5" in terms of likelihood and impact. Furthermore, it has to be pointed out, that one of the major challenges is dealing with complex risks in systems characterized by feedback loops and tipping points that can make interventions problematic (IRGC 2018).

City administration around the world are already well aware of climate change mitigation and the most important hydro-meteorological hazards relevant for their city. On the policy level damaging events mostly open a window of opportunity to improve the prevention against natural hazards, and to adapt actively to future climate impacts. But, with regard to climate change adaptation, however, there exist some ambiguities. A recent study for Germany shows, that nearly all cities with more than 100,000 inhabitants have a climate action plan or a mitigation strategy. In contrast, adaptation plans or strategies can be found preferably in the bigger cities with more than 500,000 inhabitants (Thieken et al. 2018).[1] Generally speaking, mitigation options that are quite easier to implement and presented to the public are preferred.

Even though effective adaptation measures are known—such as the preservation and expansion of green areas and water elements or the use of climate-sensitive construction materials—identifying, planning, implementing and monitoring respective measures is challenging and face many administrative barriers. Besides the lack of financial and human resources (Betsill and Bulkeley 2007), there is another big challenge: the high complexity of climate change impacts including their interaction with non-climatic drivers, and the occurrences at the interfaces between different urban fields of actions and administrative responsibilities. To face these challenges urban administrations developed many gradiations of adaptation actions (Reckien et al. 2014). However, with respect to adaptation actions there still exists the misbelief that developing an adaptation strategy or carrying out workshops is sufficient to be prepared for climate change. In reality, main work starts beyond the strategy development, where theory meets practice with the numerous existing barriers, conflicts and frames. Compared to mitigation, planning and implementation processes for adaptation actions are much more complex, because of a broad variety of interacting factors and drivers to be considered. Overall it is essential to understand the whole system

[1] State of data collection 05.07.2017.

with a holistic approach, that combines different methods, information, needs, challenges and knowledge to create synergies. This can be done with a so-called modular approach, because it can be tailored to the given framework.

The Specific Adaptation Environment in Urban Areas

The main goal for city administrations with respect to climate change impacts is the strengthening of resilience to protect inhabitants, assets, and elements of critical infrastructure. This includes measures to improve the skills of the urban society to learn from past events with regard to current and future climate impacts to define precautions and adaption options. A further challenge for the planning of successful adaptation actions is the necessity to consider impacts of cross-cutting climatic drivers—such as increasing temperature, heatwaves, droughts, river and urban flooding, sea level rise, changing precipitation patterns—and non-climatic drivers—such as demographic change or economic development—including their interactions. According to Moser and Ekstrom (2010) adaptation involves changes in social-ecological systems in response to actual and projected impacts. Hence, regional climate impacts can be described and linked easily to known adaptation activities (adaptation in theory, Fig. 5.1).

In practice, one has to face further environmental and legal components that lead to a more complex process when it comes to climate change adaptation on the local level. What is needed is a method that allows integration of state-of-the-art scientific knowledge with local information. With regard to the so-called policy regime (May and Jochim 2013) which defines the maneuvering space for adaptation actions

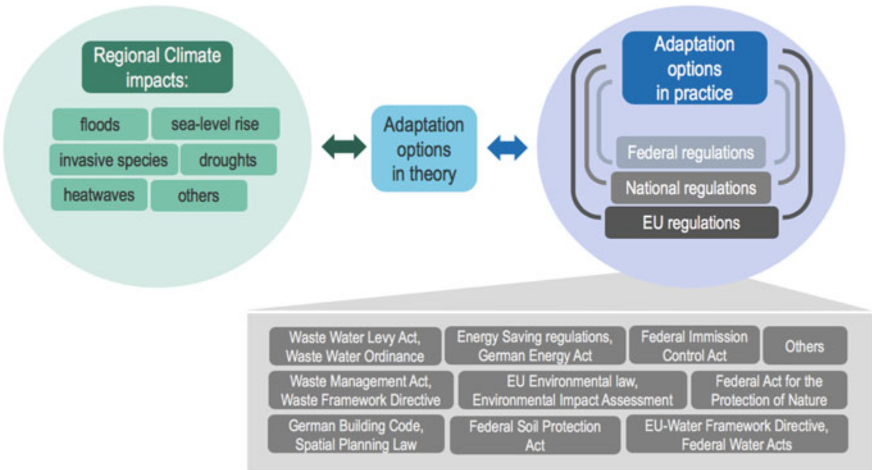

Fig. 5.1 Impact-tailored adaptation in theory and practice

there is only little room left for the development, implementation and maintenance of adaptation measures. The overall legal framework consists of different legislation levels from European laws to federal regulations characterized by conflicting interest of administrative units from the EU down to local scales. Each legislation level contains numerous acts, codes, directives, laws, guidelines and recommendations for each sector. Inside this complex framework conditions, adaptation action has to face several conflicts and competing processes that are lowering the implementation speed. Further important boundary conditions are limited financial and human resources, cultural habits, operational capabilities, and urban-rural relationship (Bender et al. 2015; Cortekar et al. 2015; Dilling et al. 2015; Terenzi and Westerlind Wigström 2014; Ricardo 2013). The planning and implementation of adaptation actions in urban areas are embedded in a complex frame influenced by internal and external drivers (Groth and Nuzum 2016; Umweltbundesamt 2015; Kalafatis et al. 2015; Ricardo 2013). In the last years climate change and its impacts are more and more included in law and regulation. However, in most cases it is unclear how to deal with climate change adaptation in practice, mostly due to missing methodology or experiences. Furthermore, adaptation in general is currently not particularly considered in administrative processes. Therefore, a modification of existing workflows and a functional allocation of responsibilities is needed. Both is challenging due to the cross-sectoral and transdisciplinary dimension of climate change impacts.

What is needed is a method that recognizes legal requirements and can be integrated in existing work flows.

A common procedure to bring together competing demands is the use of no-regret or low-regret-options, because they generate benefits even if the expected impacts of climate change do not occur or with a smaller impact (Bender et al. 2017a). These options however, are not easy to identify in practice due to conflicting interests. Another approach is to develop innovative measures that address two or more goals such as multiple functions of urban green spaces for the reduction of urban heat, increase of biodiversity, the possible use as retention room for rainwater after heavy rain events and the function as recreational areas. But besides theoretically best options, discussions with practitioners show, that addressing a new function in practise often goes hand in hand with new challenges due to the necessary integration of new parties and institutions in the adaptation process.

What is needed is a method that builds on intensive stakeholder integration, co-design of measures and communication.

With regard to local vulnerabilities or fields of actions each city has its own footprint depending on the climatic (now and in the future), environmental and socio-economic frame. This covers aspects such as geographic location, urban climate, relationships between city and surroundings, population density, projected climate impacts, local climate vulnerabilities, financial and human resources, and stakeholder interests. Each aspect has to be addressed specifically. Thereby a precise analysis and description of the different challenges is the basis for the development and implementation of scientifically sound and appropriate solutions. With regard to good practice in other cities, the individuality of each city and climate change related questions makes it nearly impossible to transfer an adaptation measures or strategy that was specifically designed for a given framework one-to-one from one to another city.

What is needed is a method that is flexible enough to tailor solutions to the individual needs and challenges.

In order to identify the specific opportunities and challenges arising from climate change for the city, it is necessary to understand all direct and indirect risks related to climate change throughout the entire urban adaptation process. Therefore, all related activities have to focus on the whole system instead of single elements, in order to avoid misleading action in sectors that would otherwise be overlooked or not adequately considered. Due to the large number of stakeholders and players, political and individual interests, single and interacting drivers, policies and regulations as well as short- and long-term challenges the urban system is complex. Besides, the associated interacting and competing components, sectors and institutions, the following aspects are necessary to develop sustainable and climate change-suitable city structure elements: the climate system (regional to local scale), the (urban) water cycle, the material cycle and numerous of value chains. Due to many non-linear relationships between different elements and dynamic processes with moving targets, this is a great challenge and still characterised by the need for both scientifically sound and user-based climate services.

What is needed is a method that is based on a holistic view.

Hence, the importance of addressing hands-on recommendation that support adaptation actions should not be underestimated. Most available tools, recommendations or developed products do not fit to the level of expertise found in the common local administrations. To guarantee the success and long-term benefit of a climate service product it is necessary to establish a transdisciplinary process in order to develop solutions that are useful for non-scientists and support for example municipal urban planners or other stakeholders in their daily work. This allows to integrate stakeholders from the very beginning on to ensure that their requirements are identified and thoroughly addressed from the start of the adaptation action development and on an equal footing (Steuri et al. 2018).

What is needed is a method that supports transdisciplinary processes.

All these aspects and specific needs have to be considered in climate change adaptation in urban areas. Consequently, an innovative and flexible methodological frame is needed that allows the integration of these multiple challenges.

The "GERICS Adaptation Toolkit for Cities" ("GERICS-Stadtbaukasten")

Experiences gained from several case studies (Bender et al. 2017a; Weyrich 2016) and research projects with regard to climate change impacts and associated adaptation measures in cities shows the necessity for a flexible tool that addresses a whole range of actions (Cortekar et al. 2016) based on a combination of scientific knowledge and local expertise. In fact, solutions have to be harmonised while considering existing administrative barriers as well as planning processes and structures. A flexible approach is needed, that can be tailored to individual needs within a city. This includes the applicability in all parts of the city and on all scales, independent of their specific settings, such as the environmental framework, the existing degree of information or the most pressing challenges.

With respect to the existing legal framework, administrative structures and procedures we developed a methodology that can easily be integrated into existing administrative process chains. This includes the possibility to bridge two or more workflows and making use of synergies. This function helps to reduce additional administrative efforts and it increases the acceptance of adaptation action in general. This is of utmost importance since in many cases adaptation activities compete with activities in other sectors such as educational and cultural services.

The idea behind the adaptation toolkit for cities (German product name: "GERICS-Stadtbaukasten") is the provision of a flexible and transparent product enabling a holistic view on the urban system, based of state-of-the-art regional climate information and options for all types of communication including transdisciplinary processes. This is done by the provision of numerous independent but easy-to-connect and easy-to-use modules within different module groups, which address different important aspects for cities—e.g. the vulnerability against all types of floods, the climate proofing of compensation measures (Bender et al. 2017a, b), or the thermal comfort in the future. The main idea is the support of the development and implementation of all kinds of adaptation actions. This includes techniques for a systematic assessment of current and future opportunities and vulnerabilities due to climate change impacts, based on the best available climate as well as social and environmental data and information.

The "GERICS-Stadtbaukasten" provides eleven independent but connectable thematic module groups—such as "Economics and financing", "Communication" or "Critical infrastructure"—including interfaces for example to the "GERICS adaptation toolkit for companies". It covers the most important areas of activities that are relevant for planning, developing and implementing adaptation actions. Thereby, each module group consists of one or more modules with specific priorities (Fig. 5.2). The module group "Urban water", for instance, consist of different modules such as "Temporary flow paths and retention rooms" or "Awareness rising: floods".

The modular structure allows flexibility that is needed to ensure applicability in different cities, independent of their specific settings, and its transferability to other regions regardless of the available information or the complexity of the system under

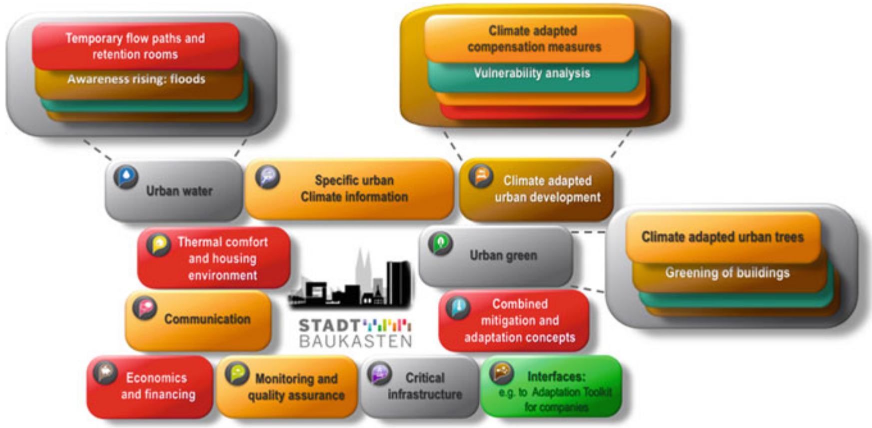

Fig. 5.2 A look inside the module groups “Urban water”, “Urban “Green”, and “Climate adapted urban development” of the “GERICS-Stadtbaukasten”

consideration. Despite the fact that flexibility is not per se an adequate methodological approach to deal with complex systems, it here refers to the possibility for decision-makers to pick and combine individually those tailored elements of the framework that fit best to their needs. In case there are no modules available that address the topics raised, new modules can be developed to meet the demand.

The Working Process

The whole process of applying the “GERICS-Stadtbaukasten” starts with the elaboration of the toolkit-frame according to the individual needs of the municipality and the analysis of all site characteristics. This includes the collection of the current individual needs and potential conflicts, the determination of available local information, the identification of relevant stakeholders and administrative processes, and the simulation of regional climate information of the past, present and future.

According to the existing and available information the given methodology is modified with regard to the city characteristic information with respect to the administrative and legislative framework. This is necessary in order to identify the specific opportunities and challenges arising from climate change for a city or specific districts or sectors, and to be able to understand all potential direct and indirect risks related to climate change impacts throughout the entire adaptation process.

Starting Point: Regional and Local Climate Information

Independent of the individual scope and strategic objectives, state-of-the-art regional to local climate change information is one of the corner stones to estimate possible climate change impacts and the related hot spots in a region under investigation. Currently, regional climate models do not reach the resolution to simulate local conditions and urban climate models often lack processes or the possibility to simulate longer time-scales. At the Climate Service Center Germany (GERICS) two pathways are followed to close this gap. On the one hand, climate modelling capacities are enhanced by implementing idealized urban modules into regional climate models to better study feedbacks between urban areas and their environment on longer time-scales. This also helps identifying episodes, for which a more detailed analysis with urban climate models is required.

Whereas regional climate models are used to create a better understanding of the climate system, climate information is needed for decision makers to derive procedures and planning processes. The recent applicable information for Europe is provided by the EURO-CORDEX Initiative with a resolution of 12 × 12 km (Jacob et al. 2014), which has been recently extended by the ReKlies-De (Regional climate projections ensemble for Germany—Regionale Klimaprojektionen Ensemble für Deutschland) project (ReKlies-De 2017). Independent of the specific question or the availability of climate information, the scientific basis for all adaptation actions should be an ensemble of high-resolution climate simulations of reasonable size to cover the entire bandwidth of possible future climate conditions (Bender et al. 2018a, b).

In order to be able to answer specific questions related to adaptation action it is often necessary to deal with the complex interaction between climatic and non-climatic drivers. This requires the combination of regional or local climate information with socio-economic and environmental data including multi-sectoral expert knowledge at the local scale (Bender et al. 2017b). Because data availability and data quality differ for each case, sometimes only rough estimates for one or several components are possible. However, for several aspects this information can be sufficient to initiate further steps—including enhancing monitoring activities, creating new strategies or starting new scientific research.

By using the "GERICS-Stadtbaukasten", it is possible to tailor an already tested methodology to the available information frame. It should be noted that due to this process, differences in the bandwidth, quality and validity of the results can be expected.

Communication Is Key

Experience shows that the most important fact for the planning and implementation of adaptation action is communication. As Brasseur and Gallardo (2016) mention, using web portals or catalogues of best-practice adaptation solutions—or in other word the sole dissemination of information from science to local practitioners ("top-down"-approach)—is not the best solution to start adaptation processes. Moreover, activities are needed, that are carried out in close cooperation between stakeholders or representatives of city administrations (mostly with the local environmental protection authority, environmental authority or the climate city office) and scientists. This process, however, is no fast-track activity, and time is needed to modify administrative processes and to communicate how to appropriately use the existing regional climate information including the bandwidth of results.

For this purpose different forms of communication have to be used to (i) ensure the best possible (pre-)conditions for the application of the toolkit, (ii) to interact efficiently between the different stakeholders—such as the moderation of processes, stakeholder consultations, analysis of needs, improvement of system understanding—, (iii) to raise awareness of local weaknesses and hot spots by consultating local experts, companies and citizens, (iv) to translate scientific results into practicable knowledge, (v) to transfer user requirements into science, and (vi) to stimulate all kinds of the transdisciplinary dialogues for the combination of local knowledge and regional climate information. This approach follows on the one hand side the common administrative communication approach, but on the other side offers sufficient space for the promotion of third parties from outside the administration.

It is often the case that at the beginning of the process it is highly recommended to define the most important technical terms, to build a common understanding. This helps to avoid different understanding of processes and major goals. Furthermore, it is important to clearly define and distinguish between terms such as adaptation, exposition, hazards, risk, resilience and vulnerability, as they are strongly related (Cortekar et al. 2016). With this common understanding it is possible to combine all the various expertise, which is important to improve the integrative system understanding. This not only benefits the success of the project but is also expected to increase the overall acceptance.

The whole process of the development and implementation of sound solutions is carried out in close cooperation with local stakeholders and experts as well as decision makers. The co-development- and co-design-processes are key to tailor each action for specific challenges. Communication is at this point essential to pave the way that all important local information is added to the set of information climate information from observations to climate projections and to overcome the gap between adaptation in theory and in practice. The exchange of knowledge supports (a) the understanding of existing needs and associated conflicts, (b) the identification of known barriers regarding the implementation (Weyrich 2016), (c) the analysis of what has been done so far, (d) the development of consensus about threats and preferences for adaptation measures between the stakeholders, and (e) the building of trust between all partners.

Typical actions in urban adaptation concepts are mainly focused on the thermal comfort and health, flood related questions and different kinds of preventions measures (Thieken et al. 2018).

Example: The Adaptation Challenge Thermal Comfort

With regard to the thermal comfort the interest for administrations are directed towards thermal stress and bioclimate (Steuri et al. 2018), because the globally observed growing urban population and demographic change are two major challenges for cities of the future. Due to improved living conditions and health care, average life expectancy in developing countries has been rising worldwide for many decades (United Nations 2017). For example, in Germany the proportion of the total population over 65 will increase from 27% (2014) to 35% (2030) and 38% (2060) respectively (Statistisches Bundesamt 2016). As the number of elderly people increases, so does the number of people affect by physical heat stress caused by heat waves.

Growing cities need free space for further building activities, but this space is increasingly rare. Each new building or structure reduces the available green spaces. But urban green offers at least many ecosystem services. They are important for the urban climate, the maintenance of fresh air corridors, biodiversity, recovery, retention of precipitation, or the reduction of urban heat islands.

Climate-related risks for health and human security are projected to increase with global warming of 1.5 °C and increase further with 2 °C (IPCC 2018), so that adaptation actions are needed to optimize the thermal comfort in urban areas under the conditions of climate change and land-use change. By the middle of the 21st century, most people living in major cities will have to adjust to an increase in the annual average temperature and the higher number of summer days, heat days and tropical nights. However, climate-friendly and climate-adapted urban planning gives people the opportunity to reduce the negative effects of climate change on the urban climate and to influence the inner-city microclimate in such a way that overheating can be reduced. With regard to the increasing heat in cities, three major challenges can be identified in urban climatology: (1) unfavourable local wind conditions due to interactions between the building structure, (2) a critical thermal situation caused by the lack of evaporation possibilities or shading, and (3) a high heat storage capacity of building and soil surfaces.

To raise the awareness of the complex challenges and the numerous factors—such as the temporal and spatial distribution of surface and air temperature, the arrangement of build-up structures, the location of cold-air corridors, air circulation in the street, characteristics of the paving (color, degree of sealing), existing blue and green infrastructure—an important step is the visualization of current and future hot spots in city districts. One helpful tool for this approach are simulations of urban climate models. They can be used to locate recent and potential future hot-spots and for demonstrating the effectiveness of single or multiple adaptation measures.

By the application of the "GERICS-Stadtbaukasten" (module group "thermal comfort and well-being") regional climate information is used as input for urban climate models (Bender et al. 2017a). Figure 5.3 shows one example for the simulations of the changes of the thermal well-being within a district with respect to selected

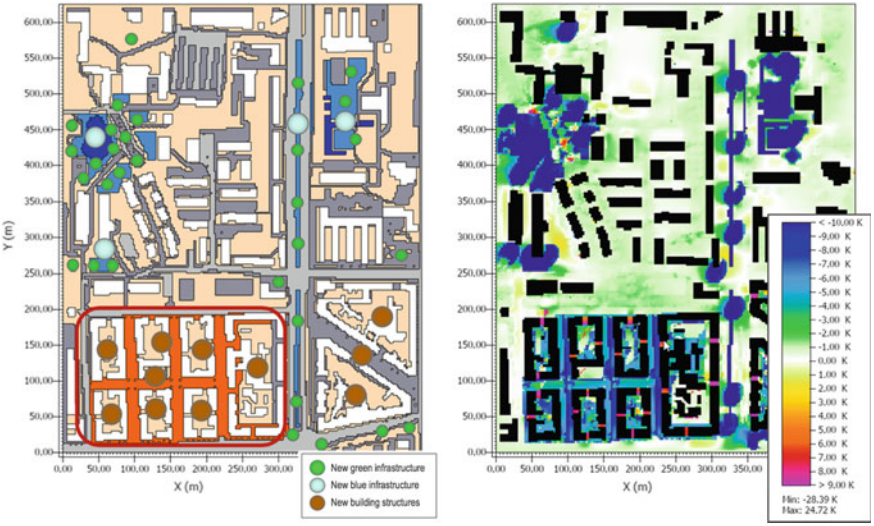

Fig. 5.3 ENVI-Met-model area with location of adaptation measures (left) and map with absolute difference of surface temperature 2021–2050 compared to 1976–2005, at 14:00 h (right)

adaptation measures such as the combined application of trees and blue infrastructure elements, and new building structures. The results of the simulations show the high potential of local cooling effects (blue colour scale). The focus here is not on the exact extent of temperature reduction through individual measures, but rather on identifying potential challenges and possible solutions, and to raise awareness in order to pave the way for integrating adaptation into future city planning activities. The simulation shows the positive effects of shading, water elements, and from a more open building structure. Whereas existing blocks of houses cannot be changed easily in the housing stock, it gives an impression which structural elements should be preferred in new city areas. By using urban climate models, it is also possible, to show temperature related challenges of today and in the future for all typical reference districts of a city and transfer the result to other developed and undeveloped areas of the city with similar structural elements (Germann 2018).

More detailed observations with higher sophisticated urban city models are possible, too. Curently a new model building-resolving athmospheric model for entire city regions is under development (Scherer et al. 2019; Steuri et al. 2018), that should be finally incorporated as a new “GERICS-Stadtbaukasten” module. With regard to the applicability an important point for the use of such a model are open- or easy-to-access-information (such as Google Maps, Bing Maps, Open Street Maps, urban development plans) to build the model. Where no precise information is available, such as for vegetation, surfaces and floor types, there exist proven standard data, that can be used. Even though the scientific standard is not on the highest possible level, the biggest advantages of this approach is the detection of potential hot spots, the awareness creation which measures at which place might be helpful to reduce climate change impacts and the visualization which building structures should be avoided in further urban development.

Example: The Adaptation Challenge Urban Flooding

Heavy precipitation and related river and urban floods cause costs in the hundreds of million Euros every year—such as the heavy rain events in June and July 2017, that caused total damages of EUR 600 million in the mid-part of Germany (GDV 2017). Because such events have already affected cities and municipalities all over the world there is a high pressure on local administrations to react. Additionally, recent studies show that as temperature will increase, also the number and intensity of extreme events—including precipitation amounts and number of heavy rain events—is expected to rise (IPCC 2018; ReKlies-De 2017).

Climate change is one of the most important drivers that can heavily influence all components of the water cycle (Bender et al. 2017c). Main impacts will happen at the extremes—long lasting drought periods and heavy rain events. One of the most important aspects for cities (and its inhabitants) is the knowledge of the system weaknesses and its most vulnerable parts, ranging from single critical infrastructure element up to the whole city districts. Besides own observations and personal concerns, whereas the positive aspects last for few years only, this can be addressed by creating maps visualizing vulnerable parts or showing the spatial impact on selected events.

With regards to urban flooding after heavy rain events or as a result of river floods there exist many hydraulic models for flood simulations (Hunter et al. 2008) or hydrological GIS-tools such as FloodArea (Disse and Assmann 2003) or the Geomorphic Flood Area tool (Samela et al 2018). Using these kinds of software tools selected parts of the city can be swamped virtually with defined amounts of precipitation or selected amounts of water.

The GERICS-Stadtbaukasten approach combines structured surveys, historical records of the local fire brigade, observations and other local expert knowledge—as a base for the validation of model results—with regional climate information and a GIS-tool simulation. The finally validated model simulations show accumulation areas of the water, potential bottlenecks for the flow, or the effects of poorly maintained elements with increased floodplain behind the blocked passages (Fig. 5.4).

The results of such simulations could be:

(1) a starting point for the development of new protection concepts for the local administration,
(2) a valuable pointer to raise the awareness for a regular control of the drainage functionality by the cleaning of the culverts and removal of growing plants and waste in discharge channel,
(3) an important note to visualize the vulnerable parts of the system where adaptation is needed in a first step,
(4) a base for the information for the public to raise awareness with respect to flood impacts about the self-responsibility of property owners.

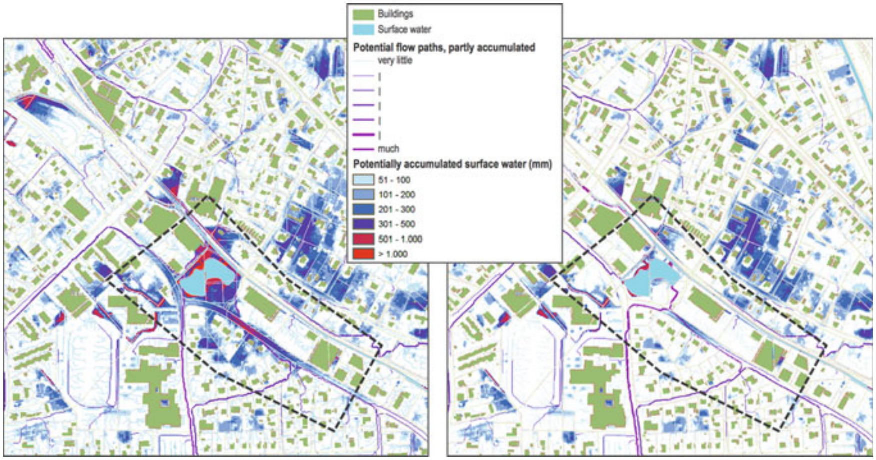

Fig. 5.4 Simulation of rain accumulation after a heavy rain events (60 mm in 1 h) with the GIS-tool "WOLK". Results with blocked drain (left) and operative drain (right)

The Role of Climate Services and Further Needs for Research

Although impacts of climate change will cause considerable stress to all parts of the city including the population and local administration, adaptation is still not the preferred option for action. Limiting factors are restricted human, financial, and information resources, the lack of foresight, competing interests or local political priorities (Weyrich 2016). Whereas there are currently many plans for mitigation action, there is still a limited awareness with regard to adaptation. Nevertheless, mitigation and adaptation are closely linked. The comparison of a "business-as-usual"-world with a "mitigation"-world (ReKliEs-De 2017) or a 1.5 °C-future with 2 °C-future (IPCC 2018) shows, that in a warmer world there is a significant increase of extreme events with the subsequent increase of climate impacts. To keep investments on a low level and to leave the business-as-usual-path—it is necessary to reduce CO_2-emissions and keep climate impacts and associated adaptation costs on a lower level—it is mandatory to adapt to local and regional projected climate impacts as fast as possible. This also shows the need to consider mitigation and adaptation jointly and equally when developing and implementing adaptation action.

Climate service providers can support urban adaptation actions in many ways. Typical climate service products are education and awareness raising, consulting services, monitoring, the provision of regional climate information and assistance in the interpretation of the results. The demands reflect individual, sectoral and regional specifications, in different temporal and spatial scale.

When dealing with information on regional climate change it becomes clear that the data basis for the development of adaptation measures is often not yet sufficient. In particular, there is a lack of comprehensive, reliable, spatially high-resolution information on small-scale local structures. Also, a distinction between longer-term trends (e.g. for forestry) and extreme events (e.g. heavy rainfall, for urban planning) is needed, whereby on a local scale there is an even greater need for information on extreme events than on long-term trends. Furthermore, results of existing high-resolution simulations and knowledge needs to be brought together and made easily accessible.

Besides these necessary developments in the field of climate services, it must be clear, that limiting global warming to 1.5 °C will require immediate action within and across sectors, as well as multilevel governance. Thereby successful city-level climate action urgently needs to take the next step from bringing strategies—already in place worldwide—much more into strong and impactful climate action within the next two decades.

Lessons learnt from the co-development process at the interface of science and practice showed the importance of communication as an important element during the whole process (Steuri et al. 2018). It ensures that local experience, findings, and knowledge as well as state-of-the art scientific knowledge, is integrated to develop together sound solutions. One main goal of this approach is the development of new applications that are easy-to-understand and address actual local needs. With regard to the fuzziness of stakeholder needs that might change during the adaptation process it is necessary to work with highly flexible approaches to enable fine adjustment. Furthermore, there is a growing need to evaluate the output and outcome of research and knowledge transfer activities in the field of climate services and to carry out a formative evaluation during the research process itself, based on existing guidelines and methodologies from the area of socio-ecological research (Bergmann et al. 2005; Schuck-Zöller et al. 2017). Additional need for research can be separated into the field of information on regional climate change as well as regarding the cooperation between research and practice.

Conclusion

Due to the interactions of many sectors as well as non-climatic and climatic drivers bordered by environmental, social, administrative and legal boundary conditions climate service products should be highly flexible in order to guarantee an optimal fitting to the respective problem. Furthermore, this characteristic allows the transfer—with minor or major modifications—to other sites, cities or regions, an important factor for successful knowledge transfer.

The development of adaptation actions in daily operations is often a complex and time consuming task. From all the necessary steps—which end at the implementation and maintenance phase—the development of a strategy is the easiest step, because the barriers at this stage are quite small, and it is a fast track action. This might be the reason why city administrations often stops after finishing an adaptation strategy.

For successful adaptation actions several points have to be fulfilled:

- The development must be carried out individual and site-specific based on detailed local information.
- It is necessary to understand the complex nature of interacting climatic and non-climatic drivers and their impacts on other fields of action.
- Taking into account close cooperation between research and practice there is a need for an easier communication that present different approaches and their consequences in a comprehensible, fast and clear way.
- Results, data and information must (be able to) be integrated into existing administrative processes, which applies not only to models, but also, for example, to planning tools and requirements.

Factors that can help to prevent the slowdown of the process are (1) the clarification of the responsibilities and the managerial authority, (2) the use of synergies between different administrative process chains, (3) the combination of efforts from different fields of action with respect to their impacts on the whole system, and (4) the integration of information on climate change, mitigation and adaptation into standards and regulations

References

Bender S, Cortekar J, Groth M (2015) Adaptation strategies: looking for best practices only can lead to deadlock. Book of abstracts "European Climate Change Adaptation Conference (ECCA) 2015". Denmark, Copenhagen, pp 72–73

Bender S, Brune M, Cortekar J, Groth M, Remke T (2017a) Anpassung an die Folgen des Klimawandels in der Stadtplanung und Stadtentwicklung—Der GERICS-Stadtbaukasten. GERICS-Report 31, 75 pp. Climate Service Center Germany, Hamburg

Bender S, Brune M, Cortekar J, Groth M, Remke T (2017b) Klimawandeltaugliche Kompensationsmaßnahmen—Überprüfung der Funktionstüchtigkeit von Kompensationsmaßnahmen unter klimatisch veränderten Bedingungen am Beispiel der Stadt Kiel. GERICS-Report 32, 73 pp. Climate Service Center Germany, Hamburg

Bender S, Butts M, Hagemann S, Smith M, Vereecken H, Wendland F (2017c) Der Einfluss des Klimawandels auf die terrestrischen Wassersysteme in Deutschland. Eine Analyse ausgesuchter Studien der Jahre 2009 bis 2013. GERICS-Report 29, 77 p. Climate Service Center Germany, Hamburg

Bender S, Groth M, Raub T (2018a) Regionale Klimainformationen für Bremerhaven—Überprüfung, Erweiterung, Anwendung. GERICS City Series 01, 28 pp. Climate Service Center Germany, Hamburg

Bender S, Groth M, Pfeifer S, Raub T (2018b) Regionale Klimainformationen für Bremen—Überprüfung, Erweiterung, Anwendung. GERICS City Series 02, 28 pp. Climate Service Center Germany, Hamburg

Bergmann M, Jahn T, Knobloch T, Krohn W, Pohl C, Brohmann B, Hoffmann E, Loibl MC, Rehaag R, Schramm E, Voß JP (2005) Quality criteria of transdisciplinary, research—a guide for the formative evaluation of research, projects, ISOE-studientexte, 13, Institute for Social-Ecological, Research (ISOE), 78 pp, Frankfurt/M., Germany

Betsill M, Bulkeley H (2007) Looking back and thinking ahead: a decade of cities and climate change research. Local Environ 12(5):447–456

Brasseur GP, Gallardo L (2016) Climate services: lessons learned and future prospects. Earth's Fut 4(3):79–89

CDP (2014) CDP cities 2014 information request. https://www.cdp.net/en-US/Program-mes/Documents/CDP-Cities-Information-Request-2014.pdf (accessed 19.05.2016)

Collins M, Knutti R, Arblaster J, Dufresne J-L, Fichefet T, Friedlingstein P, Gao X, Gutowski WJ, Johns T, Krinner G, Shongwe M, Tebaldi C, Weaver AJ, Wehner M (2013) Long-term climate change: projections, commitments and irreversibility. In: Stocker TF, Qin D, Plattner G-K, Tignor M, Allen SK, Boschung J, Nauels A, Xia Y, Bex V, Midgley PM (eds) Climate change 2013: the physical science basis. contribution of working group I to the fifth assessment report of the intergovernmental panel on climate change, pp 1029–1136

Cortekar J, Bender S, Groth M (2015) How to adapt to climate change—challenges for cities. In: Book of abstracts "European Climate Change Adaptation Conference (ECCA) 2015". Copenhagen, Denmark, p 43

Cortekar J, Bender S, Brune M, Groth M (2016) Why climate change adaptation in cities needs customised and flexible climate services. Clim Serv 4:42–51

Dilling L, Lackstrom K, Haywood B, Dow K, Lemos MC, Berggren J, Kalafatis SE (2015) What stakeholder needs tell us about enabling adaptive capacity: the intersection of context and information provision across regions in the United States. Am Meteorol Soc 7:5–17

Disse M, Assmann A (2003) Bestimmung der Überflutungsflächen infolge von Deichbrüchen mit GIS-basierten Werkzeugen. Hydrol Wasserbewirtsch 6:228–233

GDV (2017) Die Starkregen-Bilanz eines Sommers. Mitteilung vom 22.09.2017, https://www.gdv.de/de/themen/news/die-starkregen-bilanz-eines-sommers-11640 (15.10.2018)

Germann P (2018) Entwicklung und Anwendung eines Vulnerabilitäts-Index für Hitzestress am Beispiel der Stadt Heidelberg. M.Sc.-Arbeit, Uni Lüneburg, 68 pp

Groth M, Brück M, Oberascher T (2015) Climate change related risks, opportunities and adaptation actions in European cities—insights from responses to the CDP cities program. University of Lüneburg working paper series in Economics, 347, 38 p

Groth M, Nuzum A-K (2016) Informations- und Unterstützungsbedarf von Kommunen zur Anpassung an die Folgen des Klimawandels. GERICS-Report 25, 57 pp. Climate Service Center Germany, Hamburg

Hunter NM, Bated PD, Neelz S, Pender G, Villanueva I, Wright NG, Liang D, Falconer RA, Lin B, Waller S, Crossley AJ, Manson DC (2008) Benchmarking 2D hydraulic models for urban flood simulations. Proc Inst Civ Eng Water Manag 161(1):13–30

IPCC (2018) Summary for policymakers. In: Masson-Delmotte V, Zhai P, Pörtner HO, Roberts D, Skea J, Shukla PR, Pirani A, Moufouma-Okia W, Péan C, Pidcock R, Connors S, Matthews JBR, Chen Y, Zhou X, Gomis MI, Lonnoy E, Maycock T, Tignor M, Waterfield T (eds) Global warming of 1.5 °C. World Meteorological Organization, Geneva, Switzerland, 32 pp

IRGC (2018) Guidelines for dealing with systemic risks in the context of transitions. International Risk Governance Council, Lausanne, Switzerland, p 82

Jacob D, Petersen J, Eggert B, Alias A, Christensen AB, Bouwer LM, Braun A, Colette A, Deque M, Georgievski G, Georgopoulou E, Gobiet A, Menut L, Nikulin G, Hänsler A, Hempelmann N, Jones C, Keuler K, Kovats S, Kroner N, Kotlarski S, Kriegsmann A, Martin E, van Meijgaard E, Moeseley C, Pfeifer S, Preuschmann S, Radermacher C, Radtke K, Rechid D, Rounsevell M, Samuelsson P, Somot S, Soussanna J-F, Teichmann C, Valentini R, Vautard R, Weber B, Yiou P (2014) EURO-CORDEX: new high-resolution climate change projections for European impact research. Reg Environ Changes 14(2):563–578

Kalafatis SE, Lemos MC, Lo Y, Frank KA (2015) Increasing information usability for climate adaptation: the role of knowledge networks and communities of practice. Glob Environ Change 32:30–39

May PJ, Jochim AE (2013) Policy regime perspectives: policies, politics and governing. Policy Stud J 41(3):426–452

Moser SC, Ekstrom JA (2010) A framework to diagnose barriers to climate change adaptation. Proc Natl Acad Sci 107(51):22026–22031

Reckien D, Flacke J, Dawson RJ, Heidrich O, Olazabal M, Foley A, Hamann JJ-P, Orru H, Salvia M, de Gregorio Hurtado S, Geneletti D, Pietrapertosa E (2014) Climate change response in Europe: what's the reality? Analysis of adaptation and mitigation plans from 200 urban areas in 11 countries. Clim Change 122:331–340

ReKliEs-De (2017) ReKliEs-De Ergebnisbericht, 56 pp

Revi A, Satterthwaite DE, Aragón-Durand F, Corfee-Morlot J, Kiunsi RBR, Pelling M, Roberts DC, Solecki W (2014) Urban areas. In: Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL (eds) Climate change 2014: impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, pp 535–612

Ricardo AEA (2013) Adaptation strategies for European cities. A toolkit for cities. Final report. Report for EC Directorate General for Climate Action, Oxfordshire. 41 pp

Samela C, Albano R, Sole A, Manfreda S (2018) A GIS tool for cost-effective delineation of flood-prone areas. Comput Environ Urban Syst, 10 pp

Scherer D, Antretter F, Bender S, Cortekar J, Emeis S, Fehrenbach U, Gross G, Halbig G, Hasse J, Maronga B, Raasch S, Scherber K (2019) Urban Climate Under Change [UC]2—A national research programme for developing a building-resolving atmospheric model for entire city regions. Meteorlo Z Contrib Atm Sci. PrePub https://doi.org/10.1127/metz/2019/0913

Schuck-Zöller S, Cortekar J, Jacob D (2017) Evaluating co-creation of knowledge: from quality criteria and indicators to methods. Adv Sci Res 14:305–312

Statistisches Bundesamt (2016) Ältere Menschen in Deutschland und der EU, 99 pp

Steuri B, Cortekar J, Bender S (2018) Überprüfung der Praxistauglichkeit eines neuen Stadtklimamodells: #1 Anforderungserhebung als Basis. GERICS-Report 33, 61 pp. Climate Service Center Germany, Hamburg

Terenzi A, Westerlind Wigström A (2014) WP 9: Stakeholder dialogues—D9.1: Stakeholder Survey Report. RAMSES Project—Reconciling Adaptation, Mitigation and Sustainable Development for Cities. 64 pp

Thieken A, Dierck J, Otto A (2018) Deutschlandweiter Überblick zu städtischen Klimaschutz- und Klimaanpassungskonzepten. In: Thieken A, Dierck J, Dunst L, Göpfert C, Heidenreich A, Hetz K, Kern J, Kern K, Lipp T, Lippert C, Meves M, Niederhafner S, Otto A, Rohrbacher C, Schmidt K, Strate L, Stumpp I, Walz A (eds) Urbane Resilienz gegenüber extremen Wetterereignissen—Typologien und Transfer von Anpassungsstrategien in kleinen Großstädten und Mittelstädten (ExTrass), 15–32, Universität Potsdam

Umweltbundesamt (2015) Entscheidungsprozesse zur Anpassung an den Klimawandel in Kommunen. Climate Change 04/2015. Umweltforschungsplan des Bundesministeriums für Umwelt, Naturschutz, Bau und Reaktorsicherheit, Dessau-Roßlau, 99 pp

United Nations (2017) World population prospects: The 2017 revision. United Nations, New York, p 46

United Nations (2018) World urbanization prospects. The 2018 revision—key facts. United Nations, New York, 2 pp

Weyrich P (2016) Barriers to adaptation in urban areas in Germany, GERICS-Report 26, 110 pp. Climate Service Center Germany (GERICS), Hamburg

World Economic Forum (2018) The global risks report 2018, 13th edn, 72 pp

Chapter 6
COREDAR: A Coastal Climate Service Framework on Sea-Level Rise Risk Communication for Adaptation Policy Planning

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Abstract Accelerated sea-level rise (SLR) is a major long-term outcome of climate change leading to increased inundation of low-lying areas and put global cities and coastal communities at greater risk. Building capacities at the community level to address the challenges of SLR is an important first step towards adaptation policy planning and decision-making. Building capacity through risk communication is a bottleneck challenge to translate complex climate science into policy and actions. To meet these challenges, this paper has put forth the research question as what information do the coastal stakeholders need and how does it need to be communicated in the context of SLR and to build capacities that favor for effective SLR policy planning and decision-making at the local level. As a result, we have evolved COREDAR (COmmunicating Risk of sea-level rise and Engaging stakeholDers in framing community-based Adaptation strategies), a climate service capacity building framework that provides an important exploratory study, examining the SLR risk communications and community-based adaptation, extending and clarifying certain findings within the current SLR literature. The framework highlight the need to consider the relevance of addressing SLR risk communication in a systemic and holistic approach that integrates science, society, and policy in SLR research, whilst at the same time pointing to some interesting directions for engaging local communities in the decision-making process for framing adaptation strategies that are community-centric. Importantly, this framework emphasizes the significance of climate communication strategies and use of climate information in policy planning and decision-making as one of the potential climate services for SLR risk research.

Introduction

Climate change induced sea level rise (SLR) and associated phenomena such as raised storm surge and coastal flooding from inland extreme rainfall (henceforth referred

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to as SLR) are among the greatest challenges that humanity will face in the 21st century. Low-lying coastal plain regions are more vulnerable to the impact of SLR (Khan 2013). Particularly, global cities that are located on or near the coasts are often situated in low-lying areas and these locations put cities at greater risk from current and projected climate hazards like SLR (Rosenzweig and Solecki 2001; De Sherbinin et al. 2007; Moser and Snover 2012). According to United Nations, coastal flooding affects 10 million people each year, a number expected to increase exponentially due to climate change (UNDP 2007). IPCC (2013a) states that about 65% of the world's cities with populations of over 5 million are located in the LECZ (Low Elevation Coastal Zone). The SLR is not uniform across regions; some communities in places such as subsiding deltas are highly vulnerable (IPCC 2007a). In particular for developing countries, urban poor communities will bear the brunt of its effects since they live in informal settlements that are more exposed to hazards like SLR.

Therefore, building capacity for resilience and adapting to climate change threats like SLR are increasingly high priorities for urban coastal cities. There has been much focus on the potential of cities to contribute to mitigation, yet there is growing recognition of the need for urban adaptation (Romero-Lankao and Dodman 2011; Khan 2017). Cities can take a number of steps to help build the adaptive capacity of the most vulnerable (World Bank 2011, 2017). A city can do the following (i) communicating risk and raise awareness about the specific climate change impacts like SLR on the most vulnerable; (ii) informing residents about technical adaptation plans, policies, and actions that the city proposes to undertake to meet these threats and ensure their well-being; (iii) inviting the involvement of citizens in the decision-making process by soliciting their ideas and inputs (or) include vulnerable groups in the adaptation planning and policy-making process; (iv) suggesting how actions taken by individuals and groups can contribute toward the city's resilience; and (v) incorporate CBA into city plans (World Bank 2011).

Thus, the focus on adaptation is welcome, but many of the adaptation efforts have adopted a top-down approach with little attention being paid to communities' experiences related to the SLR and other efforts to cope with their changing environment (Reid et al. 2009). Importantly, most CBA has been undertaken in rural communities, and to be effective in cities will have to accept a broader and more complex definition of "community" that is not solely based on geographical location, and will have to engage in the more complex political economies characteristic of urban areas (Dodman and Mitlin 2011; Archera et al. 2014). There are calls for increased participation at the community scale (Polack 2008). This is particularly true for those working with urban poor communities since they largely shape the fabric of many urban spaces in cities in developing countries, and are often highly vulnerable to the effects of climate change, particularly because of their greater exposure to hazards and lower levels of adaptive capacity (Dodman and Satterthwaite 2008; Carmin et al. 2011). At the same time, these groups are given few opportunities to participate and influence policies. Community-Based Adaptation (CBA) experiences emphasize that it is important to understand a community's unique perception of their adaptive capacities in order to identify useful solutions and that scientific and technical information on anticipated coastal climate impacts needs to be translated into a suitable language and format that allows people to be able to participate in adaptation planning (IPCC 2013a; Khan 2017).

However, the major challenge for climate scientists is explaining to non-specialists about the risks and uncertainties surrounding potential changes over the coming years, decades and centuries. There are many guidelines for climate communication, there is little empirical evidence of their efficacy, whether for dispassionately explaining the science or for persuading people to act in more sustainable ways (Pidgeon and Fischhoff 2011). Importantly, climate communication faces new challenges as assessments of climate-related changes confront uncertainty more explicitly and adopt risk-based approaches to evaluating the impacts (Pidgeon and Fischhoff 2011). Whereas, research in social and decision science has identified several key lessons that are especially relevant to communicating climate science. First, identify climate risks and convey the message to targeted people; second, understand climate risks and make people understand the extent of risks, which can be voluntary, controllable, uncertain, irreversible or catastrophic (Slovic 2000); third, equip people with skills to cope with the anticipated risk; and fourth, find suitable solutions to face or overcome the risk (Khan et al. 2012).

Given its critical importance, public understanding of climate science deserves the strongest possible communication science to convey the practical implications of large, complex, uncertain physical, biological and social processes (Pidgeon and Fischhoff 2011; Khan 2017). On the other hand, adaptation practitioners in both developed (Gardner et al. 2010; Tribbia and Moser 2008) and developing nations (Bryan et al. 2009; Deressa et al. 2009) continue to identify a deficit of information as a significant adaptation constraint. This includes questioning assumptions regarding the need for more accurate/precise information about future climates (Preston et al. 2013), as well as the utility of vulnerability assessment methods and metrics for informing adaptation decision-making (Barnett et al. 2008; Preston et al. 2011). These critics suggest the ongoing expansion of adaptation science is occurring in the absence of a robust understanding of how science can or should contribute to successful adaptation (Preston et al. 2013). Importantly, the rationale behind this book chapter is based on Article 6 and Article 11 (capacity building for climate action on Paris Agreement) of the United Nations Framework Convention on Climate Change (UNFCCC 2011) that emphasizes the importance of climate change communication and engaging stakeholders in the issue. It highlights the responsibility of participating countries to develop and implement educational and public awareness programmes on climate change and its effects to ensure public access to information and to promote public participation in addressing the issue (Khan et al. 2012). Thus, there is an urgent need for meaningful information and effective public processes at the local level to build awareness, capacity, and agency on climate change, and support planning and decision-making (Sheppard et al. 2011). In this context, the aim of this article is to evolve a capacity building framework that responds to the call of the United Nations. The objective of this framework is to make a platform to educate, inform and involve all stakeholders who have stake on SLR such as from the scientific community, academia, NGO, local communities, policy-planners, decision makers and the public.

Need for a Coastal Climate Service Framework on Sea-Level Rise Risk Communication for Adaptation Policy Planning and Decision-Making

Climate services are an influential mechanism to build capacity by communicating the climate risks to different stakeholders in general and local communities in particular by creating awareness about the changing climate and enhance their capacity to respond to the challenges. Climate services may be defined as scientifically based information and products that enhance users' knowledge and understanding about the impacts of climate on their decisions and actions (AMS 2012). In other words, it is a decision aide derived from climate information that assists individuals and organizations in society to make improved ex-ante decision-making. It requires appropriate and iterative engagement to produce a timely advisory that end-users can comprehend and which can aid their decision-making and enable early action and preparedness (WMO 2013). SLR communication shares challenges with climate change communication, including the scope of the problem; the complexity of the science; and developing policy-driven solutions (Covi and Kain 2015). Messages about SLR risks may fail to adequately inform audiences or persuade them to respond to consequences (Harvatt et al. 2011) because of SLR information may be too general for people to relate to; scientific and technical information is too specialized; and messages are not sufficiently tested with representative audiences to gauge potential reactions (Covi and Kain 2015). Given its critical importance, public understanding of climate science (SLR) deserve the strongest possible communication science to convey the practical implications of large, complex, uncertain physical, biological and social processes (Pidgeon and Fischhoff, 2011). Risk communicators work to bridge the gaps between the scientific and public understanding of risk and provide a process to address the concerns of both (Covi 2014). Hence, there is a pressing need for developing a framework that addresses and integrates SLR risk communication and urban CBA. However, "framework" is defined as "a set of ideas that provide support" or "skeletal structure designed to support", in this case for SLR risk communication and urban CBA. Framing theory and research seek to understand the ways in which related sets of ideas of SLR and CBA in the public sphere are organized, presented and debated, and is increasingly being used to understand a range of problems and issues (Miller 2010; Spence and Pidgeon 2010). A frame allows complex issues to be pared down and for some aspects of that issue to be given greater emphasis than others in order that particular audiences can rapidly identify why an issue may be relevant to them (Nisbet and Mooney 2007; Spence and Pidgeon 2010). Frames can also serve ideological and governance purposes, and as a consequence different social actors within the climate change policy domain (as within other fields) constantly compete in order to present and legitimize their own interpretations of the salient issues (Carvalho and Burgess 2005; Spence and Pidgeon 2010). Thus, there is a need to evolve a conceptual framework to meet these requirements by generating alternative, coherent, holistic climate change scenarios and visualizations at the local scale, in collaboration with local stakeholders and scientists (Sheppard et al. 2011). In this context, this article has put forth three research questions to evolve a framework from the lens of SLR and urban CBA, (1) What information do stakeholders and local communities need and how does it need to be communicated, in order to be better prepared and have a greater sense of agency? and (2) What, if any, community engagement in addressing SLR is occurring in urban areas?, How can government agencies from city to federal levels facilitate community engagement and action in adaptation decision-making? (Khan 2017).

Methodological Approach

Conceptual analysis has been adopted with a multidisciplinary perspective that together synthesizes and assembles the theoretical framework to address the challenges SLR risk communication and CBA in the coastal urban areas. An extensive literature on the multidimensional perspective of SLR risk has been reviewed. However, in this paper, we take the position and procedures of the IPCC as an intermediary between science and policy as a given and do not discuss alternative ways of communicating scientific climate change research and associated uncertainties, ways that may or may not be more effective (Swart et al. 2009). The document analysis method was adopted to review the documents. Document analysis is a form of qualitative research in which documents are interpreted by the researcher to give voice and meaning around an assessment topic (Bowen 2009). In other words, documents as a data source in qualitative research and document analysis involve obtaining data and information from the existing documents, without having to question people through interview, questionnaires or observe their behaviors (Glen 2009). In this review, document analysis method was done to review the various documents and recommendations of IPCC by following IPCC Assessment Report 5, Working Group I Report on Climate Change 2013: The Physical Science Basis; Working Group II Report on Climate Change 2014: Impacts, Adaptation and Vulnerability; Climate Change 2014: Synthesis Report with an emphasize on SLR and CBA. In addition, “Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties” has been followed and present an approach for the treatment of uncertainty and the communication of key findings of the AR5 and together provide a more integrated framework for evaluating and communicating the degree of certainty in the findings of the assessment process (Mastrandrea et al. 2010). Based on the investigation of above-mentioned literatures, this study has underlined 6 questions (what, why, where, when, whom and how to communicate) as a guiding principle to evolve a framework that addresses SLR risk communication and urban

Fig. 6.1 Schematic representation of the guiding principle of COREDAR framework

CBA. A schematic representation of the rationale and the guiding principle of the framework is outlined in Fig. 6.1.

COREDAR: A Coastal Climate Service Framework on Sea-Level Rise Risk Communication for Adaptation Policy Planning and Decision-Making

COREDAR is the framework for sea-level rise risk communication and urban community-based adaptation for coastal cities. COREDAR is an acronym of the framework and it stands for communicating the risk of sea-level rise and engaging stakeholders in farming community-based adaptation strategies (Khan et al. 2015; UNAI 2016). The aim of this framework is to build capacity to meet the challenges of communicating complex SLR science in a simplistic way to diverse stakeholders and to make a platform to build capacity for stakeholders to engage them in urban CBA policy planning and decision-making process. It provides a template for a process to integrate the different dimensions of SLR risk in systematic and stepwise approach to evolve suitable urban CBA strategies. The framework presented here provides the much-needed conceptual clarity and facilitates bridging the various approaches to researching (Fussel and Klein 2006) SLR risk communication and urban CBA.

Architecture of the Framework

The framework provides a platform to integrate both top-down and bottom-up approaches on SLR decision-making for framing effective CBA strategies by integrating SLR "science, society and policy" paradigm that constructs the three components of the architecture. This has been achieved by improved conceptualization and integration of the multidisciplinary perspective of SLR in a systematic approach.

First, it articulates the science behind SLR which includes geography and climate of the coastal cities and SLR, documenting the past SLR trend, projecting future SLR, predicting SLR impact and assessing vulnerabilities to SLR. Second, it identifies the communities that involve in SLR both as an exposure to SLR risk and also influence in the decision-making process and it includes identifying vulnerable communities to SLR, communicating SLR risk and involves them in the decision-making process. Third, it caters policy dimension of SLR that includes identifying and prioritizing urban CBA strategies to SLR and mainstreaming urban CBA strategies with existing developmental strategies. The outline of the architecture of the COREDAR framework is given in Fig. 6.2. The framework is intended to serve as a "capacity building tool" to different stakeholders in the risk of SLR such as scientific communities, researchers, academia, local communities, NGOs, the general public, policy-planners, decision-makers and others who are interested to have insights on communicating risk of SLR and to develop a robust picture of the CBA that is grounded in pressing community priorities.

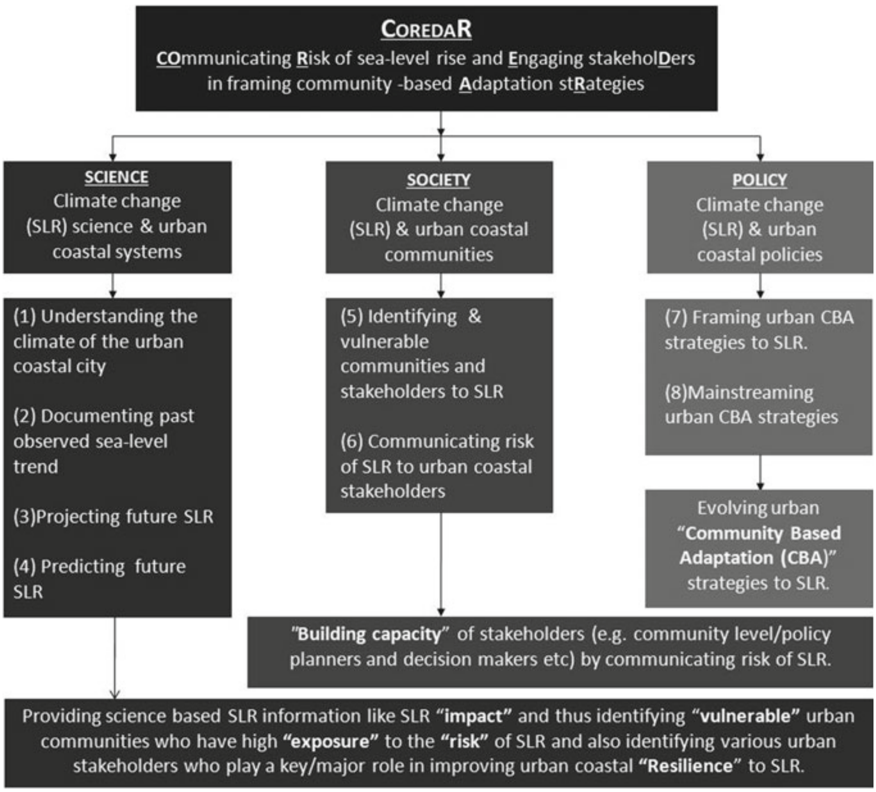

Fig. 6.2 The architecture of the COREDAR framework

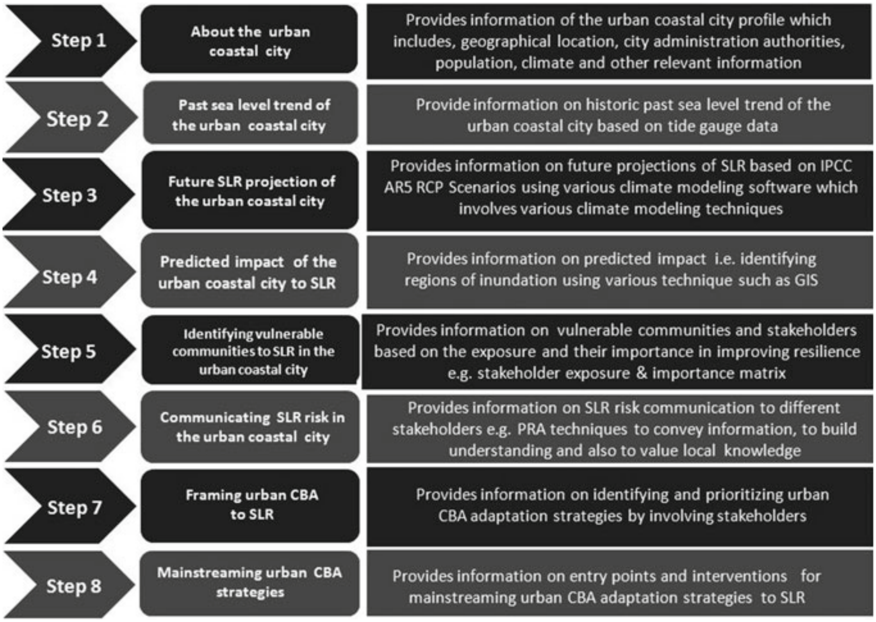

Fig. 6.3 An outline of the step-wise approach of the COREDAR framework

Stepwise Approach of the Framework

This framework is neither a technical document, nor a description of a single methodology. Instead, it provides high-level insights on how to develop a robust picture of systematic step-wise approach to addressing SLR communication and urban CBA, by consulting with both technical advisors and community stakeholders (World Bank 2011). This framework involves step by step approach (Fig. 6.3) and an outline of each step approach is described below:

Step 1 Understanding the climate of the urban coastal city
Step 2 Documenting past observed sea-level trend
Step 3 Projecting future SLR
Step 4 Predicting SLR impact
Step 5 Identifying vulnerable communities and stakeholders
Step 6 Communicating SLR risk
Step 7 Framing urban CBA strategies to SLR
Step 8 Mainstreaming urban CBA strategies.

Step 1 Understanding the climate of the urban coastal city

The lack of comprehensive information on the climate of the coastal region results in an insufficient understanding of the impact of changing climate on the coastal ecosystems and also impedes the framing of suitable climate-based adaptation strategies and policies at the regional and local level (Khan et al. 2014). However, knowledge on coastal vulnerability enables scientists and policymakers to anticipate impacts that could emerge as a result of SLR and other effects of climate change. It can thus help to prioritize management efforts that need to be undertaken to minimize risks or to mitigate the possible consequences (Hinkel and Klein 2009). Thus, in order to build the capacity of urban coastal cities to address SLR, it is essential to understand the (a) nature of the urban coastal city (geographical location, total area, and total population, etc.); (b) the administrative structure of the urban coastal city (governing body of the city such as a municipality, corporation and other relevant department that involves in city governance); and importantly (c) general climate pattern of the coastal city (temperature, precipitation, wind speed, humidity, elevation from mean-sea level, information on coastal disasters etc.).

Step 2 Documenting past observed sea-level trend

There are multiple processes that contribute to SLR, including changes in ocean mass distribution and density; changes in the mass of glaciers, ice caps, and ice sheets; water storage on land; vertical land movements; and gravitational, elastic, and rotational effects resulting from ice mass loss. Historically, the majority of the observed rise in global mean sea level has been attributed to thermal expansion. More recently, the contribution of land-based ice loss to global mean SLR has begun to rival that of thermal expansion (Church et al. 2011; Hortan et al. 2015). It is, therefore, important to understand the magnitude of the past sea level change in the target city, since local SLR is contingent on a number of factors. Past SLR is measured by local tide gauges situated along continental coastlines and islands and by satellite altimetry (Cazenave and Llovel 2010; Breaker and Ruzamaikin 2011). According to the IPCC (2007b), the observation of twentieth-century sea level trend (for e.g. in statistics, trend analysis often refers to techniques for extracting an underlying pattern of behavior in a time series) is based on high-quality tide gauge records from stable land regions. Tidal datum is used as a reference to measure local sea levels near the tide gauge at which the measurements were collected. Tidal datum is based on average stages of the tide, such as mean high water and mean low water (NOAA 2010a). A global network of long-term tide gauges provides an instrumental record of sea level over approximately the past 100 years (Donoghue 2011). Estimates of twentieth-century SLR are primarily based on the historical tide gauge data maintained by the Permanent Service for Mean Sea Level (PSMSL) (Woodworth and Player 2003). The PSMSL data are the source of all major work on long-term analysis and projection of global sea level upon which the IPCC reports are based (Nandy and Banyopadhyay 2011).

Step 3 Projecting future SLR

Planning for adaptation strategies by coastal managers, policy-planners and decision-makers requires a pragmatic approach. Thus, the first step for planning adaptation policies is to project local level SLR using different scenarios because decision-makers and technical personnel need to estimate SLR to evaluate their decisions in light of alternative profiles (Hoffman 1983). For time scales relevant to anthropogenic warming, the rate of SLR is roughly proportional to the magnitude of the warming and this relationship results in an increase in rise of projected SLR (Rahmstorf 2007). Although in the short-term, projections of SLR can be made without using climate models, for longer term projections climate models may be important. For long-term projections, these climate models are needed to determine likely changes on which to base adaptation planning. In order to make informed adaptive decisions, the uncertainties associated with their output must be recognized and taken into account (Foley 2010). To address the uncertainty associated with climate system dynamics and greenhouse gas (GHG) emission, the IPCC has developed a range of alternative futures (scenarios). For the Fifth Assessment Report of IPCC, the scientific community has defined a set of four new scenarios, denoted as Representative Concentration Pathways (RCPs). They are identified by their approximate total radiative forcing in the year 2100. It includes four RCPs (RCP 2.6; RCP 4.5; RCP 6.0; RCP 8.5) and represents a range of 21st century climate policies (IPCC 2013b). In spite of the uncertainties, climate models play a major role in projecting SLR under different scenarios and at different time slices (Foley 2010) and provide valuable information for the robust decision-making in adaptation policy-planning.

Step 4 Predicting SLR impact

The specific impacts of SLR on each city will depend on place-based factors (World Bank 2011), and will include, among other, increased flooding, inundation of low-lying areas, shoreline retreat, salt-water intrusion, loss of land, livelihood, and wetlands. Coastal impact models can help determine the vulnerability of areas and populations to changes in sea level. Model outputs may be used to guide decisions about the location and design of future protected areas and development, and to prioritize adaptation of existing protected area investments (Mc Leod et al. 2010). A number of impact models are available to study the impact of SLR at the city level. For example, SLR inundation models can be used to predict the area of inundation from rising sea level. Inundation models incorporate various sea-level rise scenarios (Titus and Richman 2001; Rowley et al. 2007) providing an approximation of coastal vulnerability to SLR. Potentially inundated areas can be calculated (e.g., in a GIS) based on both elevation and proximity to the shoreline. They can rely on digital elevation models or topographic maps to identify potential impact zones, where these are identified as those areas that lie below a given elevation contour (Titus and Richman 2001; Poulter and Halpin 2008). Importantly, mapping on impact and vulnerability (SLR impact maps or inundation maps) will provide valuable input to climate change adaptation planning and implementation (NOAA 2010b). These models may be applied at local, regional, or global scales and can address a range of objectives, including predicting SLR impacts and raising awareness of these impacts (Mc Leod et al. 2010).

Step 5 Identifying vulnerable communities and stakeholders

The SLR will have significant impacts on coastal megacities, because of the concentration of the populations in hazardous areas (Nicholls 2004; IPCC 2007b; Adelekan 2009). The urban poor face a worsening situation as the effects of climate change, including floods arising from the increasing frequency of storm surges, and heavy rainfall of long duration or high intensity become more severe. Although the risks faced by urban populations to climate change impacts, especially in developing societies have been acknowledged in various regional assessments, their vulnerability cannot be reliably estimated without detailed knowledge of local contexts since vulnerabilities are so specific to each location and societal context (Adelekan 2009). Identifying vulnerable communities in relation to coastal flood risk are one of the most important prerequisites to plan for city adaptation strategies to rising sea-level. Identifying stakeholders such as representatives of local communities, city governments, NGOs, the general public and others is an important first step. Stakeholder analysis is one such technique frequently used to identify and investigate any group or individuals who are or who will be affected by a change to better understand whether they are equipped to deal with it. It is a process of systematically gathering and analyzing qualitative information to determine interests that should be taken into account when developing and implementing a policy or programme. Thus, identifying communities that are more vulnerable to SLR and prioritizing stakeholders can inform adaptation response planning for SLR and help to develop communication strategies to engage community members in the climate adaptation planning process (Grifman et al. 2013). However, in conjunction with the assessment approaches outlined cities may find it beneficial to pursue a participatory process of prioritization that integrates both top-down and bottom-up, community-based perspectives (World Bank 2011).

Step 6 Communicating SLR risk

Effective risk communication requires more than conveying accurate information (Fischhoff 1995) it should raise awareness, increase understanding, and move audiences to action. It involves understanding the perceptions, issues, and attitudes of at-risk populations so that personal or community decisions can be made based on the best available information about risks (Leiss 1996; Covi and Kain 2015). Importantly, communicating environmental risks—especially the unfamiliar, non-voluntary, scientifically complex, and politically controversial—may be one of the most difficult tasks scientists, city planners, managers, and policy-makers face in dealing with adaptation to climate change and SLR. However, many scientists recognize the importance of communicating scientific findings to citizens to help them become aware of the urgent need to act and to enable them to carry out anticipatory actions. Nevertheless, this is one of the most difficult and sensitive objectives of SLR communication and education (Khan 2013). To be effective in presenting information and moving audiences to action, communication about SLR risk must use appropriate framing, compelling visuals, and accessible language, preferably tailored to the audience for the information (Covi and Kain 2015). Two step-wise interventions could be made to communicate SLR risk to concerned stakeholder through a participatory approach: (1) Convey information: one-way transmission of information to provide basic understanding of SLR science and its impacts on the study area to the concerned stakeholders, providing data on the local SLR (impact and vulnerability assessment and build awareness of their present and future state of exposure). (2) Build understanding: a two-way transmission of information that aims to facilitate opportunities for stakeholders to develop their own methods to understand the concept of SLR. It includes citizen science program, cooperative learning workshops, etc. (Khan et al. 2012). As a result, improving public awareness and developing overall communication strategies to make climate change science accessible to the average citizen in a way that could induce action that would reduce their vulnerability (UNFCCC 2007). Thus, these interventions will enhance the capacities of various stakeholders in the community and improve sustainability at the local level.

Step 7 Framing urban CBA to SLR

CBA explicitly addresses, the needs of marginalized groups that are the most vulnerable to the types of climatic and socioeconomic changes likely under perturbed climates (Baas and Ramasamy 2008) like SLR. CBA draws on participatory approaches and innovative participatory methods to help communities analyze the causes and effects of climate change, to integrate scientific and community knowledge of climate change, and to plan adaptation measures (Reid et al. 2009). Building on existing community capacity, knowledge and practices used to cope with climate hazards (Huq 2008), appropriate adaptation options can be identified. Through an understanding of how people might cope and adapt to predicted climate-change effects, meaningful measures can be taken to reduce their vulnerability. Importantly, localized patterns of the vulnerability of communities and demographic groups highlight the need to channel adaptation responses through the spatial planning system. It is also vital that communities are made aware of these issues and engaged at the point of developing community-based bottom-up adaptation responses (Adger et al. 2009; Carter et al. 2015). Thus, communicating and engaging stakeholders at the different levels plays a vital role in planning and designing appropriate adaptation strategies to SLR at the local level of the given coastal region such as urban coastal cities.

Step 8 Mainstreaming urban CBA strategies

To reduce vulnerability and to enhance resilience to projected scenarios of SLR it is important to mainstream adaptation through a coastal management and urban planning. Mainstreaming means integrating climate concerns (SLR) and adaptation responses into relevant policies, plans, programs and projects at the national, sub-national and local scales. It is to advocate strongly for climate change (SLR) adaptation and for bundles of adaptation measures to address priority issues within the scope of development goals (USAID 2009). However, Integrated Coastal Zone Management (ICZM) has been identified and highlighted by the IPCC and also by the UNFCCC as the most important vehicle for adapting to climate change while at the same time improving the present situation in the coastal areas (Bijlsma 1997). SLR and climate change will not occur in a vacuum, and these responses need to be placed within an ICZM framework (Bijlsma et al. 1995) and also understanding climate change (SLR) in the coastal zone is a fundamental component to ICZM particularly through the lens of urban coastal cities. Thus, in terms of responding to climate change (SLR), ICZM can be seen as an essential institutional mechanism that can deal with all competing pressures on the coast, including short, medium and long-term issues (Kavikumar 2005). It is essential to note that SLR adaptation presents a fundamental challenge to managing coastal resources and communities, and it should be mainstreamed into coastal management and development of coastal cities at all levels. Hence, city governments should, therefore, do more to prepare for ongoing and future climate changes focusing on actions that are no regrets, multi-sectoral and multi-level, and that improve the management of risks to SLR.

Limitations and Scope

This paper has outlined only the rationale, guiding principle and the architecture of the COREDAR framework. Though, the framework address urban, coastal communities and urban CBA, nevertheless the framework is also applicable to rural coastal communities and rural CBA as long as it is a low-lying coastal region that is vulnerable to changing climate and rising sea levels. The major applications of this framework is (1) to build capacity of local communities and various stakeholders to understand and address sea-level rise; (2) to make a suitable decision at the local level by the policy planners and decision-makers to rising sea-levels. However, the framework has laid the foundation to develop COREDAR tool. It is a SLR science-policy communication tool that gathers holistic information on SLR risk communication and urban CBA in a systematic step-wise approach. It has been designed in the form "checklist" (a comprehensive list of important or relevant information and steps to be taken in a specific order) in a "check sheet" (a simple data recording sheet, custom designed to enable a user to readily interpret the results of an activity or process) (Khan 2017). Furthermore, this tool has been tested with New York City as a case study; however, the description of the case study does not fit into the scope of this paper. Importantly, the framework also opened promising opportunities to develop it as a web-based tool and a mobile application. It is important to provide an avenue to engage citizen participation and citizen action within social networks to understand, learn from and develop local adaptation strategies (Lenhart 2009). In this context, the innovative scope of this framework through the lens of climate services is to develop a "Mobile App" which is primarily a "Climate Service App" (viz., COREDAR App) for communicating the risk of climate change and sea-level rise risk for vulnerable coastal communities and to build capacity at the local level. The app will provide a customized template to record local level sea-level observation and planning. In addition, the app will provide additional local climate information and case studies.

Conclusion

SLR represents one of the primary shifts in urban climate change risks, given the increasing concentration of urban populations in coastal locations and within low-elevation zones (McGranahan et al. 2007). Large coastal cities are particularly at risk from rising sea levels, storms and storm surges and other aspects of climate change. Indeed, the region's densely populated deltas and other low-lying coastal urban areas are identified in the IPCC as "key societal hotspots of coastal vulnerability" with many millions of people potentially affected (START 2009). Thus, climate change, particularly, with its consequent SLR, will have substantial impacts on the vulnerability of coastal communities to flooding (Ye Wu et al. 2002). However, cities are often the first responders to climate impacts. Because cities are dynamic systems that face unique climate impacts, their adaptation must be location specific and tailored to local circumstances. The starting point in managing risks and building long-term resilience is for a city to understand its exposure and sensitivity to a given set of impacts, and develop responsive policies and investments that address these vulnerabilities (World Bank 2011).

Capacity building is a key issue for climate adaptation measures in urban areas (Hartmann and Spit 2014). It is one of the most urgent requirements for addressing climate risk, particularly at the local level (IFRC 2009). Therefore, either to enhance the strengths or to develop skills and infrastructure, cities can build their capacity to adapt effectively through both formal planning and informal preparation to existing and future climate impacts while also experimenting and innovating in policy-making and planning (World Bank 2011). Thus, there is a strong need to equip the planning mechanisms in urban areas to withstand, adapt, and become resilient to climate change impacts (APN 2014). However, one fundamental condition for adaptation planning in urban contexts appears to be the availability of a good planning capacity, including the knowledge and participation base needed for informing decision making for the urban future (Johnson and Breil 2012). Thus, the ability to act collectively to develop and implement adaptation responses based on a sound knowledge of climate science, an intervention of policies and the role of societies are prime factors in building adaptive capacity. Partnerships of local authorities and other stakeholders have also been identified as important drivers for adaptive actions in cities around the world (Wilson 2006; Bulkeley et al. 2011). Importantly, the practitioners and various stakeholders in the urban space not only need an understanding of climate science but also the linkages to climate impacts to city systems, such that this information could be logically applied to decision-making processes and could be inbuilt into the development paradigm (APN 2014). Communicating risk of SLR and engaging stakeholders in framing CBA is one such an attempt of capacity building. However, risk communication is now a major bottleneck preventing science from playing an appropriate role in climate policy (Sterman 2011).

To meet these requirements and challenges this chapter (1) *Developed a framework:* The study has developed a conceptual framework COREDAR for SLR risk based on the past SLR trend, future SLR projection, predicted impacts, identifying vulnerable communities, farming CBA strategies and mainstreaming adaptation strategies from the context of urban coastal cities that synthesizes a variety of approaches; (2) *Framework for SLR risk communication:* This framework provides an important first exploratory study examining the SLR risk communications and urban CBA, extending and clarifying certain findings within the current SLR literature. We highlight the need to consider the relevance of addressing SLR risk communication in a systemic and holistic approach that integrates "science-society and policy" in SLR research; (3) *Framework for SLR adaptation policy planning and decision making*: The framework is also pointing out some interesting directions for engaging local communities in the decision-making process for framing urban CBA strategies. Importantly, it emphasizes that adaptation in urban areas depends on the competence and capacity of local governments and a locally rooted iterative process of learning about changing risks and opportunities, identifying and evaluating options, making decisions, and revising strategies in collaboration with a range of actors (Revi and Satterthwaite 2014). This conceptual framework, with different key elements and general components of each, provides a way to think differently about the urban CBA in cities to SLR. By assembling and describing these conceptual features of urban CBA in cities to SLR, we provide a framework that can guide all stakeholders from policy-planners, decision-makers, scientists, researchers, local communities and the general public. However, the future prospects of this framework opens window of promising opportunities to evolve as a tool and also develop the tool in a user friendly web and mobile application. The framework also requires testing and refinement (Moser and Ekstrom 2010) with case studies before it aid for decision-making and scaling up. Nevertheless, the framework could be used as a foundation to systematically gather information on different perspectives of SLR and holistically synergies for effective decision-making such as framing urban CBA to SLR.

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References

Adger WN, Dessai S, Goulden M, Hulme M, Lorenzoni I, Nelson DR, Wreford A (2009) Are there social limits to adaptation to climate change? Clim Change 93(3–4):335–354

Adelekan IO (2009) Vulnerability of poor urban coastal communities to climate change in Lagos, Nigeria. In: Fifth urban research symposium. Online http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/3363871256566800920/6505269-1268260567624/Adelekan.pdf. Accessed 09th Apr 2019

AMS (2012) Climate services. A policy statement of the American Meteorological Society. Online https://www.ametsoc.org/index.cfm/ams/about-ams/ams-statements/archive-statements-of-the-ams/climate-services/. Accessed 15 Feb 2019

APN (2014) A comprehensive capacity building program on urban climate resilience in India. Project Reference Number: CBA2014-04NSY-Divya Sharma. TERI and Asia-Pacific Network for Global Change Research

Archera D, Almansib F, DiGregorioc M, Roberts D, Sharma D, Syam D (2014) Moving towards inclusive urban adaptation: approaches to integrating community-based adaptation to climate change at city and national scale. Clim Dev 6(4):345–356

Baas S, Ramasamy S (2008) Community based adaptation in action: a case study from Bangladesh. Project summary report (Phase I) on improved adaptive capacity to climate change for sustainable livelihoods in the agriculture sector. Food and Agriculture Organization of the United Nations, Rome and Department of Agricultural Extension, Dhaka, Bangladesh, p 55

Barnett J, Lambert S, Fry I (2008) The hazards of indicators: insights from the environment vulnerability index. Ann Assoc Am Geogr 98(1):102–119

Bijlsma L (1997) Climate change and management of coastal resources. Climate Res 9(1–2):47–56

Bijlsma L, Ehler CN, Klein RJT, Kulshrestha SM, McLean RF, Mimura N, Nicholls RJ, Nurse LA, Pérez Nieto H, Stakhiv EZ, Turner RK, Warrick RA (1995) Coastal zones and small islands. In: Watson RT, Zinyowera MC, Moss RH (eds) Climate change 1995: impacts, adaptations and mitigation of climate change: scientific-technical analyses. Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, pp 289–324

Bowen GA (2009) Document analysis as a qualitative research method. Qual Res J 9(2):27–40. http://dx.doi.org/10.3316/QRJ0902027

Breaker LC, Ruzamaikin A (2011) The 154-year record of sea level at San Francisco: extracting the long-term trend, recent changes, and other tidbits. Clim Dynam 36(3–4):545–559

Bryan E, Deressa TT, Gbetibouo GA, Ringler C (2009) Adaptation to climate change in Ethiopia and South Africa: options and constraints. Environ Sci Policy 12(4):413–426

Bulkeley H, Schroeder H, Janda K, Zhao J, Armstrong A, Yi Chu S, Ghosh S (2011) Cities and climate change: the role of institutions, governance and urban planning. Report prepared for the World Bank urban symposium on climate change, World Bank Group, pp 125–159

Carmin J, Dodman D, Harvey L, Lwasa S, Romero-Lanko P (2011) Urban adaptation planning and governance: challenges to emerging wisdom. In. Otto-Zimmermann K (ed) Resilient cities: cities and adaptation to climate change. Proceedings of the global forum 2010, Volume 1 of Local Sustainability. Springer Science and Business Media, p 576

Carter JG, Cavan G, Connelly A, Guy S, Handley J, Kazmierczak A (2015) Climate change and the city: building capacity for urban adaptation. Prog Plann 95:1–66

Carvalho A, Burgess J (2005) Cultural circuits of climate change in the UK broadsheet newspapers, 1985–2003. Risk Anal 25:1457–1470

Cazenave A, Llovel W (2010) Contemporary sea level rise. Annu Rev Mar Sci 2:145–173

Church JA, White NJ, Konlkow LF, Domingues CM, Cogley JG, Rignot E, Gregory MJ, Van den broeke MR, Monaghan AJ, Velicogna, I (2011) Revisiting the Earth's sea-level and energy budgets from 1961 to 2008. Geophys Res Lett 38(18): L18601. http://dx.doi.org/10.1029/2011gl048794

Covi MP (2014) Water's gonna rise: sea-level rise risk perception, communication and policy-making in North Carolina. Doctoral dissertation, East Carolina University, p 195

Covi MP, Kain DJ (2015) Sea-level rise risk communication: Public understanding, risk perception and attitudes about information. Environ Commun 10(5):612–633

Deressa TT, Hassan RM, Ringler C, Alemu T, Yusuf M (2009) Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Global Environ Change 19(2):248–255

De Sherbinin A, Schiller A, Pulsipher A (2007) The vulnerability of global cities to climate hazards. Environ Urban 19(1):39–64

Dodman D, Mitlin D (2011) Challenges for community-based adaptation: discovering the potential for transformation. J Int Dev 25(5):640–659

Dodman D, Satterhwaite D (2008) Institutional capacity, climate change adaptation and the urban poor. IDS Bull 39(4):67–74

Donoghue JF (2011) Sea level history of the northern Gulf of Mexico coast and sea level rise scenarios for the near future. Clim Change 107(1–2):3–17

Fischhoff B (1995) Risk precipitations and communication unplugged: twenty years of process. Risk Anal 15(2):137–145
Foley AM (2010) Uncertainty in regional climate modelling: a review. Prog Phys Geog 34(5):647–670
Fussel HS, Klein JTR (2006) Climate change vulnerability assessments: an evolution of conceptual thinking. Clim Change 75(3):301–329
Gardner J, Parsons R, Paxton G (2010) Adaptation benchmarking survey: initial report. CSIRO Climate Adaptation Flagship, Kenmore, p 58 Online https://research.csiro.au/climate/wpcontent/uploads/sites/54/2016/03/4_WorkingPaper04CAF_pdf-Standard.pdf Accessed 10th May 2019
Grifman PM, Hart JF, Ladwig J, Newton Mann AG, Schulhof M (2013) Sea level rise vulnerability study for the city of Los Angeles. Prepared by the University of Southern California Sea Grant Program. USCSG-TR-05-2013
Hartmann T, Spit T (2014) Capacity building for the integration of climate adaptation into urban planning processes: the Dutch experience. Am J Clim Change 3:245–252
Harvatt J, Petts J, Chilvers J (2011) Understanding householder responses to natural hazards: flooding and sea-level rise comparisons. J Risk Res 14(1):63–83
Hinkel J, Klein RJT (2009) Integrating knowledge to assess coastal vulnerability to sea-level rise: the development of the DIVA tool. Global Environ Change 19(3):384–395
Hoffman JS (1983) Projecting future sea level rise: methodology, estimates to the year 2100. Strategies studies Staff office of Policy Analysis, Office of Policy and Resource Management. U.S. Environmental Protection Agency, Washington DC, USA, p 115
Horton R, Little C, Gornitz V, Bader D, Oppenheimer M (2015) Chapter 2: Sea level rise and coastal storms. New York city panel on climate change 2015 Report. building the Knowledge base for climate resiliency. Annals of New York Academy of Sciences. New York Academy of Science, New York, NY, USA, pp 36–44
Huq S (2008) Community based adaptation. Tiempo 86:7
IFRC (2009) Climate change adaptation strategies for local impact key messages for UNFCCC negotiators. Prepared by the, Technical Paper for the Inter Agency Steering Committee. Task Force on Climate Change, International Federation of Red Cross and Red Crescent Societies, p 11
IPCC (2007a) Observation: oceanic climate change and sea level. In. Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL. (eds) The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, p 996
IPCC (2007b) Summary for policymakers. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (eds) Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK, pp 7–22
IPCC (2013a) Chapter 5: Coastal systems and low-lying areas. In: Poh Poh W, Iñigo J. Losada (eds) Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK, pp 1–28
IPCC (2013b) Summary for policymakers. In: Stocker TF, Qin D, Plattner GK, Tignor M, Allen SK, Boschung J, Nauels A, Xia Y, Bex V, Midgley PM (eds) Climate change 2013: the physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp 3–29
Johnson K, Breil M (2012) Conceptualizing urban adaptation to climate change: findings from an applied adaptation assessment framework. Fondazione Eni Enrico Mattei, Venice, Italy, pp 3–63
Kavikumar K (2005) Relative vulnerability of Indian coastal districts to sea level rise and climate extremes. Envisage 1(3):9–11

Khan AS (2013) Climate change induces sea-level rise and its impacts on the Tamil Nadu coast, India: Framing ecosystem and community-based adaptation strategies. Ph.D. thesis. Anna University, Chennai, Tamil Nadu, India, p 226

Khan AS (2017) COREDAR for cities: developing a capacity building tool for sea-level rise risk communication and urban community-based adaptation. In: Leal Filho W, Keenan JM (eds) Climate change adaptation in North America: fostering resilience and the regional capacity to adapt. Climate Change Management, Springer, Berlin, pp 137–157

Khan AS, Ramachandran A, Usha N, Arul Aram I, Selvam V (2012) Rising sea and threatened mangroves: a case study on stakeholders' engagement in climate change communication and non-formal education. Int J Sus Dev World Ecol 19(4):330–338

Khan AS, Ramachandran A, Palanivelu K, Malini P (2014) Climate portfolio' of Pichavaram mangrove region of Tamil Nadu coast, India: an add-on information for adaptation policy planning. J Integr Environ Sci 3–4:173–186

Khan AS, Chen RS, De Sherbinin A, Ramachandran A, Palanivelu K (2015) COREDAR framework-communicating risk of sea-level rise and engaging stakeholders in framing community-based adaptation strategies. American Geophysical Union (AGU), Fall Meeting, 16 Dec 2015, San Francisco, California, USA

Leiss W (1996) Three phases in the evolution of risk communication practice. Ann Am Aca Pol Soc Sci 545(1):85–94

Lenhart J (2009) Empowering social networks to localize climate strategies in impoverished urban communities: examining the Basic Urban Services Strategy in Embu, Kenya. In: Fifth urban research symposium, June 28–30, 2009. Marseille, France, pp 1–13

Mastrandrea DM, Field CB, Stocker TF, Edenhofer O, Ebi KL, Frame DJ, Held H, Kriegler E, Mach KJ, Matschoss PR, Plattner G, Yohe GW, Zwiers FW (2010) Guidance note for lead authors of the IPCC fifth assessment report on consistent treatment of uncertainties. Jasper Ridge, CA, USA

McGranahan G, Balk D, Anderson B (2007) The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones. Environ Urban 19(1):17–37

Mc Leod E, Poulter B, Hinkel J, Reyes E, Salm R (2010) Sea-level rise impact models and environmental conservation: a review of models and their applications. Ocean Coast Manage 53(9):507–517

Miller T (2010) North Carolina Division of Coastal Management sea level rise scoping survey. Unpublished report

Moser SC, Ekstrom JA (2010) A framework to diagnose barriers to climate change adaptation. PNAS 107(51):22026–22031

Moser SC, Snover A (2012) Successful adaptation in coastal environments: project rationale, key issues and preliminary literature review. A white paper in support of a workshop on successful adaptation in coastal environments" to be held on Oct 15–16, 2012, Stanford University

Nandy S, Banyopadhyay S (2011) Trend of sea level change in the Hugli estuary, India. Indian J Geo Mar Sci 40(6):802–812

NOAA (2010a) Technical considerations for use of geospatial data in sea level change mapping and assessment. U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), National Ocean Service, Silver Spring, MD, USA, p 130

NOAA (2010b) Adaptation strategy. In: Adaptation to climate change: a planning guide for state coastal managers. National Oceanic and Atmospheric Administration, National Ocean Service, Office of Ocean and Coastal Resource Management, Silver Spring, MD, USA, p 57

Nicholls RJ (2004) Coastal flooding and wetland loss in the 21st century: changes under the SRES climate and socio-economic scenarios. Global Environ Chang 14:69–86

Nisbet MC, Mooney C (2007) Framing science. Science 316:56

Pidgeon N, Fischhoff B (2011) The role of social and decision sciences in communicating uncertain climate risks. Nat Clim Change 1:35–41

Polack E (2008) A right to adaptation: securing the participation of marginalized groups. IDS Bull 39(4):16–23

Poulter B, Halpin PN (2008) Raster modeling of coastal flooding from sea-level rise. Int J Geogr Inf Sci 22(2):167–182
Preston BL, Westaway RM, Yuen EJ (2011) Climate adaptation planning in practice: an evaluation of adaptation plan from three developed nations. Mitig Adapt Strat Gl 16(4):407–438
Preston BL, Rickards L, Dessai S, Meyer R (2013) Waters, Seas and wine: science for successful climate adaptation. In. Moser SC, Boykoff MT (eds) Successful adaptation to climate change: linking science and policy in a rapidly changing world. Routledge, p 360
Rahmstorf S (2007) A semi empirical approach to projecting future sea-level rise. Science 315(5810):368–370
Reid H, Alam M, Berger R, Cannon T, Huq S, Milligan A (2009) Community-based adaptation to climate change: an overview. In: Theme section: community-based adaptation to climate change, Participatory Learning and Action 60. International Institute for Environment and Development, Russell Press, Nottingham, United Kingdom, p 210
Revi A, Satterthwaite DE (2014) Urban areas. In: Climate change 2014—impacts, adaptation and vulnerability: global and sectoral aspects. Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, p 1140
Romero-Lankao P, Dodman D (2011) Cities in transition: transforming urban centers from hotbeds of GHG emissions and vulnerability to seedbeds of sustainability and resilience. Curr Opin Env Sust 3(3):113–120
Rosenzweig C, Solecki WD (2001) Climate change and a global city. Environment 43(3):8–18
Rowley RJ, Kostelnick JC, Braaten D, Li X, Meisel J (2007) Risk of rising sea level to population and land area. Eos Trans Amer Geophys Union 88(9):105–116
Sheppard RJS, Shaw A, Flanders D, Burch S, Wiek A, Carmichae J, Robinson J, Cohen S (2011) Future visioning of local climate change: a framework for community engagement and planning with scenarios and visualization. Futures 43(4):400–412
Slovic P (2000) The perception of risk. A collection of core readings in risk perception and communication. Earthscan
Spence A, Pidgeon N (2010) Framing and communicating climate change: the effects of distance and outcome frame manipulations. Global Environ Chang 20:656–667
START (2009) Communicating climate risks insights gained through the ACCCA project. Online https://start.org/wp-content/uploads/accca09-web.pdf. Accessed 9th Apr 2019
Sterman JD (2011) Communicating climate change risk in a skeptical world. Clim Change 108:811–826
Swart R, Bernstein L, Ha-Duong M, Peterson A (2009) Agreeing to disagree: uncertainty management in assessing climate change, impacts and responses by the IPCC. Clim Change 92:1–29
Titus JG, Richman C (2001) Maps of lands vulnerable to sea level rise: modeled elevations along the US Atlantic and Gulf coasts. Clim Res 18(3):205–228
Tribbia J, Moser SC (2008) More than information what coastal managers need to plan for climate change. Environ Sci Pol 11(4):315–328
UNAI (2016) New tool helps communities better understand climate change. United Nations Academic Impact, United Nations Headquarters, New York, USA
UNDP (2007) Climate change and forced migration: observations, projections and implications. Geneva, Switzerland, p 20 Online. http://hdr.undp.org/sites/default/files/brown_oli.pdf. Accessed 10th May 2019
UNFCCC (2007) Climate Change: impacts, vulnerabilities and adaptation in developing countries. United Nations Framework Convention on Climate Change, Bonn, Germany, pp 5–64
UNFCCC (2011) Communicating, teaching and learning about climate change. United Nations Framework Convention on Climate Change, Bonn, Germany
USAID (2009) Adapting to coastal climate change: a guidebook for development planners. U.S. Agency for International Development, Washington, DC, USA, p 162
Wilson E (2006) Adapting to climate change at the local level: the spatial planning response. Local Environ Intl J Just Sust 11(6):609–625

WMO (2013) What do we mean by climate services? Bulletin 62 (Special Issue). Online https://public.wmo.int/en/bulletin/what-do-we-mean-climate-services. Accessed 15 Feb 2019

Woodworth PL, Player R (2003) The permanent service for mean sea level: an update to the 21st century. J Coastal Res 19(2):287–295

World Bank (2011) Guide to climate change adaptation in cities. e International Bank for Reconstruction and Development and World Bank, Washington DC, USA, p 100

World Bank (2017) Guide to climate change adaptation in cities. The international bank for reconstruction and development and urban development and local government unit sustainable development network. The World Bank, Washington DC, USA, p 100

Ye Wu S, Yarnal B, Fisher A (2002) Vulnerability of coastal communities to sea-level rise: a case study of Cape May County, New Jersey, USA. Clim Res 22(3):255–270

Chapter 7
What Do Users Expect from Climate Adaptation Services? Developing an Information Platform Based on User Surveys

Esther Hoffmann, Johannes Rupp and Kirsten Sander

Abstract We present the preparatory research for the German Climate Preparedness Portal (KLiVO—www.klivoportal.de)—a meta-portal of climate adaptation and climate information services initiated by the German Government. Our work focuses on user needs and expectations and we followed the four-step user integration process suggested by Swart et al. (2017), but added a fifth step, which involves continuing the exchange with users after implementation of the KLiVO Portal through developing a user-provider network. To analyze user needs we conducted two online surveys with a total of 972 participants and 55 qualitative interviews. The overarching research questions for our analysis were: What kind of adaptation services do users need? What are current deficits in addressing user needs? How can authoritative climate adaptation services be selected and presented on the KLiVO Portal? Even though 82% of the respondents deal with climate adaptation in their work, only a third were aware of the adaptation services presented and only one in ten had actually used them. Respondents reported that the services are difficult to find, not sufficiently specific, and of indeterminate quality. Demand, however, is high: half of the respondents reported a need for such adaptation services for assessing risks and for planning, assessing, and implementing adaptation measures. We used the results of our research to develop the KLiVO Portal and draw conclusions for climate adaptation services and meta-platforms in general: The landscape of climate adaptation services needs to be restructured; quality assurance would ensure reliability; communication between users and providers must be improved and must continue when services are on the market. We suggest further research on continuous user integration and an evaluation of climate adaptation services regarding their effectiveness.

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Introduction

Preparing for and adapting to the unavoidable impacts of climate change, including the avoidance or minimization of loss and damages and consideration of potential opportunities arising from a changing climate requires knowledge, experience, and action at all levels of government and society and in all sectors and geographical regions. In order to steer the national policy process on climate adaptation, the German government adopted, in 2008, the German Strategy for Adaptation to Climate Change (see The Federal Government 2008; Stecker et al. 2012; Vetter et al. 2017). Even though its focus is on strategies at the national level, it is intended to enable other responsible regional and local authorities as well as non-governmental actors (NGOs) to likewise engage in adaptation activities (The Federal Government 2008).

During the last years, national and regional authorities have been engaged in planning and implementing adaptation strategies and measures. Thereby, they have developed and improved methods and generated results. Scientists, administrative authorities, and other organizations have then used this experience to develop knowledge- and experience-based products, tools and services, such as guidelines, checklists, web tools, best-practices databases, handbooks, maps, trainings, consultancies, and networks. We refer to all of these collectively as *climate adaptation services—the products and services that support the various institutional actors and stakeholders in their decision-making, planning, and acting with respect to the impacts of climate change*. The users of these services may be administrative individuals or organizations at the national, regional or local level, or from the private sector, NGOs, and even private citizens.

In recent years, many adaptation services have been developed, both in Germany and in other countries. However, there is a mismatch between users' needs and provided services (e.g. Capela Lourenço et al. 2016). Integrating users in the development of adaptation services is considered as a fruitful approach to increase the usability of services and to improve the consistency with user needs (e.g. Palutikof et al. 2019b). Moreover, little is known about services' effectiveness and benefits (Vaughan and Dessai 2014), and knowledge on usage and uptake is limited. In addition, the landscape of services is fragmented (e.g. BBSR 2016) and quality assurance is needed to help users to find authoritative climate adaptation services (e.g. Webb et al. 2019).

The German Federal Government hence decided to support research on user needs for adaptation services and to implement an ongoing, quality-assured service platform for climate information services and climate adaptation services (Bundesregierung 2015).[1] At the behest of the Federal Government, the German Federal Environment Agency, together with a scientific project team, conducted background

[1]The interministerial working group Adaptation Strategy is the steering committee; implementation is being led by the German Federal Environment Agency (Umweltbundesamt, UBA), which is in charge of coordinating the presentation of climate adaptation services, and the German National Meteorological Service (Deutscher Wetterdienst, DWD), which is responsible for the presentation of climate information services.

research and conceptualized this general service. The concept later on evolved into the German Climate Preparedness Portal (Klimavorsorgeportal or KLiVO, www.klivoportal.de) that was brought online in September 2018. KLiVO covers a broad range of services and connects data-driven climate science with context-dependent tools for adaptation action.

In the following, we will present the analyses on user needs for climate adaptation services and present how insights from these analyses were considered during the preparation of the KLiVO Portal. The overarching research questions for our analysis were: What kind of adaptation services do users need? What are current deficits in addressing user needs? How can authoritative climate adaptation services be selected and presented on the KLiVO Portal?

In order to bring these services into usage and effectively support adaptation, the platform implied a broader approach to the interplay between supply and demand going beyond a solely online-based approach. Thus, in our research, we also looked at how to intensify and promote the greater exchange of information between users and providers of climate adaptation services, and analyzed which kinds of tasks would be dedicated to such a user-provider interface, later referred to as the KlimAdapt user-provider network.

Climate Adaptation Services

Adaptation to climate change is not a singular activity, but rather a continuous process—an ongoing policy cycle—of understanding and describing the changes that are occurring; analyzing and assessing their impacts and risks; developing, comparing and selecting adaptation options; planning and implementing adaptation measures; and monitoring and evaluating the effectiveness of such measures and strategies (see Fig. 7.1 and BBSR 2016; Kind et al. 2015; Vetter et al. 2017).

Within the adaptation process, climate adaptation services help to identify and assess climate impacts; to select, plan and implement adaptation measures; and to assess their effectiveness. Adaptation services are complemented by climate information services, which comprise meteorological and climatological data as well as climate projections. Regarding the adaptation policy cycle (see Fig. 7.1), climate adaptation services support Phases 1–4 and climate information services support Phase 0.

Our understanding of climate adaptation services is derived from the term *climate services*, the use of which, however, varies in its interpretation and framing as well as in its extent and depth (Capela Lourenço et al. 2016; EEA 2015). For example, the World Meteorological Organization's Global Framework for Climate Services states that climate services consist in "providing climate information in a way that assists decision making" (WMO 2014, p. 2). The European Commission's Research and Innovation Roadmap for Climate Services includes under the term "customized products such as projections, forecasts, information, trends, economic

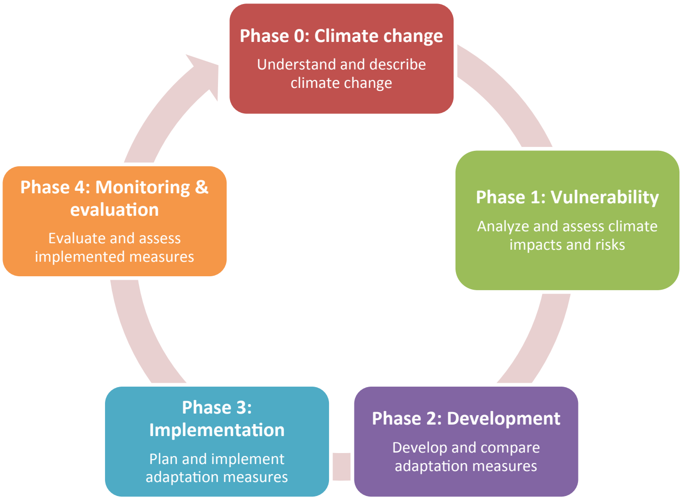

Fig. 7.1 Policy cycle for climate adaptation (adopted and translated from BBSR 2016: p. 23; Kind et al. 2015: pp. 26f.)

analysis, assessments (including technology assessment), counselling on best practices or development and evaluation of solutions" transformed from climate-related data and other relevant information (European Commission 2015, p. 10).

The term *climate adaptation services* was introduced by Goosen et al. (2014) as "an information service supporting the assessment of vulnerability in a wider perspective and includes the design and appraisal of adaptation strategies" (Goosen et al. 2014, p. 1036). The European Environment Agency (EEA) differentiates between climate services and climate adaptation services, noting that the latter "provide a broader set of services to support adaptation, including vulnerability and risk assessments of regions and sectors, adaptation strategies, adaptation options, case studies' planning tools, policy frameworks and processes" (EEA 2015, p. 14). Based on these definitions, we define *climate adaptation services as products and services that support the various institutional actors and stakeholders in their decision-making, planning, and acting with respect to the impacts of climate change*.

Literature Review: Awareness and Use of Climate Services

Several studies have analyzed the awareness, use, usefulness, and uptake of climate services in general, including the factors hampering their broader application, and/or offered recommendations on how to improve these services. Most of the studies regarding the use of climate services do not distinguish between climate information services and climate adaptation services; for exceptions see Goosen et al. (2014) or Webb et al. (2019), who focus on climate adaptation services.

Studies on awareness, use, and usefulness of climate services mostly focus on single or a few selected climate services (e.g. Clar and Steurer 2018; Mees et al. 2018). In a study among Dutch municipalities, Mees et al. (2018) found that only half of the municipalities were aware of the communicative tool under study—the online platform *Spatial Adaptation Knowledge Portal*—and only a quarter had used it. Porter et al. (2015) on the contrary, found that most British local authorities are familiar with official scientific sources of climate information—the study's focus, however, is not on climate services but on climate information. Other authors also stated that the use of climate services is not widespread (e.g. Terrado et al. 2018) or that the potential market is untapped (Street 2016). According to Vaughan and Dessai (2014), little is known about the effectiveness of climate services, as there has been little evaluation of their performance.

Several studies identify a mismatch between users' needs and provided services (e.g. Clar and Steurer 2018; Capela Lourenço et al. 2016; Hammill et al. 2013). Capela Lourenço et al. (2016) were critical that many climate services have been developed with too little attention to users and their specific terminology, needs, and conditions: "climate services need to move from science-driven and user-informed to demand-driven and science-informed practices" (Capela Lourenço et al. 2016, p. 14). An understanding of the users of these services varies among studies; Swart et al. (2017), for example, looked at climate scientists, impact researchers and boundary workers, whereas Houtkamp et al. (2016) characterize users as those actually using such tools or adaptation services and looking for support in their activities—a definition more closely in line with our own understanding of users.

The literature describes further weaknesses of climate services. Goosen et al. (2014), for instance, found that most climate services only address the first phase of the adaptation policy cycle (vulnerability). Webb et al. (2019) noted critically that adaptation services often support only one phase of the adaptation policy cycle without positioning it in the broader process. Brasseur and Gallardo (2016) explain the limited use of climate services through users' insufficient awareness of their vulnerability, a lack of relevant services, an unsuitable format of the information, and an inappropriate business model for climate services. Questions of trust in science or in the developers of these tools can also be a barrier to applying climate services (e.g. Golding et al. 2017).

Going further, the landscape of climate services is described as fragmented—users have difficulty finding their way through the multitude of available climate services and identifying appropriate and reliable services suitable to their situation (BBSR 2016; Cortekar et al. 2014; Hammill et al. 2013; Hauge et al. 2017; Webb et al. 2019). Several authors stress that quality assurance is important to increase transparency and to help users find authoritative climate services (e.g. Máñez et al. 2014; Webb et al. 2019).

Quality and selection criteria for a platform presenting climate services would help to identify and maintain relevant content and ensure reliability to the user (EEA 2015). General criteria important for the knowledge transfer between science and practice and the uptake and usage of knowledge are salience (the relevance of knowledge for an actors' decision-making), credibility (perception whether information meets scientific standards) and legitimacy (perception of fair and unbiased knowledge production) (Cash et al. 2003). For climate adaptation services and platforms different authors have developed specific quality criteria. Cortekar et al. (2014) differentiate between first-level quality criteria, which characterize the service itself and second-level criteria, which assess the provision of the service. The European Adaptation Platform Climate-ADAPT has implemented a quality-control process for all presented content. The quality criteria allow for an assessment of whether and where content can be included. Webb and Beh (2013) have assessed 300 adaptation tools regarding their functional coverage features, user-oriented features, and good adaptation principles. For each of these features there is a set of criteria for classifying the tools. Such criteria help to structure, assess, and compare services in a transparent way. When defining quality criteria for climate adaptation services and overarching portals it is, however, important to identify users' own quality criteria in order to make information more salient and legitimate.

Notwithstanding the various studies that have been conducted, knowledge on the actual use of climate services is still limited. Moreover, insights into the varied needs of the differing user groups (with respect to their particular institutional roles, areas of action, and experience) are scarce, and to make matters worse, several studies on user needs involve representatives of users, knowledge brokers, or researchers rather than actual users. We aim at closing these gaps by conducting a broad user survey and completing interviews with a variety of end users—looking into their specific needs and expectations towards climate adaptation services and the quality of services.

Literature Review: Involving Users in the Development of Climate Services

Literature on climate services stresses the importance of involving users in the development process in order to increase the usability of climate services (Brasseur and Gallardo 2016; Cortekar et al. 2016; Clar and Steurer 2018; Goosen et al. 2014; Haße and Kind 2019; Hewitt et al. 2017; Monfray and Bley 2016; Palutikof et al. 2019b; Street 2016; Swart et al. 2017). User involvement can also help to increase the acceptance and legitimacy of climate services (Cortekar et al. 2016; Vaughan and Dessai 2014). However, when analyzing products and tools on adaptation for urban and regional development in Germany, the Federal Institute on Building, Urban Affairs and Spatial Development (BBSR 2016) found that in most cases tools are driven and developed solely by scientific institutes with little involvement of prospective users.

Swart et al. (2017) suggest that the user-engagement process consists of the following steps:

- Mapping experiences from other projects
- Identifying and prioritizing user categories

– Surveying user requirements
– Engaging user panels in testing subsequent portal versions

These are important tasks for user engagement and we will follow this approach in the development of the KLiVO Portal.

Examples of user integration in the development of climate services usually combine interviews or surveys with workshops or usability tests (e.g. Swart et al. 2017; Webb et al. 2019), or test cases after introducing a service (Palutikof et al. 2019a). Different authors suggest setting up communities of practice or knowledge brokering (Mees et al. 2018; Webb et al. 2019). In communities of practice, practitioners and tool developers should exchange ideas and discuss steps forward (Mees et al. 2018); such exchanges help to build trust in the community and demonstrate the credibility and quality of services (Street 2016).

Representative and systematic evaluations of climate services in use are rare and mostly limited to web statistics (Palutikof et al. 2019b; Swart et al. 2017). Since user needs and the landscape of climate services are changing, climate services, however, need to be evaluated and updated in regular intervals (Haße and Kind 2019). Moreover, user interaction often stops with completion of development, rather than being carried forward in a continuous co-creative process that also includes ongoing use and further development of the services. This is partly explained by the fragmented development of climate services and a lack of continuous support that hampers learning and improvement processes (Webb et al. 2019).

The literature shows that interaction with users often stops with the publication of available climate services. Our approach is oriented on the four-step user engagement process suggested by Swart et al. (2017), but we add a fifth step: we recognize the ongoing need for users to be involved in developing, implementing, evaluating, and further-developing climate services and a comprehensive platform.

Methodologic Approach for Identifying User Needs for Climate Adaptation Services

In accordance with the user-engagement process proposed by Swart et al. (2017), we began with a broad literature review and an analysis of existing portals and networks. We then mapped the user landscape, identified potential user groups for the KLiVO Portal, and set priority target groups. We emphasized addressing all of the action fields included in the German Adaptation Strategy as well as a broad range of actors, from government administrators at various levels as well as NGOs and business representatives.

Based on this user mapping, we conducted two online surveys and 55 interviews with potential users (in 2016 and 2018). The aim was to discern both user needs and current user behavior regarding existing climate adaptation services. Both surveys and interviews were anonymous. The online surveys each took roughly 15 min for the participant to complete and were online for one month. The interviews took around

45–90 min and were conducted by telephone. We chose this combined approach due to different strengths of the two formats. While the online surveys allowed us to reach a large group of respondents the interviews offered the possibility to discuss complex issues and to have a dialogue on the development of climate adaptation services and the KLiVO Portal between the interviewer and the interviewee.

Based on the results of the first survey we started to develop the concept for the KLiVO Portal and finalized it based on the results of the second survey. In the second survey, we roughly used the same questionnaire but sharpened a few questions to get further details on user needs. The survey and interview partners in 2016 addressed climate adaptation services and users from those action fields in the German Adaption Strategy that face major challenges from climate impacts—as identified in Germany's Vulnerability Study (Adelphi et al. 2015) and the progress report of the Federal Government (Bundesregierung 2015). These comprise the following sectors or so-called action fields: *Water regime and water management*, *Energy industry* and *Transport, transport infrastructure* (these two were combined in the survey), and *Human health,* as well as the cross-sectional topic *Spatial, regional and physical development planning and civil protection*. In the second survey and interviews in 2018, we covered further action fields from the German Adaptation Strategy, namely: *Agriculture*, *Biological diversity*, *Forestry and forest management*, *Soil*, *Financial services industry*, *Trade and industry*, and *Tourism industry.* Both surveys hence addressed different respondents. We will present the combined results for both surveys because we were interested in the overall results and the results per action field. We used the overall results to plan the KLiVO Portal and we will use the action field-specific results for developing ideas on how to improve existing field-specific climate adaptation services.

The Federal Environment Agency disseminated information about how to participate in the two surveys via two mailings based on a total of almost 7,000 (mainly personal) address listings. In addition, the Federal Environment Agency sent an invitation to more than 800 so-called multipliers, including 63 newsletters and web portals. The 2016 survey reached 495 participants and the 2018 survey 477 participants, resulting in 972 completed questionnaires.

In selecting interview partners, we looked for individuals from all action fields and categories of institutional actors having a good base of knowledge and extensive experience with climate adaptation and who were involved in making decisions regarding planning and implementing climate adaptation measures on the regional and local level.

The questionnaires in the two surveys and the interview guidelines had approximately the same structure. The online surveys comprised mainly closed questions, with single or multiple-answer options, and in part options for additional contributions. In contrast, we kept the interview questions open-ended in order to get more substantial feedback.

In all cases, in order to have a better understanding of the users, their needs and the effectiveness of climate adaption services (cp. i.a. Capela Lourenço et al. 2016; Vaughan and Dessai 2014), the following aspects were queried:

– Background of the participant or interview partner
– Current and future adaptation activities, according to the phases of the adaptation policy cycle
– Awareness and use of cross-sectoral and sector-specific climate adaptation services (see Table 7.1 for an overview of analyzed cross-sectoral climate adaptation services)
– Preferred types of climate adaptation services
– Need for information and data on action field-specific topics that climate adaption services should address in the future

We specifically emphasized the question of which additional climate adaptation services users were in need of. We asked about which tasks users needed support with, addressing the various phases of the adaptation policy cycle (see Fig. 7.1). We subdivided the second phase into two sub-phases, because we assumed that different kinds of support are needed. Thus, we asked about additional support with respect to the tasks listed in Fig. 7.2 and provided examples of such information in brackets.

In the interviews, we additionally asked about the participants' own standards for quality when searching for climate adaptation services, and their expectations with regards to a web portal. We also asked about major barriers to planning and implementing adaptation measures and the kind support needed to overcome these. This information will help us to improve future services. Finally, the interviews gathered feedback and ideas on the user-provider interface.

In parallel to the online surveys and interviews with users, we conducted a review to take stock of current climate adaptation services in Germany. Our focus was on services provided by federal and state authorities and these were addressed with three surveys in 2016 and 2018. The Federal Environment Agency sent out the surveys and we received reports on a total of 93 services from 11 federal authorities and 13 state authorities. The authorities were asked to characterize the services they offered, specifically their objectives and focus with regard to action fields, phases of the adaptation policy cycle, climate impacts, actor categories, and service types. Furthermore, we asked whether the services are regularly updated, whether they were based on scientific research, whether their users were involved in their development, and whether they provided best-practice examples. With this information, we hoped to get a better picture of the degree of match or mismatch between user needs and the services provided.

Based on the identified user needs (see next section), we developed a concept for the KLiVO Portal. Potential users discussed the concept in a user-provider workshop and their feedback was carefully considered when revising the concept. During the implementation phase, usability tests were conducted and the resulting feedback from about 20 users was used to improve and fine-tune the portal. Figure 7.3 gives an overview of our approach.

Table 7.1 Overview of cross-sector German climate adaptation services included in the online surveys and interviews

Climate adaptation service	Provider	Link
Klimalotse (adaptation web tool for municipalities)	Competence Centre on Climate Impacts and Adaptation at the Federal Environment Agency	https://www.umweltbundesamt.de/themen/klima-energie/klimafolgen-anpassung/werkzeuge-der-anpassung/klimalotse
Stadtklimalotse (adaptation web tool and database for municipalities)	Federal Institute for Research on Building, Urban Affairs and Spatial Development	http://www.klimastadtraum.de/DE/Arbeitshilfen/Stadtklimalotse/stadtklimalotse_node.html
KlimaStadtRaum (web portal containing research results, practice examples, and practical support tools)	Federal Institute for Research on Building, Urban Affairs and Spatial Development	http://www.klimastadtraum.de/DE/Home/home_node.html
KomPass-Tatenbank (database compiling examples of adaptation measures and projects)	Competence Centre on Climate Impacts and Adaptation at the Federal Environment Agency	https://www.umweltbundesamt.de/themen/klima-energie/klimafolgen-anpassung/werkzeuge-der-anpassung/tatenbank
Methodenhandbuch zur regionalen Klimafolgenbewertung (guidelines on assessing climate impacts in regional planning)	Federal Institute for Research on Building, Urban Affairs and Spatial Development	https://www.klimastadtraum.de/SharedDocs/Downloads/Veroeffentlichungen/BMVBS_Sonderv/2013/DL_BMVBS_Sonderv_2013_09.html

(continued)

Table 7.1 (continued)

Climate adaptation service	Provider	Link
Klimanavigator (web portal containing research results on climate change and adaptation)	Climate Service Center Germany—GERICS	http://www.klimanavigator.de/
Webseiten des Förderprogramms KLIMZUG (web portal containing results, publications and information from the research program Climate Change in Regions)	Federal Ministry for Education and Research	Not available anymore
Monitoring report 2015 for the German Adaptation Strategy	Competence Centre on Climate Impacts and Adaptation at the Federal Environment Agency	https://www.umweltbundesamt.de/publikationen/monitoringbericht-2015
Vulnerability analysis for Germany	Competence Centre on Climate Impacts and Adaptation at the Federal Environment Agency; Network Vulnerability	https://www.umweltbundesamt.de/publikationen/vulnerabilitaet-deutschlands-gegenueber-dem
Klimacheck (web tool for businesses)	Federal Ministry for Economic Affairs and Energy	http://www.bmwi.de/Redaktion/DE/Publikationen/Industrie/klimacheck.html http://www.bmwi.de/Redaktion/DE/Downloads/klimacheck-tool.html

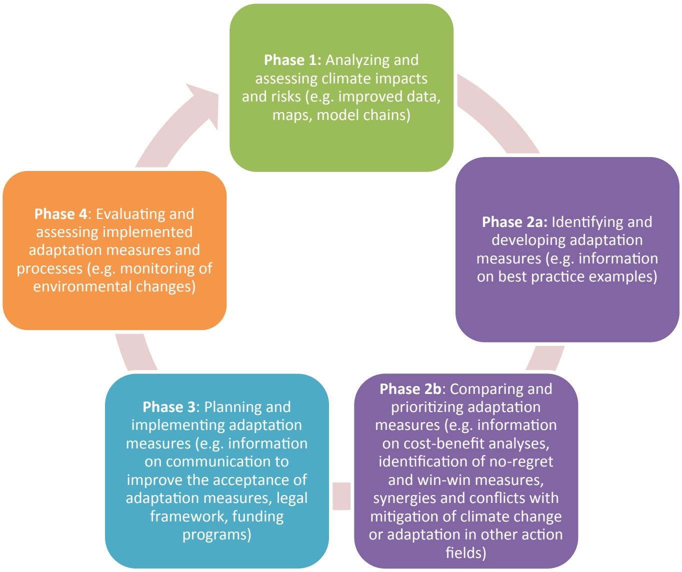

Fig. 7.2 Overview of adaptation tasks (and corresponding information)

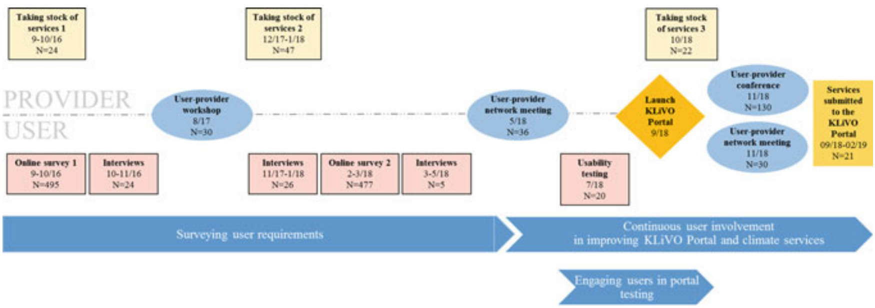

Fig. 7.3 Overview of approach to assess user needs and review of adaptation services

Results: Identified User Needs for Climate Adaptation Services

In the following subsections, we will present the results of our online surveys and interviews, regarding users' backgrounds, their current awareness and use of climate adaptation services, their needs for additional services, requirements for adaptation services and a web-portal, perceived barriers and their expectations regarding the exchange between users and providers.

Background of Potential Users

A total of 972 individuals participated in the two online surveys. Figure 7.4 shows that the participants came from various action fields. Most were from the action fields *Water regime and water management*, *Spatial, regional and physical development planning and civil protection,* and *Human health*. The fields *Financial services industry*, *Tourism industry*, and *Soil* are significantly less represented in the surveys. About half of the participants work administratively at various levels (especially in municipalities and at the state level), somewhat less than a quarter are in the private sector, and 16% were in research, consultancy, and education (see Fig. 7.5). About one tenth work in NGOs, are private persons or work in other organizations. The participant structure closely reflects the target group structure of the KLiVO Portal, which is mainly intended for individuals in the areas of government administration and business.

Eighty-two percent of the participants had already dealt with adaptation issues in their work. Looking at the adaptation policy cycle (see Fig. 7.1), the majority of these experienced respondents have analyzed and assessed climate impacts and risks (Phase 1; see Fig. 7.6). About one third have also developed and compared adaptation measures (Phase 2) and planned and implemented adaptation measures (Phase 3). In contrast, only 13% have evaluated and assessed implemented adaptation measures and processes. Most of the respondents have thus already accomplished working tasks for which climate adaptation services might be supportive and qualify as at least potential users.

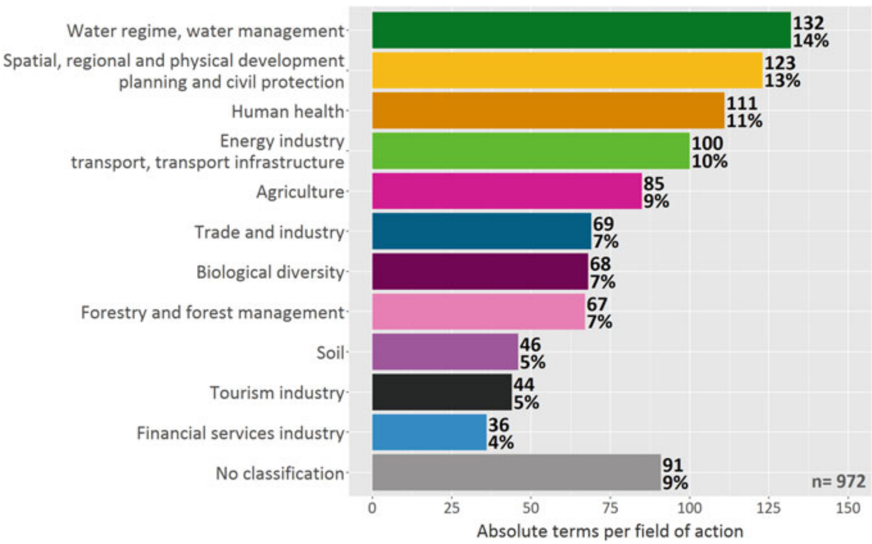

Fig. 7.4 Distribution of participants by action field

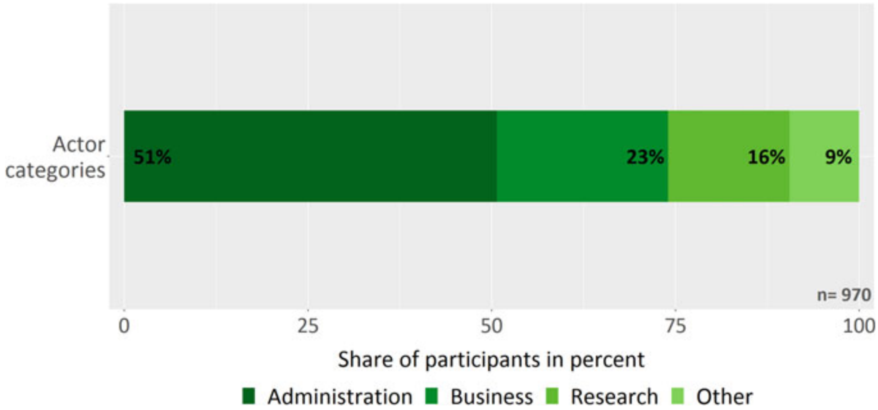

Fig. 7.5 Distribution of participants by institutional actor category. *Business* comprises companies, economic associations and trade groups; *Research* comprises actors from academia, research, consultancy, and education; *Other* consists in part of actors from non-governmental organizations (NGOs)

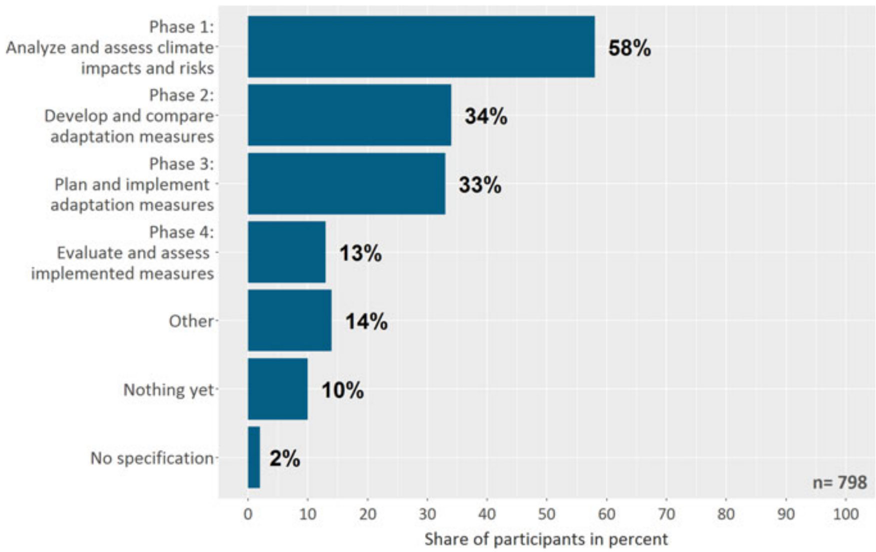

Fig. 7.6 Participants' experience with adaptation

Awareness and Usage of Climate Adaptation Services

Albeit respondents have been engaged with climate adaptation, only a small number were aware of cross-sectoral (German-language) climate adaptation services (see Fig. 7.7); on average, less than one third were aware of these services. The most well-known service was the *Monitoring Report to the German Adaptation Strategy*, of which half of the respondents were aware. Looking at the different action fields,

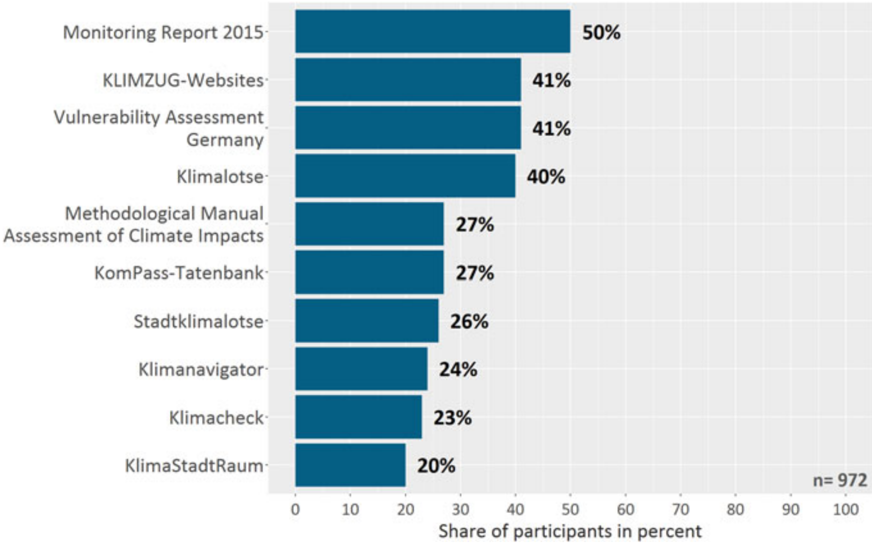

Fig. 7.7 Participants' awareness of cross-sector adaptation services in Germany. *Awareness* is a combination of the answers "I have already used this service and it was helpful", "I have already used this service and it was not helpful", "I know this service and have already looked at it," and "I have heard of this service"

actors in the area of *Spatial, regional and physical development planning and civil protection* were the most aware of various services, followed by those involved in the fields of *Soil*, *Water regime and water management*, and *Biological diversity*. Compared to respondents in fields of administration and research, respondents in the private sector were less aware of available climate adaptation services, an exception being *Klimacheck*, a tool specifically tailored to companies. The share of those respondents who have already used climate adaptation services is even lower, on average, one tenth. The most used services are–again–the *Monitoring Report* (17%) and the *Vulnerability Study* (16%).

The surveys also queried respondents about climate adaptation services specific to their fields. In most cases, the respondents were more familiar with the services specific to their area of expertise, with the exception of *Trade and industry*, *Water regime and water management*, and *Spatial, regional and physical development planning and civil protection*. The greatest awareness and use rates regarding field-specific services were found in the areas *Soil*, *Financial services industry*, and *Human health*.

Asked about reasons for the limited use of climate adaptation services, 54% responded that the services were difficult to find, 27% perceived them as not sufficiently specific to their field, and 14% said they were unsure about the quality of the services being offered (see Fig. 7.8).[2] In the action fields of *Soil* and *Forestry and forest management*, the percentage was even higher (20%). The interviewees

[2]This question was only included in the 2018 online survey.

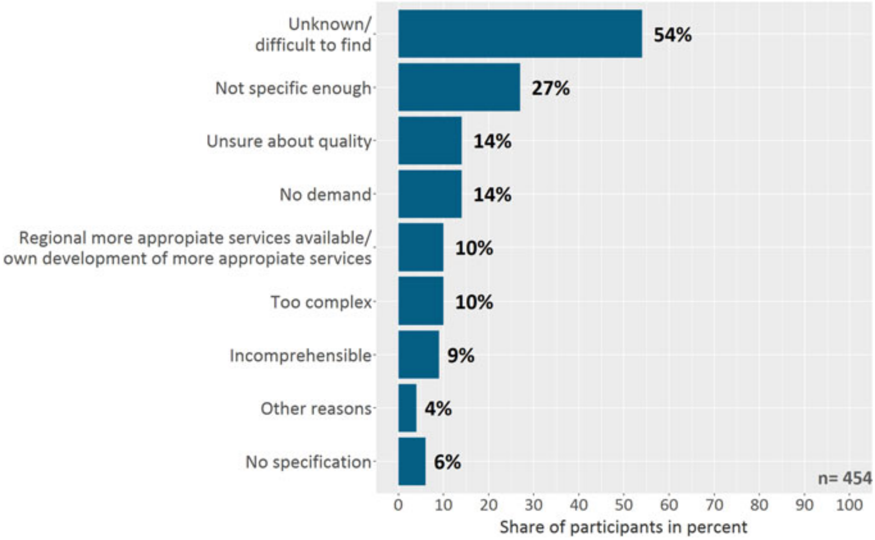

Fig. 7.8 Participants' reasons for not using climate adaptation services

especially discussed aspects of quality and trust as barriers to using climate adaptation services. They stressed that it is important who develops and offers services and asked for a quality control for services. This shows a clear need for improved visibility, accessibility, and quality assurance for climate adaptation services.

The interviewees were a bit more familiar with the available sectoral and cross-sectoral climate adaptation services. They described the overall offering of climate adaptation services as extensive and diversified, but found the range unfocused, confusing, and to some extent redundant. Particularly with regard to the services provided by federal and state governments, they identified a need for better coordination. The services should not compete but rather complement each other.

Further Needs for Climate Adaptation Services

We found that respondents need additional support for all phases of the policy cycle (see Fig. 7.9). While the need in phases 1 and 2a is slightly higher, respondents described a lower need for services in Phase 4. The need for services in Phase 3 is especially high in the action field *Agriculture* (55% of the respondents in this field). The answers they provided also gave hints as to the kind of information users are looking for: examples of best practices, maps, cost benefit analysis, and the legal framework.

Asked about the different types of adaptation services, respondents express the greatest need for manuals, including guidelines or checklists, and for knowledge

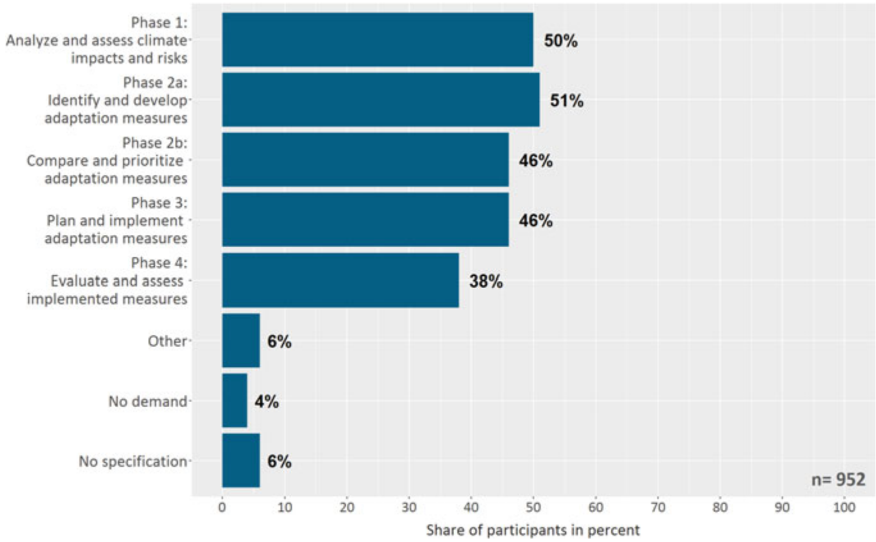

Fig. 7.9 Need for further climate adaptation services for different adaptation phases

portals, e.g. databases (see Fig. 7.10).[3] More than a third also expressed a need for maps and for research studies or reports. Interactive web tools were important to a bit more than a quarter of respondents. The need for consultancy, networking, or training services was less pronounced; however, in the interviews, a stronger need

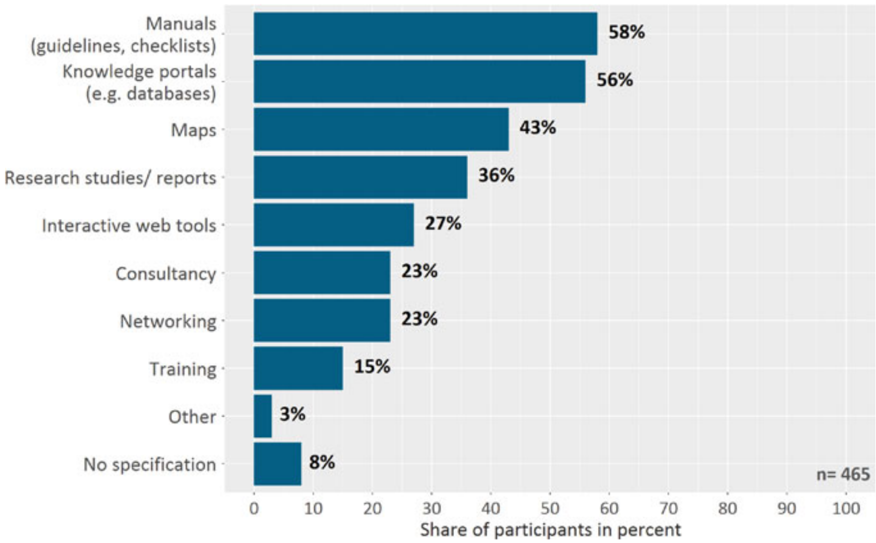

Fig. 7.10 Further need for different types of climate adaptation services

[3]This question was only included in the 2018 online survey. In the 2016 survey, we distinguished the need for different tools according to the individual phases of the adaptation policy cycle.

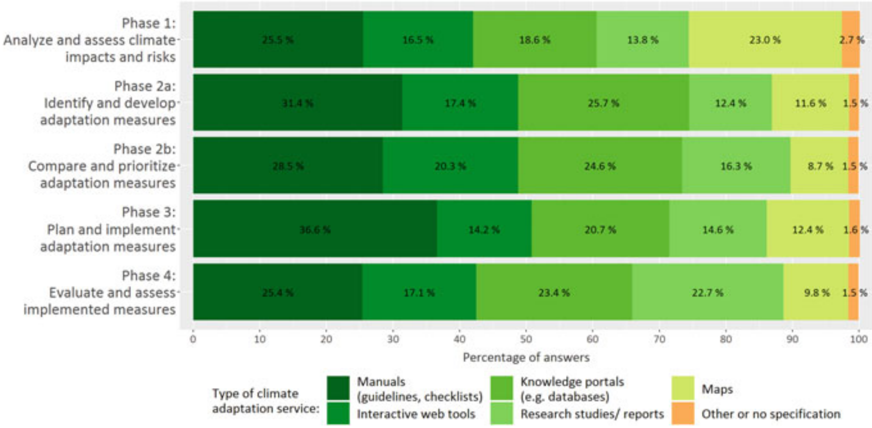

Fig. 7.11 Further need for different types of climate adaptation services in different phases of the adaptation policy cycle

for these kinds of services was expressed. Looking at the individual action fields, consultancy is especially relevant for *Agriculture,* and training in the action fields *Human health* and *Trade and industry*.

In the 2016 online survey, we distinguished the need by phases of the adaptation policy cycle and found that in all phases, manuals are most important and knowledge portals are the second most important—expect for phase 4. We moreover identified that maps are particularly important in Phase 1, knowledge portals in Phase 2 (2a and 2b), practical support tools in Phase 3, and research studies and reports in Phase 4 (see Fig. 7.11). We also asked for the relevance of consultancy, networking and training in the different phases. There are, however, only little differences among the phases. Consultancy is the most important service in all phases. Networking becomes slightly more important in the later phases, while phases 1 and 2a reach slightly higher shares for training, and phases 1, 2a and 2b slightly higher shares for consultancy.

Topics for which additional climate adaptation services are needed show a great variety across the various action fields (see Table 7.2). They range from choosing tree species to address changing site conditions in *Forestry and forest management* to climate change and animal-borne diseases in the area of *Human health,* and impacts on underwriting risks and insurance coverages in the *Financial services industry* sector.

Table 7.2 Need for further climate adaptation services for different topics (by action field; the table includes the three most often chosen topics from the online surveys; if more than three topics are listed, the topics reached the same rank)

Action field/sector	Need for climate adaptation services on the following topics
Agriculture	– Climate change impacts on vegetation and management periods – Climate change impacts on pests – Regional climate impacts
Biological diversity	– Shift, degradation and loss of habitats caused by climate change – Climate impacts on vegetation periods – Managing biodiversity hotspots and climate change – Climate impacts on species behavior
Energy industry and transport, transport infrastructure	– Integrating climate adaptation in infrastructure planning – Identifying particularly vulnerable infrastructure – Climate impact assessment/climate proofing of critical infrastructure
Financial services industry	– Impacts on underwriting risks and insurance coverages – Political requirements for the insurance sector – Climate change impacts on economic or industry sectors – Integrating climate information in risk models and risk assessment tools – Regional climate impacts
Forestry and forest management	– Selecting tree species under changing site conditions – Forest conversion and stock treatment – Regional climate impacts
Human health	– Climate change and animal-borne diseases – Climate change and communicable diseases – Climate change and heat impacts
Soil	– Climate change impacts on soil water budget – Climate change impacts on erosion – Climate change impacts on soil organic matter and soil organisms
Spatial, regional and physical development planning and civil protection	– Integrating climate adaptation in regional and urban development planning instruments – Determining particular vulnerable sites – Climate-adapted settlement development

(continued)

Table 7.2 (continued)

Action field/sector	Need for climate adaptation services on the following topics
Trade and industry	– Damages to industrial infrastructure caused by extreme weather events – Adverse effects on employees' health – Adverse effects on production processes through heat or extreme weather events
Tourism industry	– Climate change impacts on tourism – Alternative touristic offerings – Changes in peak tourist seasons and regional demand – Regional climate impacts
Water regime, water management	– Preparing for heavy rainfall/flash flood management – Flood management – Surface water management – Groundwater management – Rainwater management

Requirements for Climate Adaptation Services

With regard to the credibility of climate adaptation services, the interviewees and, in part, the responses to the open-ended questions in the online surveys stressed the quality criteria summarized in Box 1.

Box 1: Users' quality criteria

Topicality: Climate adaptation services should be a source of current, accurate information and updated on a regular basis,
Relevance: Services should focus on the needs of users who are looking for solid advice on climate change and adaptation,
Scientific basis: Climate adaptation services should be based on sound scientific research and evidence,
Accessibility: The information and data provided should be easily accessible and the use of climate adaptation services should fit within a reasonable cost framework,
User-friendliness: Presentations should be compact, i.e. short and concise; information, data, and tools provided should be simple and self-explanatory; and services of high practical relevance. Climate adaptation services should be compatible with the tools and data that users already use.
Reputation: Some interviewees believe that the reputation of the service provider is important for establishing trust, credibility, and reliability.

Users expressed a need for easy-to-use tools for getting started with climate adaptation as well as for data they can analyze themselves and compare to own data. For this, the respondents expressed in part a need for (geo-) web services or exchange formats such as Web Feature Service, Web Mapping Service, Web Coverage Service, or Web Processing Service.

Presentation on a Web Portal

If climate services are presented on a web portal, the majority of respondents expect the presentation to include photos, figures, and maps (78%), scientific background information (67%), and short printable information (55%) (see Fig. 7.12). An overview of possible applications (47%) and the sharing of user experiences or exchanges with other users (36%) were also important for many respondents. About one quarter are interested in links to comparable services, frequently asked questions, contact persons, and films or videos. Only 18% are interested in a comparison of different services. Actors from the action field *Trade and industry* show a comparably broad interest in access to contact persons (48%) and in films or videos (45%). Short printable information is especially needed in the fields *Forestry and forest management* (67%), *Human health* (66%) and *Tourism industry* (65%). The interviewees shared this feedback and stressed the relevance of visualization (photographs, maps)

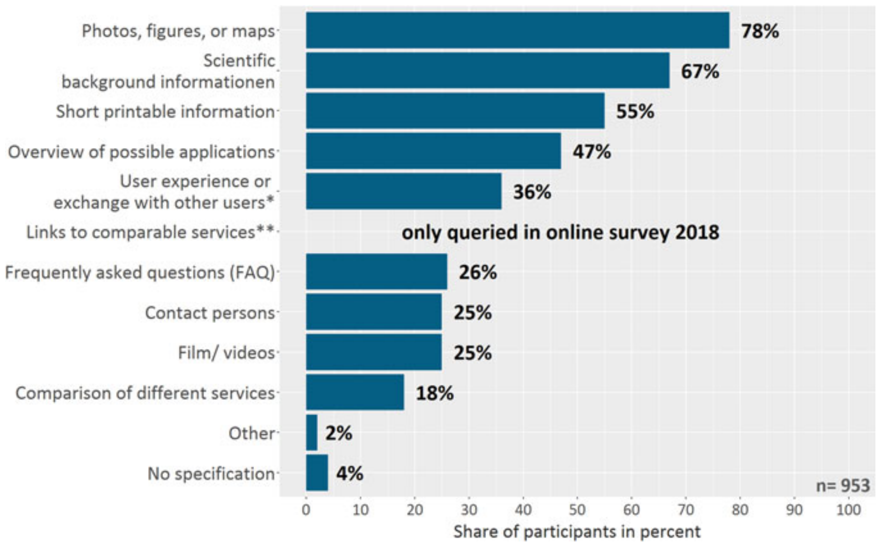

Fig. 7.12 Expectations as to how climate adaptation services should be presented on a web portal. * *User experience or exchange* was divided into two options in the survey conducted in 2016; ** *Links to comparable services* was only included in the 2018 survey and chosen by 29% of participants

and contact persons and suggested direct links to the services as well as recommendations for related services and background information. The interviewees additionally stressed that the portal as a meta platform should provide an easy entry. They asked for well-structured, clear and understandable information. Moreover, they pronounced that the benefits of using the portal should become clear directly when entering the portal.

Barriers to Climate Adaptation

The answers of the interviewees and open comments of the online surveys show that the respondents struggle with a range of barriers when it comes to planning and implementing climate adaption measures. The interviewees described that their fellows, superiors or partners did not perceive climate adaptation as relevant and urgent need. In many cases, colleagues and superiors do not yet sense the consequences of climate change, and are hence not motivated to act. The interviewees also described that they had difficulties in reaching citizens. Moreover, the respondents mentioned restricted financial and personnel resources. Planning adaptation measures additionally is hampered by short planning horizons and a lack of knowledge on costs and benefits. They, moreover, described that they had difficulties in finding good practices or examples that they may use as reference and orientation.

Regarding the potential of the KLiVO Portal to help overcoming these barriers the interviewees suggested that the portal should show the consequences of inaction, demonstrate vulnerabilities, and present information on cost and benefits of adaptation measures. Respondents recommended that the portal should present adaptation as a continuous process that needs constant action. Moreover, they proposed that the portal should provide good practice examples and contact persons, and that it should support networking among users.

Networking and Continued Exchange Among Users and Providers

In the interviews, respondents shared their expectations for a user-provider network. Most would like to have regular meetings where the various stakeholders can exchange views, bring in their own questions and problems, and discuss needs for further development regarding climate adaptation services and the KLiVO Portal. Some interviewees emphasized that participants should be able to actively engage in the meetings and to learn from each other. Many considered one meeting per year to be sufficient, while others suggested up to four meetings per year. While some interviewees emphasized that the meetings should be cross-sectoral (addressing multiple action fields) and include a broad variety of users, others suggested additional sector- or topic-specific meetings. In addition, many respondents suggested online networking as a supplement to meetings.

Developing the Climate Preparedness Portal Based on Identified User Needs

In the following sub-sections, we will present how we used the insights from the online surveys and interviews to develop the KLiVO Portal and the accompanying KlimAdapt user-provider network.

Structure, Quality and Synthesized Content of the KLiVO Portal

In order to increase knowledge about the different services and provide guidance and credibility, the KLiVO Portal aims at presenting quality-assured climate adaptation services and climate information services in a structured, concise way. This is realized through a service catalogue structure, similar to a database. By means of various filters and a search function, users are able to browse the service catalogue by different categories (see Box 2).

Box 2: Filter categories on the KLiVO Portal

Phase in the adaptation policy cycle
Action field
Climate impact
Topographical region (e.g. urban regions, mountain regions, river catchments)
Target group (e.g. state or municipal administration, business)
Federal state
Service type (e.g. map, manual, publication)
Climate variable (e.g. precipitation, air temperature, soil moisture content)
Keyword

Our results show that some users have doubts about the quality and reliability of climate services and hence refuse to use them. Based on a literature review as well as on the results of the interviews, we developed a three-tier set of 20 criteria to be applied to all services represented in the KLiVO portal (see Table 7.3). The set comprises mandatory criteria—such as topicality, scientific background—facultative criteria (e.g. user-friendliness, feedback), and classification criteria that help to structure the service with respect to the above mentioned filter categories. Only

Table 7.3 Overview of quality criteria for selecting climate services for the KLiVO Portal

Mandatory criteria	Facultative criteria	Classification criteria
– Clear reference to climate change – Applicable to Germany or German regions – Up-to-date and regularly updated – Scientific basis – Free-of-charge/open access	– Tailored to user needs – User-friendly – User involvement in the development of the service – Clarity – Feedback – Practical experience with the service – Best-practice examples included	– Phase within adaptation policy cycle – Field of action – Climate impact – Region – Target group – Type of climate service – Federal level or federal state level – Climate variable

those services that pass this internal quality assurance check are accepted for inclusion in the portal. On the basis of the quality assurance results, the interministerial working group on Adaptation Strategy determines the final approval for the proposed services.

Based on the user needs for the presentation of services on a web portal, we developed a template for the profile that presents each service. It provides for a brief description of the service and provider, the scientific background, links to relevant climate variables, further documents and other thematically related services as well as a direct link to the service itself.

KLiVO also provides background information on the portal itself and the supporting networks, information on the German Adaptation Strategy and corresponding documents, news about the portal, and answers to frequently asked questions. By means of an online form, visitors can also suggest additional services to be included in the KLiVO Portal. So far, 21 additional services have been submitted.

Gap Analysis on Provided Services

Comparing the user needs identified with the climate adaptation services currently offered by public authorities in Germany, we can identify some information gaps and areas for improvement. There are, for example, hardly any specific offers for the action fields *Energy industry*, *Financial services industry*, *Trade and industry*, or *Coastal and marine protection*. In the *Financial services industry* field, insurance companies have developed climate adaptation services that are being widely used, but in the area of banking, for example, almost no services are being offered. There is also a need for more general services, such as recommendations on how to deal with the legal framework associated with climate adaptation, cost-benefit-analyses, interaction between action fields, synergies and conflicts with other policy fields, financial support, and civil society engagement.

Regarding adaptation policy cycle phases, currently only a few services address Phase 4 (evaluation and monitoring). Even though the demand for services that support the evaluation of measures is not yet as high as for other phases, it will probably increase as stakeholders move forward in the adaptation process and increasingly implement adaptation measures; further services for evaluating and assessing adaptation measures should be action-field specific.

With regard to the target groups, it can be stated that most of the services address administrative bodies, in particular local municipalities. There are much fewer offerings directed to business, NGOs, or private citizens. As more and more societal and institutional groups learn about or become aware of their vulnerability to climate change, it is important to address these groups and topics with targeted services.

With regard to the types of services being offered, the need for products such as manuals and knowledge portals is currently well covered. On the other hand, there is a lack of consultancy, training, and networking services. In the online survey the need for these types of services was less broadly indicated than for other types; however, in the interviews a need for them was clearly expressed. Looking at the current offerings, we find only three services offering training and only one offering networking. It is worth investigating whether such services are in development or whether existing services can be enhanced through the addition of training and consultancy features. The identified barriers to climate adaptation indicate further gaps in adaptation services. Some barriers can be overcome with the KLiVO Portal, for example a lack of knowledge on good practice examples and contact persons and limited possibilities to exchange with others. The other identified suggestions on how to overcome barriers—for instance presenting consequences of inaction and vulnerabilities—rather deal with the content of individual services and are beyond the scope of the KLiVO Portal as a meta-portal.

Continuous Exchange Between Users and Providers

The results of the literature review, the online surveys, and interviews were valuable for designing the KLiVO Portal in the first place and also for deriving recommendations regarding the future development of climate adaptation services. However, enhancing local and sectoral capacities and enabling adaptation requires more than a solely web-based platform, which is why the German Federal Environment Agency initiated the KlimAdapt user-provider network on climate adaptation services in 2018. The network accompanies the KLiVO Portal and thus will further strengthen user integration following implementation of the portal.

The objective of the user-provider network is to increase the usage of services and further develop adaptation services based on user needs and with regard to their applicability within a specific action field or working environment. Gaps between provided and needed climate adaptation services should also be identified and formulated. In order to achieve a public outreach, the network members should advocate for an increased usage of climate adaptation services within and beyond their organization. These objectives, as well as direct feedback from the network members, should further improve both the KLiVO Portal and the climate adaptation services.

Presently, the network consists of around 50 members from national, regional, and local authorities, business associations, NGOs, and companies, representing diverse fields. The network members meet about three times per year. Following an interactive approach of dialogue, presentations, and working groups, the network bridges the gap between the various actors and stakeholders involved in climate adaptation. With this in mind, closed network meetings, exclusively for network members, alternate with thematic meetings, which are open to others dealing with the addressed topics. Each meeting is evaluated with regard to the satisfaction of the members with the constellation of participants, possibilities for interaction, ambience, results, content, co-determination, knowledge transfer, facilitation methods, documentation, and flow of information. So far, the evaluation results show a high satisfaction with the network and give hints for some improvements. Network participants wish for even more possibilities to exchange with each other and for more knowledge input.

One issue the network has discussed, so far, is the relevance of the quality assurance process. Also, it has been proposed that existing services should be improved or merged with other services instead of developing new ones. Such input will be used to improve the KLiVO Portal. Furthermore, the KLIVO Portal will further be developed by means of a web analytic software that analyzes user behavior and by means of a user survey. Moreover, real-use cases on climate adaptation services and increased feedback possibilities for users and providers are further steps for the KLiVO Portal to bridge the gap between providers and users.

Conclusions: How to Develop User-Friendly Climate Services

The focus of our efforts and analysis was on Germany. Many of the findings, however, are transferable to other countries. As other researchers have previously noted, we find that awareness and use of climate services is limited; many users do not know about or do not find these services. For such problems, a national web-based meta-portal providing a structured search mechanism can help. Such a meta-information portal, as well as the climate services themselves, should be trustworthy and based on scientific research and methods. To assure this, a quality assurance process for choosing the content of any such portal is necessary. This can be based on the quality criteria already discussed here.

However, a standardized approach for identifying and assessing services is limited to some extent. One reason is that the understanding of climate adaptation services varies broadly due to the different contexts in which the services are developed and used. We found this in the literature as well as in our own research results and in experience with practitioners within the KlimAdapt network. Users often do not think in categories of climate adaptation services but are rather interested in thematically helpful methods or measures. Thus, users and climate scientists perceptions on content, methodological approach and design of a climate adaptation service might be different. Consequently, selecting a service and assuring its quality based on determined criteria is still a case-by-case decision, guided by a quality assessment process. We addressed this limitation of a standardized approach by a clear argumentation and transparent documentation of the assessment process.

For successful development of user-friendly climate services, early and ongoing interaction with potential users is recommended. User integration cannot be limited to a single step, but rather needs to be considered as a continuous process. A variety of methods can support this process. In the beginning it is important to map potential users, breaking them down, for example, according to actor category, action field (sector), and extent of experience with adaptation. Surveys and interviews help to identify diverse user needs and to understand the barriers users are struggling with. A broad overview on user needs helps to identify gaps in the current landscape of climate services and offers hints as to where additional services or improved services are needed. When preparing new services or updating existing services, users should moreover take part in usability tests, testing phases, and/or workshops.

As an enhancement to the four-step user engagement process suggested by Swart et al. (2017), we recommend a fifth step, which involves continuing the exchange with users after implementation of climate services. The user-provider network presented here is a potential approach to ensure this kind of continuous exchange. Since user needs are changing, it is important to regularly monitor and evaluate climate services by integrating users or user feedback into this process. This applies also for climate adaptation platforms in general. For the latter, surveys on user needs should be conducted on a regular basis to identify needs, gaps, and potentials for improving these platforms.

As the available time and commitment of relevant actors for such processes is limited, the individual and collective benefits and goals have to be clearly defined. Close links to a political process such as the German Adaptation Strategy can yield more effective and compatible results and make a constant engagement more attractive. At the same time, ongoing support and feedback to and from a scientific team ensures that the methods and content being applied remain viable and consistent with ongoing research.

There are some limitations of the present study and this paper: The assessment of the provided climate adaptation services focusses on the characteristics, user involvement and applicability of each service. A comprehensive assessment of the content and methods of each service would have been beyond the scope and capacity of the work. Moreover, even though the research covered the usage of and satisfaction with climate adaptation services, the authors cannot assess whether the applied services increased the effectiveness of climate adaptation measures on the ground. Thus, the impact evaluation of services as well as of the KLiVO Portal should be a subject for further research.

Further research is also needed on approaches that support continuous user integration and the integration of users in evaluating climate adaptation services. In order to do so, more information on the real use of climate adaptation services is needed. Transdisciplinary methods, in which scientists and practitioners jointly work on a common problem and reintegrate the knowledge gained into their science and practice community, can be a suitable methodological approach to improve the use and further development of climate adaptation services.

Even though climate adaptation services are applied regionally and locally, transregional and international exchange on the development and application of such services can help to abstract from the singular point of view towards transferable solutions. Adaptation platforms are a common ground to strengthen this exchange and to draw further lessons on the user-provider interface. A transnational comparison and evaluation of such platforms and accompanying user-provider interaction can thus be helpful to identify barriers constraining their use, strategies to overcome these barriers, and good practices, and to spark mutual learning.

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References

Adelphi, PRC, EURAC (2015) Vulnerabilität Deutschlands gegenüber dem Klimawandel. Umweltbundesamt. Climate Change 24/2015. Dessau-Roßlau, Germany, 689 pp. English summary: https://www.umweltbundesamt.de/sites/default/files/medien/378/publikationen/climate_change_24_2015_summary_vulnerabilitaet_deutschlands_gegenueber_dem_klimawandel_2.pdf, 62 pp

BBSR (Bundesinstitut für Bau-, Stadt- und Raumforschung im Bundesamt für Bauwesen und Raumordnung) (ed) (2016) Querauswertung zentraler Verbundvorhaben des Bundes zur Anpassung an den Klimawandel mit Fokus Stadt- und Regionalentwicklung. BBSR Online-Publikation 04/2016. Bonn, Germany, 211 pp

Brasseur GP, Gallardo L (2016) Climate services: lessons learned and future prospects. Earth's Future 4:79–89

Bundesregierung (2015) Fortschrittsbericht zur Deutschen Anpassungsstrategie an den Klimawandel. Bonn, Germany, 275 pp. English summary: https://www.bmu.de/fileadmin/Daten_BMU/Pools/Broschueren/fortschrittsbericht_anpassung_klimawandel_en_bf.pdf, 40 pp

Capela Lourenço T, Swart R, Goosen H, Street R (2016) The rise of demand-driven climate services. Nat Clim Change 6:13–14

Cash DW, Clark WC, Alcock F, Dickson NM, Eckley N, Guston DH, Jäger J, Mitchell RB (2003) Knowledge systems for sustainable development. PNAS 100(14):8086–8091 https://doi.org/10.1073/pnas.1231332100

Clar C, Steurer R (2018) Why popular support tools on climate change adaptation have difficulties in reaching local policy-makers: qualitative insights from the UK and Germany. Environ Policy Gov 28:1–11. https://doi.org/10.1002/eet.1802

Cortekar J, Máñez M, Zölch T (2014) Klimadienstleistungen in Deutschland—Eine Analyse der Anbieter und Anwender. CSC Report 16. Climate Service Center, Germany, p 42

Cortekar J, Bender S, Brune M, Groth M (2016) Why climate change adaptation in cities needs customised and flexible climate services. Clim Serv 4:42–51
European Commission. DG Research and Innovation (2015) A European research and innovation roadmap for climate services
European Environment Agency (2015) Overview of climate change adaptation platforms in Europe. EEA Technical Report 5, Copenhagen, Denmark, 84 pp
Golding N, Hewitt C, Zhang P, Bett P, Fang X, Hu H, Nobert S (2017) Improving user engagement and uptake of climate services in China. Clim Serv 5:39–45
Goosen H, de Groot-Reichwein MAM, Masselink L, Koekoek A, Swart R, Bessembinder J, Witte JMP, Stuyt L, Blom-Zandstra G, Immerzeel W (2014) Climate adaptation services for the Netherlands: an operational approach to support spatial adaptation planning. Reg Environ Change 14:1035–1048. https://doi.org/10.1007/s10113-013-0513-8
Hammill A, Harvey B, Echeverria D (2013) Understanding needs, meeting demands: a user-oriented analysis of online knowledge brokering platforms for climate change and development. IISD, Manitoba, Canada, p 32
Haße C, Kind C (2019) Updating an existing online adaptation support tool: insights from an evaluation. Clim Change 153:559–567
Hewitt CD, Stone RS, Tait AB (2017) Improving the use of climate information in decision-making. Nat Clim Change 7:614–616
Hauge ÅL, Almås A, Flyen C, Stoknes PE, Lohne K (2017) User guides for the climate adaptation of buildings and infrastructure in Norway—characteristics and impact. Climate Services 6:23–33
Houtkamp J, La Rivière I, de Groot H, Janssen S, de Jong A (2016) From research data to web-based policy tools: user-centered design techniques in the development of the AgMIP impacts explorer. International Congress on Environmental Modelling and Software, Toulouse, France, p 9
Kind C, Protze N, Savelsberg J, Lühr O, Ley S, Lambert J (2015) Entscheidungsprozesse zur Anpassung an den Klimawandel in Kommunen. Climate Change 04/2015. Dessau-Roßlau, Germany, 101 pp
Máñez M, Zölch T, Cortekar J (2014) Mapping of climate service providers—theoretical foundation and empirical results: a German case study. CSC Report 15, Climate Service Center, Hamburg, Germany, 54 pp
Mees H, Tijhuis N, Dieperink C (2018) The effectiveness of communicative tools in addressing barriers to municipal climate change adaptation: lessons from the Netherlands. Clim Policy 18:1313–1326
Monfray P, Bley D (2016) JPI climate: a key player in advancing climate services in Europe. Clim Serv 2016(4):61–64
Palutikof JP, Leitch AM, Rissik D, Boulter SL, Campbell MJ, Perez Vidaurre AC, Webb S, Tonmoy FN (2019a) Overcoming knowledge barriers to adaptation using a decision support framework. Clim Change 153:607–624
Palutikof JP, Street RB, Gardiner EP (2019b) Looking to the future: guidelines for decision support as adaptation practices mature. Clim Change 153:643–655
Porter JJ, Demeritt D, Dessai S (2015) The right stuff? Informing adaptation to climate change in British Local Government. Glob Environ Change 35:411–422
Stecker R, Mohns T, Eisenack K (2012) Anpassung an den Klimawandel—Agenda Setting und Politikintegration in Deutschland. Z Umweltpolit Umweltr 2:179–208
Street RB (2016) Towards a leading role on climate services in Europe: a research and innovation roadmap. Climate Services 1:2–5
Swart RJ, de Bruin K, Dhenain S, Dubois G, Groot A, von der Forst E (2017) Developing climate information portals with users: promises and pitfalls. Clim Serv 6:12–22
Terrado M, Christel I, Bojovic D, Soret A, Doblas-Reyes FJ (2018) Climate change communication and user engagement: a tool to anticipate climate change. In: Handbook of climate change communication, 3, 285–302
The Federal Government (2008) German strategy for adaptation to climate change. https://www.preventionweb.net/files/27772_dasgesamtenbf1-63.pdf

Vaughan C, Dessai S (2014) (2014): Climate services for society: origins, institutional arrangements, and design elements for an evaluation framework. WIREs Clim Change 5:587–603
Vetter A, Chrischilles E, Eisenack K, Kind C, Mahrenholz P, Pechan A (2017) Anpassung an den Klimawandel als neues Politikfeld. In: Brasseur G, Jacob D, Schuck-Zöller S (eds) Klimawandel in Deutschland. Springer Spektrum, Berlin, Heidelberg, Germany, pp 325–334
Webb R, Beh J (2013) Leading adaptation practices and support strategies for Australia: an international and Australian review of products and tools. National Climate Change Adaptation Research Facility, Gold Coast, Australia, p 105
Webb R, Rissik D, Petheram L, Beh J-L, Smith MS (2019) Co-designing adaptation decision support: meeting common and differentiated needs. Clim Change 153:569–585
World meteorological organization (WMO) (2014) Implementation plan of the global framework for climate services. Global Framework for Climate Services (GFCS), Geneva, Switzerland, p 81

Chapter 8
Physical Climate Risks and the Financial Sector—Synthesis of Investors' Climate Information Needs

Karianne de Bruin, Romain Hubert, Julie Evain, Christa Clapp, Miriam Stackpole Dahl, Jaclyn Bolt and Jana Sillmann

Abstract While investors are paying more attention to climate change, there is a lack of granular data designed to support financial decisions. Climate services can provide improved indicators and metrics to help investors better manage physical climate risks. This chapter presents the results of the ERA4CS-JPI Climate project ClimINVEST aimed to co-design tailored information on climate change. It provides an overview of investors' needs and information gaps on the physical impact of climate change. It identifies what information sources financial actors rely on and what challenges they face in decision-making incorporating available climate change information while taking into account diverse investor mandates and risk management approaches. Three unique geographical cases are presented, both on commonalities and differences, namely France, the Netherlands and Norway. In France, the 2015 Energy Transition for Green Growth Act (Article 173-VI) requires institutional investors to report on their integration of climate-related risks in their investment policies. In the Netherlands, the Dutch Central Bank and financial institutions are challenged to deal with potential flood risks from more frequent precipitation and sea level rise. In Norway, actors such as Finance Norway and the Norwegian government are assessing the risks from physical impacts of climate change on the Norwegian economy.

Introduction

Climate-related risks for investors entail two main facets: (1) transition risk, or changes in climate policy and regulations, which can result in an explicit or implied price on carbon, potentially 'stranding' assets supporting fossil fuel infrastructure,

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and (2) physical climate change, e.g. changes in temperature, precipitation patterns, and extreme events. The impacts of physical climate change can place a severe strain on company facilities, employees and the communities on which companies depend. Ultimately, these can affect equity, debt, and real estate assets in investors' portfolios.

Under the current climate, approximately 1 °C above pre-industrial temperatures, we already experience the impacts of physical climate change. This includes extreme weather, floods, drought, heat stress, and sea level rise (IPCC 2014). There are risks and associated costs of direct physical impacts of weather-related events (Morel et al. 2015). Sustained high temperatures have resulted in decreased worker productivity (Kjellstrom et al. 2018), and changing rainfall patterns have affected agricultural markets (Sullivan 2014). Financial regulators are raising concerns about investors' exposure to physical risks (BoE 2018; DNB 2017). Analyses show increasing losses—both insured or not—in assets due to natural catastrophes and extreme weather events of dozens of billions USD a year (EC 2013; Swiss Re 2018).

Publicly available climate services for the financial sector are currently very limited (Hamaker-Taylor et al. 2018), thus investors draw climate information tailored to their needs mostly from consulting companies with very little transparency in their methods. While a strand of research has focused on stranded assets that could come about via changes in climate policy (transition risks), there is a lack of concentrated study on financial impacts of climate change via production and supply chain disruptions, physical damage and changes in resource pricing and demand.

Further, there is a plethora of climate scenarios and modelling at global and regional levels, but it is difficult for investors to translate the results to actual risks on their assets in specific sectors or locations, and the appropriate times' scales, i.e. 1–5 years versus 20+ years. Focused research on the sources of physical climate impacts exists; however, emission pathways are provided without a clear reference to underlying policies and drivers. It is therefore difficult for investors to understand how investments in companies contribute, or are at risk, in these different scenarios (Van Vuuren et al. 2011). Similarly, climate projections come without information about financial implications of climate change or supply chain risks, while most studies of responses of the environment to climate change in nature and their socio-economic consequences have vague references to climate projections. A review of corporate disclosures of physical climate change risks and adaptation strategies concludes that many companies either did not report the costs of physical climate change impacts or underestimate them (Goldstein et al. 2019).

Specific assessment and guidance interpreting physical climate risk linkages to financial implications are emerging. In June 2017, the Financial Stability Board's Task Force on Climate-Related Financial Disclosures (TCFD) published recommendations on improving the reporting standards for climate-related risks and opportunities (TCFD 2017). This was followed by initiatives to advance the TCFD recommendations (EBRD and GCECA 2018), such as banks piloting an assessment methodology that addresses physical risk to estimate the impact of climate change on their agriculture and energy sector portfolios, and real estate portfolios (UNEPFI 2018). Moreover, the High-Level Expert Group on Sustainable Finance recommended that the European Commission endorses and implements the TCFD disclosure recommendations at the EU level (HLEG 2018), and in 2018 the central banks and supervisors came together to establish the Network for Greening the Financial System (NGFS 2018).

Improved indicators of non-financial information on climate-related risk, particularly for physical impacts, are needed for better investment decisions in a changing climate. How can investors better secure the value of their portfolios against physical impacts of climate change? Which climate-related risks require immediate attention from investors, and what scientific information is available? Climate services can provide improved indicators and metrics to help investors better manage these risks. This chapter provides a synthesis on understanding investors' needs and information gaps regarding the physical impacts of climate change and provides a foundation for collaboration on developing climate services between research and finance.

The chapter identifies what information sources financial actors rely on and what challenges they face in their decision-making based on available climate change information. Existing service providers' approaches to physical risk analysis are reviewed, which have been built and made available on the market as of early 2018. User needs are categorised as risk awareness (developing and improving understanding of physical impacts of climate change), risk analysis (qualitative and/or quantitative estimation of these risks) and risk management (on identifying and implementing plans, actions or strategies to reduce the implications of these risks). The work has been performed under the ClimINVEST project, which brings scientists and investors together in a series of science-practice labs to co-design tailored information on climate change to support financial decision making in the face of physical climate risks and opportunities.

Three unique geographical cases are presented, with both commonalities and differences: France, the Netherlands and Norway. These countries have all been at the forefront of understanding physical climate-related risk in their respective financial and regulatory environments. In France, the 2015 Energy Transition for Green Growth Act (Article 173-VI and V) requires institutional investors to report on their integration of climate-related risks in their investment policies, and it triggered a dialogue between banks, insurers and financial regulators on how to integrate climate-related risks in risk management tools. In the Netherlands, the changing climate is challenging the Dutch Central Bank and financial institutions to deal with potential flood risks from more frequent and heavier precipitation and sea level rise. In Norway, actors such as Finance Norway and the Norwegian government are assessing the risks from physical impacts of climate change on the Norwegian economy.

Overview of Investor Approaches

The focus in this study is particularly on the physical impacts of climate change that can affect the financial sector and refers to these as physical climate risk in the following. The pool of available approaches to physical climate risk analysis tailored for financial institutions is limited in number. Specialized service providers have developed most of the approaches. Table 8.1 provides an overview of these service providers and their detailed approaches. These include Acclimatise (Asian Development Bank 2016), Moody's (2016), WRI (Gassert et al. 2014; Luck et al. 2015), Four Twenty Seven (Four Twenty Seven and Deutsche Asset Management 2017), Carbone 4 (Carbone 4 2017), Carbon Delta (Carbon Delta 2019), Mercer (Mercer 2015; Mercer and CALStrs 2016), and Trucost (Ecolab 2017). The review was done via data collection, building on online information to identify streams of literature, relevant reports and available approaches and interviews conducted with the different service providers. See I4CE (2018) for more details.

Six of these approaches are available as paid services, while WRI's Water Risk Atlas and Trucost's Water Risk Monetizer are available for free. Note that the providers of free information focus exclusively on water scarcity and do not cover flooding/sea level rise, or anything else on the overabundance of water. The target users for the different approaches are mainly investors, except for Acclimatise, Moody's and WRI. Acclimatise focuses on pre-screening before financing for project officers and risk managers (more suitable for development banks). Moody's provides an exploratory approach that does not constitute a new product to investors and is based on illustrative data for risk managers of all financial institutions. WRI provides an analysis of portfolio exposure to climate hazards for all financial institutions.

Service providers target different end-uses and end-users relevant for financial institutions. Nevertheless, they all try to answer the same type of question: how climate change can potentially affect counterparties[1] such as projects, companies or governments. To investigate potential impacts, the approaches combine information on four broad categories: climate hazards; the counterparty's exposure to these hazards; the sensitivity of the counterparty to this exposure; and its capacity to address these potential impacts. Not all of the selected approaches cover every type of counterparty and every aspect of possible effects. In terms of analysis of the potential implications, WRI and Trucost focus exclusively on a sub-category of climate hazards related to water scarcity, while the other approaches seek to incorporate different aspects of risk (i.e. information not only on hazards but also on counterparties).

The approaches reviewed build on public data sources for climate hazards which are further processed by service providers internally. The list of climate databases used are easily accessible to service providers. These include climate scenarios and projections [e.g. Representative Concentration Pathways (RCPs) (Van Vuuren et al. 2014)] and various databases with different coverages (e.g. EM-DAT on historical catastrophic events; UNEP-GRID regional databases). The situation differs regarding the information on counterparties, related to exposure, sensitivity, and adaptive capacity data. The exposure can be provided by the end-user of the approach (in the case of Acclimatise, Trucost and Mercer), or by a combination of counterparty's publicly reported information and commercial and proprietary databases (in the case of

[1]The counterparty is the entity that receives funding from the financial institution. The selected service providers' approaches aim to provide financial institutions with some information on physical climate risks for one or several types of counterparties: projects, companies or governments.

Table 8.1 Details of available approaches on physical climate risk analysis

Service provider	Acclimatise	Moody's Investors Service	WRI	Four Twenty Seven	Carbone 4	Carbon Delta	Mercer	Ecolab, Trucost and Microsoft
Approach	Aware for projects	Physical Effects of Climate Change on Sovereign Issuers	Aqueduct Water Risk Atlas	427 Climate Risk Scores	CRIS	Climate VaR	TRIP Framework	Water Risk Monetizer
Output								
Qualitative scoring	●	●	●	●	●			
Quantitative						● (Financial return impacts)	● (Financial return impacts)	● (Revenue at risk, total cost of water)
On Counterparty								
Project	●				●			
Element of value chain				●				
Sector				●	●	●	●	
Geography				●	●	●		
Asset class						●	●	
Portfolio	●			●	●	●	●	●
Sovereigns		●		●	●			
Companies				●	●	●		●
On time horizon								
Restricted to one horizon	●	●		●		●	●	●
Detail and agg. per horizons			●		●			
Time horizons adressed:								
Past	●	●	●	● (Depending on element of corporate value chain)	●			
Future	2020 or 2050 (Depending on data)		2030 and 2040	Past or 2030 (Depending on element of corporate value chain)	2050 and 2100	15 yrs from now	2050	3, 5 or 10 yrs from now
On hazard								
All hazards combined	●		●		●			
Specific hazard(s) adressed		●		●		●	●	●
Extremes								
Floods	●	●		●	●	●	●	
Landslides	●	●			●			
Fires	●	●		●	●	●	●	
Storms	●	●		●	●	●	●	
Temperature		●		●	●	●	●	
Drought		●		●	●			
Precipitation				●	●	●		
Chronic changes								
Temperature	●			●	●		●	
Precipitation	●			●	●		●	
Water scarcity	●		●	●	●			●
Sea level rise				●	●			
Ice and Snow	●							
On Scenario								
Multiple scenarios			●		●		●	
IPCC scenarios	Based on IPCC		RCPs and SSPs	RCP 8.5	RCPs and SRES			
Other						● (Extrapolation of past weather events)	● (In-house scenarios informed by FUND Integrated Assessment Model)	● (Based on WRI's Aqueduct Water Risk Atlas information)
Service	Paid	Paid	**Free**	Paid	Paid	Paid	Paid	**Free**

[a]Note that Carbone 4 is a research project partner in the ClimINVEST project
[b]"Ecolab, Trucost and Microsoft" are mentioned shortly as "Trucost"
Source I4CE (2018)

the other selected approaches). Sensitivity data can also be provided by the end user (in the case of Acclimatise and Trucost's approaches) or arise from combinations of public and commercial databases, public or proprietary cost functions, and expert judgment (in the case of the other selected approaches). And the adaptive capacity is addressed for sovereigns with publicly available databases, while it is less covered by corporate counterparties.

Existing approaches provide scores or quantitative estimates with different details. Five service providers choose to give ratings on the level of physical climate risk of the counterparty (in the case of Acclimatise, Carbone 4, Four Twenty Seven, Moody's Investors Service and WRI). Three other approaches produce quantitative information, such as estimates of potential costs or asset value impact resulting from climate-related risks to a single counterparty (in the case of Carbon Delta, Mercer and Trucost). The information provided to end users also differs through the type of detail (e.g. per type of hazard, climate scenario, time horizon, category of impact, counterparty) and the level of detail (e.g. counterparty or sectorial level analysis) they provide.

The scope of hazards covered by each approach varies. Most of the current approaches address acute[2] climate-related phenomena (e.g. hurricanes, heat waves, drought and floods) while coverage of chronic[3] phenomena is emerging (for example some approaches focus specifically on water availability) (TCFD 2017). Climate-related phenomena can be combined with each other. For instance, gradual sea level rise (a chronic phenomenon) exacerbates the magnitude of coastal flooding (an acute phenomenon). Some methodologies show differences in the indicators that describe a given hazard (for example water stress can be studied through the mean yearly water supply or intra-year variability of water supply), but several approaches offer limited transparency about the chosen indicators.

In addition, the existing methodologies covered by this analysis address different climate-related impacts on corporate counterparties. They focus on different scopes of the counterparty's exposure; for instance, some methodologies cover the upstream and downstream value chain and the logistics whereas others cover operations only. In the same vein, only a few cover capital, labor, natural resources and the macro context.

Forward-looking analyses are starting to be integrated into physical climate risk analyses. Service providers often include forward-looking scenario-based analyses for climate hazards with variable time horizons (from 15-years up to 2100) and typically use a single scenario, which is not sufficient to reflect the range of potential long-term risks. These scenarios are either 'trend scenarios' in the sense that they extrapolate trends from the past, or 'exploratory scenarios' in the sense that they extrapolate the future with various possibilities in mind.

[2]Acute climate-related phenomena are disruptive and event-driven. They refer to phenomena that are typically perceived as a shock to the system. More specifically, they include changes in frequency or magnitude of extreme events such as cyclones, heatwaves, storms, etc.

[3]Chronic climate-related phenomena refer to long-term persisting changes in mean and variability of all types of climate patterns. They include for example: sea level rise; change in mean temperature patterns and chronic heatwaves at the end of the spectrum of temperatures evolution.

Case Studies

The case studies selected in this chapter provide insights into physical climate risk and investor needs in France, the Netherlands and Norway. The cases offer unique perspectives on the context of country-specific initiatives around physical climate risk and specific user needs, their uniqueness and high-level commonalities. Why these case studies? France, the Netherlands and Norway are three countries at the forefront of creating awareness and acting on the risks and opportunities associated with physical impacts of climate change in the financial sector. They thereby complement the activities of the Financial Stability Board's Task Force on Climate-Related Financial Disclosures (TCFD), which developed recommendations at a broad level for company disclosure of climate-related risks. The content is based on a survey, interviews, literature review and preliminary conversations held during the first phase of the ClimINVEST project. These needs and the co-design of corresponding climate services will be further elaborated in the next phase of the ClimINVEST project, highlighting different hazards and sectors in different science practice labs. User needs per case study are categorised along risk awareness (developing and improving understanding of physical climate risks), risk analysis (qualitative and/or quantitative estimation of these risks) and risk management (on identifying and implementing plans, actions or strategies to reduce the implications of these risks).

Identified common needs across the case studies include the need for: i. in-house capacity building and training on physical climate risk awareness; ii. assessment of impacts of climate change on sector specific portfolios; iii. consistent, granular data on climate-related risks; iv. forward-looking scenario-based analysis and v. understanding of extreme events.

In France, the 2015 Energy Transition for Green Growth Act requires institutional investors to report on their integration of climate-related risks in their investment policy (Article 173-VI) and plans the implementation of periodic stress-tests on bank portfolios with scenarios that are representative of climate risks (Article 173 V). These provisions have urged financial actors and regulators (the Banque de France (the French central bank) and the French Prudential Supervisory Authority) to address the climate-related risks. In the Netherlands, the changing climate is challenging De Nederlandsche Bank (the Dutch central bank) and financial institutions to deal with potential flood risks from more frequent and heavier precipitation and rising sea level. Other climate hazards are currently not broadly discussed, as these are not yet considered to affect the country's financial system. Although the drought of spring and summer 2018 may trigger awareness and analysis of financial risks and opportunities associated with extreme events (Actiam 2018). In Norway, actors such as Finance Norway and the Norwegian government are assessing the risks from physical impacts of climate change on the Norwegian economy. The sovereign wealth fund manager [Norges Bank Investment Management (NBIM)] is a leader in working on climate-related risks. The following sub-sections provide the context and identified user needs per case.

France

Country-Specific Context: France

In 2015, France became the first country to impose legal requirements for climate reporting on institutional investors and asset managers, and to create a broader early momentum on disclosing on climate-related risks among financial institutions. The purpose of Article 173 (V and VI) of the Energy Transition for Green Growth Act has been to encourage financial institutions' in-depth reflection on climate-related issues and their implications for their activities, and to take action to address them.

Climate-related risks for institutional investors, asset managers and banks are explicitly targeted in Article 173-V and VI of the Energy Transition for Green Growth Act promulgated on August 17 2015.

Article 173-VI of the Act targets institutional investors and asset managers. It requires them to report on their integration of Environmental, Social and Governance (ESG) issues in their investment policies. Institutions that have a consolidated balance sheet of more than EUR 500 billion worth are required to report more specifically on the integration of climate-related risks (physical or transition risks) and their contribution to the green economy.[4] In mid-2017, institutional investors and asset managers released their first yearly reports in accordance with Article 173 requirements on the 2016 financial exercise. The final recommendations of the TCFD were released only in June 2017. This specific context raised early awareness on climate-related issues among investors. This momentum has continued while the government and the financial regulators are taking stock of the first two reporting exercises conducted in the context of Article 173-V.

This law has also impacted banks. Article 173-V mentions that the French government shall report on the implementation of periodic stress-tests on bank portfolios with scenarios that are representative of climate-related risks. The French Ministry of Finance, the Banque de France and the Supervisory Prudential Authority published a report on assessing climate-related risks for banks at the end of 2016.[5] The process triggered a dialogue on supervision between the French banks and insurance companies, and their regulators on climate-related risks (through bilateral meetings and regular surveys). The regulators are now enquiring not only about the future integration of climate-related risks in periodic stress-testing exercise, but also about their integration in day-to-day risk analyses performed at banks and their level of climate-related risks exposure. In parallel, the Banque de France has taken various initiatives on green finance and acts as the secretariat for the Central Banks and Supervisors Network for Greening the Financial System (NGFS), which was launched at the One Planet Summit in Paris in December 2017.

[4]For more information on the disclosure requirements under Article 173-VI, see the implementing decree n°2015-1850 of 29 December 2015 of article L.533-22-1 of the Financial and Monetary Code. https://www.legifrance.gouv.fr/eli/decret/2015/12/29/2015-1850/jo/texte.

[5]Direction Générale du Trésor, Banque de France, ACPR, 2016. L'évaluation des risques liés au changement climatique dans le secteur bancaire.

Financial institutions have started working on several aspects of climate-related risks because of Article 173. It began creating awareness about climate issues within financial institutions, but there is still room for improved understanding. For the purpose of reporting, institutional investors and asset managers have increased internal discussions across divisions on this topic. In some instances, it encouraged collaboration with external service providers in order to get started on climate risk analysis. These financial institutions are now experiencing the need and difficulty in finding information that fits their existing decision-making frameworks. The Banque de France and Prudential Supervisory Authority have been putting pressure on financial actors since 2015 to assess and address climate-related risks (Villeroy de Galhau 2018).

User Needs

ESG and risk divisions collaborate on the topic of physical climate risks in all sampled institutions. However, only a few institutions in the sample are taking their first steps to address these risks in their decision-making processes, with significant differences across institutions.

ESG divisions are starting to communicate and raise awareness on these topics at a high level within their institution. One large commercial banking group explicitly mentioned organizing an in-house training session on this topic with scientists and the top management (including risk divisions).

In terms of risk analysis, most of the sampled financial institutions have carried out a partial and experimental analyses of physical climate risks in portfolios in collaboration with external service providers. Three institutions of the French sample have been developing analyses at sectorial level with partial coverage in terms of sector and/or geography and/or type of physical climate risk. These early developments currently serve as risk pre-screening tools.

In the same vein, one large commercial banking group has begun integrating these risks in its sectorial policies, currently based on the same type of information used for pre-screening tools. Another large banking group is beginning to integrate these risks at the asset level for due diligence or into the ensuing monitoring process. The analysis is most mature for physical asset portfolios (e.g. real estate or infrastructure). Finally, three institutions in our sample have also started bottom-up exercises, where credit officers ask their counterparties about how they integrate physical climate risks in their process. This is organized as a first step towards understanding the type of information that counterparties could provide to help analyze these risks.

Financial institutions have expressed their views on some key dimensions to make physical climate risk information usable, specifically:

- Information should be transparent[6] and detailed in order to be able to discuss internally or with their counterparties' exposure and sensitivity to hazards.
- Data should ideally be granular enough to provide information that reflects the situation of their specific counterparties.
- In order to integrate decision-making, financial institutions need the information to be reliable. Some of them suggest scientific advice on the relevant climate datasets to be used, but also external validation of a counterparty's information.
- Information that demonstrates materiality of this risk in their own horizon of analysis (mostly decadal, but also in the longer-term for strategic purposes) and that clarifies the range of uncertainties needed.
- Comparable information is important; the information can be better used in financial risk decision-making if it allows comparison between different counterparties in different sectors and geographies, and also if it compares exposure to physical climate risks with exposure to other types of risks.[7]

Table 8.2 summarizes the most frequent types of needs that financial institutions mentioned during interviews carried out in France. The interviewees generally expressed the need for granular and asset- or counterparty-specific analysis.

The Netherlands

Country-Specific Context: The Netherlands

The unique position of the Netherlands as a low-lying delta makes the country vulnerable to the physical impacts of climate change, such as sea level rise, increasing frequency and intensity of precipitation, and drought events. The largest climate-related risk in the Netherlands is flooding from, for example, sea level rise, river discharge, and/or heavy rainfall. These risks change over time, leading to costs in preventing and dealing with the impacts of floods. Although the probability of extreme flood events is low, potential damages is substantial. Under different dike breach scenarios, damages are estimated at between EUR 20 and 60 billion (DNB 2017, p. 24).

The financial implications of floods are endured by governments and those directly affected, who are often not, or only partly, compensated by the government. Actors

[6]Transparency of information typically refers to clarity of the sources, of the methodology to carry out the analysis.

[7]Some financial institutions also express preferences for some specific information formats. Some financial institutions are willing to be provided with some intermediary indicators in order to be able to combine them by themselves and produce tailored information. One expressed example of this need is to obtain sensitivity factors that are counterparty- and hazard-specific, that the financial institution will combine with its own selection of climate hazards scenarios.

Table 8.2 Investor approaches and information gaps—France

The aspect of risk decision-making	Specific user need	Way forward
Risk awareness	In-house understanding of physical climate risk: Building awareness among internal stakeholders about physical climate risks and their materiality to financial decisions	• Training session or other training media • Targets: top management, front office staff directly managing portfolio of counterparties
Risk analysis	Framing risk assessment: need consensual guidance about what should be included in the risk analysis and what type of indicator would be relevant	• Framework or general guidelines on physical climate risk analysis • Key indicators to look at in different contexts
	Risk pre-screening: identify material risks in a ‘pre-screening’ of risks. The perimeter (e.g. aspect of risk, type of hazard and portfolio) and granularity (e.g. regional and sectorial or local and specific) of the pre-screening is to be refined	• Mapping of risks in portfolios and other alert tool
	Finding climate data for risk assessment: need to have access to and knowledge of the relevant climate hazard datasets, so that financial institutions can carry out the analysis themselves or discuss third-party analyses	• Climate datasets or guidelines on relevant climate datasets
	Finding counterparty-specific data for risk assessment: as mentioned above on climate data, the same type of issues apply to counterparty-specific data	• Exposure datasets along counterparty’s value chain • Check-list on relevant information to obtain from counterparties
	Quantified and granular financial impacts: need to progress towards quantified indicators on financial impacts from physical climate risks, at counterparty-specific level	• Methodology for quantification of financial impacts from physical climate risk at counterparty-specific level • Transparent information on financial impacts to the counterparty
Risk management	Engagement with stakeholders: manage physical climate risk through engagement with counterparties	• Check-list on relevant information to discuss risk exposure per type of asset/counterparty and hazard

Source Interviews conducted by I4CE in the context of ClimINVEST in the financial sector holding assets in affected areas or areas with increased flood risk may be directly affected as well. Indirectly, they may be hit when credit and investment portfolios are depreciated due to secondary effects. According to De Nederlandsche Bank (hereafter: DNB), future risk assessments should include both future climate change as well as government interventions that deal with flood risk. They are also advised to look for particular vulnerabilities in their portfolio. Currently, DNB does not foresee urgent financial destabilizing effects from the different flood scenarios (DNB 2017).

The Dutch financial sector, including its supervisory authority (DNB), is active in different fora and networks to promote understanding of physical climate risk, and to discuss ways of dealing with it to reduce the financial consequences. Generally, the Dutch financial sector prefers an emphasis on possible solutions and opportunities, rather than on risks, creating a more positive perspective for dealing with climate change.

DNB is active in raising awareness and exploring the climate-related risks for the Dutch financial sector. In 2017, it released the report 'Waterproof?—An exploration of climate-related risks for the Dutch financial sector' (DNB 2017). The report presents the implications of the physical consequences of climate change on Dutch insurers, investors and lenders. Insurers expect an increase in claims related to climate (change) as frequency of extreme weather events such as hail and rainfall is expected to increase and, consequently, lead to higher premiums. Insurance companies in the Netherlands are well aware of weather extremes but are less informed about long-term climate trends. They trust models provided by external parties who may not cover climate change trends for the Netherlands, even though they could prove critical for a thorough risk assessment.

DNB brings together different financial actors in working groups on sustainable finance. One working group (DNB 2018) specifically focuses on climate-related risks, reflecting on integrating TCFD-style information into risk/return decision-making. The DNB Sustainable Finance Platform's Working Group on Climate Risk brought together different Dutch asset managers, banks and financial services companies. DNB is currently investigating ways to embed climate-related risks in its supervisory assessment framework. This is a challenging task, as not all risks are yet quantifiable and most risks have yet to crystallize (Elderson 2018). In addition, DNB is developing both physical and transition-related stress tests which can help assess long-term risks faced by financial institutions. These include a stress test on weather-related risks for Dutch general insurers, and development of a stress test on transition risks, exploring four future scenarios of policy and technology (Sleijpen 2018).

User Needs

Table 8.3 summarizes the user needs and way forward identified in the Netherlands.

Table 8.3 Investor approaches and information gaps—The Netherlands

The aspect of risk decision-making	Specific user need	Way forward
Risk awareness within financial institutions	Improved understanding of physical climate risk and extreme events	• Create an understanding of how climate change and extreme weather events will result in risks and opportunities for the built environment • Create awareness on the materialization of relevant long-term risks and how these need to be mitigated in the short-term
	Improved availability of knowledge about physical climate risk	• Develop an overview of what is available, and specify what is relevant for loans and investments made by the banks in real estate or other sectors, and how to incorporate this into their investment strategy
	Develop in-house understanding of physical climate risk	• Anchoring of climate-related risk and opportunity competency at board level
	Standardization of information	• Work towards market standardization of relevant scenarios and data sources
Risk analysis	Assessment of whether and how financial institutions incorporate climate-related risks in their decision-making process	• Develop a more forward-looking approach to incorporate climate risks
	Assessment of ways in which climate-related stress tests help in assessing the long-term risks that financial institutions face	• Improve forward-looking risk management tools, such as scenario analysis and stress testing
	Common taxonomy and economy-wide disclosure to consider climate-related risks on a company level basis	• Create a common taxonomy and disclosure standard leading to climate-related risk obtaining its fair market price, and thereby also spur cost-effective adaptation measures

(continued)

Table 8.3 (continued)

The aspect of risk decision-making	Specific user need	Way forward
	Information on physical impacts	• Develop a comparison tool between companies • Create open source access • For specific financial products, spatial levels and prioritization of risk management; for example for mortgage assessment, understanding what is important to focus on in relation to physical climate risk • Integration of data on and analysis of climate-related risks into existing financial decision-making processes • More research on ways climate change affects assumptions used in asset and liability management
	Scenario analyses; for example risk/opportunity analysis with scenarios for the next 10–20 years	• Detail the extent of future climate change, how will physical risks arising from climate-related damages change, especially at the company level?
	Decision-useful metrics	• Call to service providers to provide investors and lenders with decision-useful metrics on physical risks (including post-2050 risks) • Call to service providers to provide broader and more granular quantification of metrics
Risk management	Creating awareness of the difference between passive and active management of investors	• Sophistication of engagement tool • Engagement with companies on the sector—or individual level, with passive or active investment strategies; for example a climate risk analysis needs to also be workable for a passive investment strategy

Source Based on a literature review and conversations held by WENR and CAS in the context of ClimINVEST

They reflect a range of different investor types (pension funds, asset managers, banks and central bank) and mandates for dealing with physical climate risk.

Norway

Country-Specific Context: Norway

Physical climate risk is now clearly on the agenda of the Norwegian financial sector (Norwegian Ministry of Finance 2018). Institutions are building capacity through sustainability teams and Environmental, Social and Governance (ESG) integration processes. Flooding and heavy precipitation are of immediate concern to investors in Norway and other Nordic countries, as highlighted in CICERO's report on flood risk for investors (CICERO 2018a, b).

The Norwegian government has been active in raising awareness of climate change, including physical climate risk. In October 2017, the Norwegian government appointed an expert commission «Klimarisikoutvalget» to look at climate-related risks, and their potential impacts for the Norwegian economy, which includes physical climate risk. The report was published mid-December 2018 (Norwegian Ministry of Finance 2018), and highlights the need for further analysis on physical climate risk within Norway, but also of physical impacts outside the country that can impact Norway's economy, for example via trade patterns and resource pricing. The Ministry of Finance reports annually to Norges Bank, Norway's central bank, on the financial stability and financial market in Norway. These reports include climate-related risk, in broad terms, and linkage to the TCFD recommendations and reporting.

By virtue of its ownership role, the Norwegian government sets expectations regarding climate-related risk. The government owns the sovereign wealth fund, managed by Norges Bank Investment Management (NBIM), and owns shares of the Norwegian bank DNB. The government expects the companies in which it owns shares to: (i) have a sound understanding of the risk posed to their activities by climate change and climate policy measures; (ii) be at the forefront in climate and environmental performance in their sector including initiatives to reduce greenhouse gas emissions; and (iii) be well-informed of the benefits to be reaped from early adaptation to a warmer climate (NBIM 2018).

A roadmap for green competitiveness outlines pathways forward on climate change in the financial sector, published by the financial industry organization Finance Norway (Finance Norway 2018). The roadmap states that climate change has significant economic, physical and regulatory implications for the Norwegian business sector. It provides seven recommendations regarding climate-related risk, among them: aligning climate reporting with the recommendations of the TCFD, increasing climate competence and capacity in the financial sector; and including climate-related risk in the supervisory authority's mandate.

Norwegian banks indicate that prioritization of risks and opportunities is influenced by feedback from stakeholders, strategic platforms, global development trends, support to global initiatives, and international standards and requirements imposed by the authorities. These are incorporated into GRI frameworks and materiality analyses. Climate change is an important risk and opportunity driver in long-term strategic thinking, including for group and industry sector business strategies. The Norwegian government has documented expectations on climate change for the Norwegian financial institutions in the white paper Meld.St.27 (2013–14) "Diverse and value-creating ownership" (Norwegian Ministry of Trade, Industry and Fisheries 2013).

User Needs

The results presented in Table 8.4 reflect a range of different investor types (pension funds, asset managers, and banks) and mandates on dealing with physical climate risks. The most common information gap cited was a lack of consistent company-level data on climate-related risks such as scenario and planning information and links between climate risks and company financials. For physical impacts specifically, information gaps were noted on company-level water-related risks and granular information on water stress areas.

Investors and climate researchers gathered together at the Ny Ålesund Symposium 2018 held in Svalbard in the Arctic to collaborate on navigating climate-related risk. The discussions focused on extreme events, climate scenarios, and green bonds. Climate researchers highlighted that more extreme events as experienced can be expected, for instance, in the summer of 2018 with intense hurricanes, heat waves and resulting forest fires. Changes in jet stream patterns could further complicate extreme events. Discussions revealed the need for rethinking the best indicators to assess the potential impacts of extreme events on financial systems. Further, climate models may underestimate the changing patterns of extreme events. There are observations and model projections for physical climate impacts that could be better communicated by researchers, with greater transparency on uncertainty (Ny Ålesund Symposium Summary 2018).

Key Climate Information Needs of Investors

This section provides a synthesis of financial sector needs regarding physical climate risk categorized as risk awareness, risk analysis and risk management. More specifically, it focuses on the investors information needs for developing and improving understanding of physical impacts of climate change, for qualitative and/or quantitative estimation of physical climate risk and for identifying and implementing plans, actions or strategies to reduce the implications of these risks. It reflects on the needs from a range of different investor types (pension funds, asset managers, insurance,

Table 8.4 Investor approaches and information gaps—Norway

The aspect of risk decision-making	Specific user need (based on survey results from CICERO Climate Finance Advisory Board + Wallenberg project)[a]	Way forward
Risk awareness	Information on sustainability	• Clarify interpretation and scope • Clarify relations to ESG, SRI information • Analyze limitations and trade-offs across SDGs
	Improved understanding of climate-related risks	• Build company capacity in terms of personnel, structure, and processes • Offer climate risk courses and training material
	Standardization of information	• Collaborate across climate information providers to provide publicly available comparison tools
	More comprehensive and detailed climate change information, with information on which sources are credible	• Further research and analysis • Communication of credible information sources
Risk analysis	Information on physical impacts such as assessment of impact of climate change on real estate portfolios	• Further research and analysis to develop more detailed data, with less uncertainty, including asset-level data such as company level water-related risks • Research on insurance coverage of climate risk • Third-party assessments on physical impacts of assets
	Scenario analyses, e.g. risk/opportunity analysis with scenarios for next 10–15 years	• Improve transparency, especially regarding assumptions and guidance on which scenarios to use • Communicate information in terms of a 10–15 year time horizon • Improve capacity to use scenario information, with detail on scenario sector/company/country impacts
	Climate change indicators	• Collaborative development of relevant indicators, including for extreme events associated with climate change • Improve disclosure on indicators by companies

(continued)

Table 8.4 (continued)

The aspect of risk decision-making	Specific user need (based on survey results from CICERO Climate Finance Advisory Board + Wallenberg project)[a]	Way forward
	Standards	• Research and collaboration to establish standards for climate-related risk information and stress-testing
Risk management	Avoid high-risk investments and reduce high-risk activities	• Assess physical climate risk of different activities
	Collect information on most promising technologies on improving resilience and climate robustness	• Research to support preparedness for future climate change by building resilience to reduce risk • Focus on resilience as a business opportunity
	Reduce risk through distributing activity over different locations and sectors/technologies	• Provide information on sectors/companies/regions and relative exposure to climate risk
	Assess robustness and preparedness of a company	• Develop screening tools to assess a company's: – Capacity to evolve – Flexibility – Business model viability – Long-term perspectives • Support disclosure of these aspects in company reporting

[a]See the list of Advisory Board members here: http://www.cicero.uio.no/en/cicero-climate-finance/advisory-board—note that the table excludes input from the non-Nordic members of the Advisory Board

[b]Norwegian institutions, plus including one Swedish financial institution

Source CICERO (2017) Shades of Climate Risk report [based on CICERO survey conducted among the financial stakeholders on the Advisory Board of CICERO Climate Finance.]

and banks) across France, the Netherlands and Norway. Note that this synthesis is based on inputs gained in the first stage of the ClimINVEST project and does not provide a complete picture of all user needs amongst all different investor types.

Risk Awareness

- Introduction to physical climate risk, i.e. need for basic information that can be shared and tailored for in-house use within financial institutions, for both sustainability and risk managers.
- To know what information is available in the public sphere, what is reliable and how to use it.
- Need for clearer communication on the value creation of climate change opportunities in reducing risk.

Risk Analysis

- Data on various climate scenarios and how these will impact sectors, companies, countries and equity markets.
- Information which demonstrates materiality of physical climate risk, identifying cross-sectoral indicators and geographical approaches.
- Assessment of insurance gaps, i.e. information on physical climate risk that are not covered by insurance.
- Information on how climate change, and extreme events will result in risks and opportunities for the built environment, which may affect the bank-mortgage lenders as well as other sectors.
- Need for a more short-term focus of the impacts of climate change (i.e. next 10–20 years) relevant for companies and banks. This is also relevant for risk analysis within 10 years and for strategical analysis beyond 15 years.
- Need for guidance from researchers on which physical impacts and indicators could be important with relevant spatial detail, with a specific focus on extreme events and water-related risks.
- Need for mapping of physical climate risks to an asset level.

Risk Management

- Need for guidance on engagement, for example a checklist on physical climate risk to engage with companies.
- Need for clear information from researchers on uncertainty related to the probability of physical impacts of climate change.

Conclusion and Way Forward

This chapter has highlighted how the financial sector deals with physical climate risks and the specific climate information needs of investors. These needs relate to: (i) a need for in-house capacity building and training within financial institutions on physical climate impacts to increase risk awareness; (ii) a need for better tools and metrics to assess how climate changes, including increases in flooding and extreme weather events, and associated physical impacts that affect assets in specific sectors, markets and locations; and (iii) a need for guidance and information to better engage with companies on climate-related risk.

To develop tailored climate services, it is essential to convene climate change researchers and financial decision-makers to facilitate investor's decision-making on climate-proof investments and build public understanding of climate-related risks. The user needs identified in this synthesis underscore the importance of collaborative efforts between research and finance on improving climate-related risk information. Specific ways that the ClimINVEST project will support these needs include: (i) building capacity on climate-related risk through tailored courses and training materials; (ii) co-designing information on relevant indicators for climate change and associated physical climate impacts in the next 10–15 years, and iii. developing guidance on how to engage with companies.

The ClimINVEST project team collaborates with financial institutions in France, the Netherlands and Norway in a series of science practice labs to co-design transparent and publicly available information and methodologies based on open-access data. Based on this synthesis, the first round of ClimINVEST science practice labs focuses on: (i) bank lending to SMEs in France; (ii) the built environment in the Netherlands; and (iii) extreme events/flooding in Norway.

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References

Actiam (2018) Drought: the heat is on for investors! Actiam Perspective

Asian Development Bank (2016) Project climate risk assessment and management—Guangxi Regional Cooperation and Integration Promotion Investment Program. https://www.adb.org/sites/default/files/linked-documents/50050-002-sd-01.pdf

BoE (2018) Enhancing banks' and insurers' approaches to managing the financial risks from climate change. Bank of England, Consultation Paper 23/18

Carbone 4 (2017) CRIS—Climate Risk Impact Screening. http://crisforfinance.com/wp-content/uploads/2017/11/CRIS-Guidebook_Publicversion_Nov2017.pdf

Carbon Delta (2019) Climate Value-at-Risk (VaR) https://www.carbon-delta.com/climate-value-at-risk/

CICERO (2017) Shades of climate risk—categorizing climate risks for investors. CICERO Climate Finance

CICERO (2018a) Flood risk for investors—are you prepared? CICERO Climate Finance, Report 2018:05

CICERO (2018b) Flomrisiko i Norge: Hvem betaler for framtidens våtere klima? CICERO Climate Finance, Report 2018:06

DNB (2017) Waterproof? An exploration of climate-related risks for the Dutch financial sector. DNB report

DNB (2018) Sustainable finance platform's working group on climate risk, Mar 2018. https://www.dnb.nl/en/news/news-and-archive/Persberichten2018/dnb374716.jsp

EBRD and GCECA (2018) Advancing TCFD guidance on physical climate risks and opportunities. https://www.physicalclimaterisk.com/media/EBRD-GCECA_draft_final_report_full.pdf

EC (2013) GREEN PAPER on the Insurance of Natural and Man-Made Disasters. COM(2013) 213 final. European Commission. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013DC0213&from=EN

Ecolab (2017) Water risk monetizer—smart water management for business growth: Integrating water risk into business decision making

Elderson F (2018) From mission to supervision: putting sustainable prosperity on the agenda of the Dutch Central Bank. LSE sustainable finance leadership series. http://www.lse.ac.uk/GranthamInstitute/news/from-mission-to-supervision-putting-sustainable-prosperity-on-the-agenda-of-the-dutch-central-bank/

Finance Norway (2018) Roadmap for green competitiveness in the financial sector. 47 p. https://www.finansnorge.no/contentassets/6e938f41d8a44a4984f87444a18ce320/roadmap/roadmap-for-green-competitiveness-in-norwegian-financial-sector_digital.pdf

Four Twenty Seven, & Deutsche Asset Management (2017) Measuring physical climate risk in equity portfolio

Gassert F, Luck M, Landis M, Reig P, Shiao T (2014) Aqueduct global maps 2.1: constructing decision-relevant global water risk indicators. World Resources Institute, Washington, DC. http://www.wri.org/sites/default/files/Aqueduct_Global_Maps_2.1-Constructing_Decicion-Relevant_Global_Water_Risk_Indicators_final_0.pdf

Goldstein A, Turner WR, Gladstone JU, Hole DG (2019) The private sector's climate change risk and adaptation blind spots. Nat Clim Change 9:18–25

Hamaker-Taylor R, Perrels A, Canevari L, Nurmi V, Rautio T, Rycerz A, Larosa F (2018) Results of explorations of the CS market for the financial sector. Grant agreement 730500 EU-MACS European Market for Climate Services 23/12/2018 Deliverable 2.1

HLEG (2018) Financing a sustainable European economy. Final report 2018. High-Level Expert Group on Sustainable Finance, Brussels, Belgium

I4CE (2018) Executive summary—getting started on physical climate risk analysis in finance—available approaches and the way forward. ClimINVEST WP1-Task 1.2. https://www.i4ce.org/download/getting-started-on-physical-climate-risk-analysis-in-finance-available-approaches-and-the-way-forward-3/

IPCC (2014) Climate change 2014: impacts, adaptation, and vulnerability. In: Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL (eds) Part A: global and sectoral aspects. contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, UK and New York, NY, USA, 1132 pp

Kjellstrom T, Freyberg C, Lemke B, Otto M, Briggs D (2018) Estimating population heat exposure and impacts on working people in conjunction with climate change. Int J Biometeorol 62(3):291–306

Luck M, Landis M, Gassert F (2015) Aqueduct water stress projections: decadal projections of water supply and demand using CMIP5 GCMs. World Resources Institute, Washington, DC. http://www.wri.org/sites/default/files/aqueduct-water-stress-projections-technical-note.pdf

Mercer (2015) Investing in a time of climate change. https://www.mercer.com/our-thinking/wealth/investing-in-a-time-of-climate-change.html

Mercer and CALStrs (2016) CALStrs portfolio climate change risk assessment

Moody's (2016) Environmental risks—sovereigns: how Moody's assesses the physical effects of climate change on sovereign issuers. Moody's investors service. https://www.eticanews.it/wp-content/uploads/2017/01/Moodys-climate-change-and-sovereigns-November-7.pdf

Morel R, Zhou S, Cochran I, Spencer T (2015) Mainstreaming climate change in the financial sector and its governance—part I: a necessary and timely evolution. Working paper, CDC Climate Research & the Institute for Sustainable Development and International Relations

NBIM (2018) Climate change strategy, expectations towards companies. https://www.nbim.no/contentassets/e3f8e013de754cad905b686bdb50f76a/nbim_climatechange_2018_web.pdf

NGFS (2018) First progress report, October 2018. Central Banks and Supervisors Network for Greening the Financial System. https://www.banque-france.fr/en/financial-stability/international-role/network-greening-financial-system/first-ngfs-progress-report

Norwegian Ministry of Finance (2018) Climate risk and the Norwegian economy. Official Norwegian Reports NOU 2018: 17. https://www.regjeringen.no/en/dokumenter/nou-2018-17/id2622043/sec1

Norwegian Ministry of Trade, Industry and Fisheries (2013) Meld. St. 27 (2013–2014) Diverse and value-creating ownership. https://www.regjeringen.no/en/dokumenter/meld.-st.-27-2013-2014/id763968/

Ny Ålesund Symposium Summary (2018) http://www.ny-aalesundsymposium.no/2018/Summary_of_the_Ny-Ålesund_symposium_2018.shtml

Sleijpen O (2018) Waterproofing the economy: the central bank and supervisors perspective. In: Conference "Advancing TCFD guidance on physical climate risk & opportunities. https://www.physicalclimaterisk.com/advancing-tcfd-guidance-physical-climate-risk

Sullivan (2014) Climate change: implications for investors and financial institutions. University of Cambridge/IIGCC/UNEPFI

Swiss Re (2018) Natural catastrophes and man-made disasters in 2017: a year of record-breaking losses. Sigma 1/2018. Swiss Re https://www.swissre.com/institute/research/sigma-research/sigma-2018-01.html

TCFD (2017) Recommendations of the task force on climate-related financial disclosures. https://www.fsb-tcfd.org/publications/final-recommendations-report/ and https://www.fsb-tcfd.org/wp-content/uploads/2017/06/FINAL-2017-TCFD-Report-11052018.pdf

UNEPFI (2018) Navigating a new climate—assessing credit risk and opportunity in a changing climate: outputs of a working group of 16 banks piloting the TCFD Recommendations—part 2: physical risks and opportunities. UN Environmental Finance Initiative, 78 p

Van Vuuren DP, Edmonds J, Kainuma M, Riahi K, Thomson A, Hibbard K, Hurtt GC, Kram T, Krey V, Lamarque J-F, Masui T, Meinshausen M, Nakicenovic N, Smith SJ, Rose SK (2011) Representative concentration pathways: an overview. Clim Change 109(1–2):5

Van Vuuren DP, Kriegler E, O'Neill BC, Ebi KL, Riahi K, Carter TR, Edmonds J, Hallegatte S, Kram T, Mathur R, Winkler H (2014) A new scenario framework for climate change research: scenario matrix architecture. Clim Change 122(3):373–386

Villeroy de Galhau F (2018) Green finance—a new frontier for the 21st century. Speech at International climate risk conference for supervisors. https://www.banque-france.fr/en/intervention/green-finance-new-frontier-21st-century

Chapter 9
Public-Private Cooperation for Climate Adaptation—Providing Insurance Loss Data to the Municipalities

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Abstract This chapter discusses experiences from public-private cooperation for climate services providing insurance loss data (from weather related damage) on asset level for Norwegian municipalities. 'Insurance loss data' display insurance adjustments on address level after nature hazards. The chapter compiles results from three successive studies performed in the period from 2013 to 2018. The studies examined the utility value of insurance loss data for 10 municipalities and investigated the attitudes in the 8 largest Norwegian insurance companies for sharing such data. The findings demonstrate that insurance loss data on asset level can improve municipal understanding of both current and future climate risks, and thus improve the effect and quality of measures to prevent and adapt to such risks. However, with respect to data quality, precise time and place for damage occurrence is essential. With respect to data availability, it is essential that the insurance companies are willing to share loss data with municipalities working with mitigation of risks. Commercial sensitivity is important for the companies, and therefore only restricted entities should be allowed access to the data. The insurance companies also stressed their responsibility for protection of privacy for their customers. Finding solutions to the data access and

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privacy is up to national authorities. As a direct follow-up of the findings and the recommendations from the studies, The Norwegian Directorate for Civil Protection and Finance Norway are cooperating in developing a climate service called 'knowledge bank' for compiling and providing access to data on natural hazard events. The knowledge bank is relating to both current and future climate, strengthening municipalities in their work on risk prevention, and climate change adaptation. Loss data from insurance companies are one type of data they are including.

Introduction

Responding to Climate Change

Climate scenarios for Norway, as for many of the other Nordic countries, warn of more frequent and intense precipitation. Climate change may lead to increased risk of weather-related natural hazards, such as landslides, floods and stormwater events (Hanssen-Bauer et al. 2015). Natural hazards are most commonly linked to extreme weather events, but risks of natural hazards can also be influenced by 'non-extreme' weather (Aall et al. 2015). Statistics from Finance Norway show that nature- and stormwater damages in Norway have doubled since 2008.[1] Climate forecasting indicates that the risk of damages as well as damage costs will increase further (IPCC 2018), unless private as well as public measures are implemented. The costs of natural hazards in the built environment are expected to increase due to urbanization and densification.

As opposed to developing countries, adaptation to climate change in developed countries has often been anticipated as largely unproblematic (Eriksen et al. 2009). Research does however show that developed countries also have vulnerabilities to climate change, due to both exposure and lack of adaptive capacity (O'Brien et al. 2006; Eriksen et al. 2009). Many developed countries may not be well prepared for changing climatic conditions including more extreme events caused by global warming (O'Brien et al. 2006; IPCC 2018).

O'Brien and Sygna (2013) have introduced a framework for climate transformation that recognizes three different spheres of barriers and drivers for change; (1) the practical (technical and behavioural responses), (2) political (systems and structures), and (3) personal (beliefs, values, worldviews, and paradigms). The spheres are embedded within one another, and transformations in any of the spheres may facilitate changes on other spheres. The framework illustrates the importance of more than technical solutions for climate adaptation to happen. The research presented in this chapter is looking especially at the political sphere, with a focus on the meaning of insurance and insurance loss data for climate adaptation.

[1] https://www.finansnorge.no/en/statistics/non-life-insurance/. Read on January 17th 2019.

Local governments are asserted as essential in lowering the societal vulnerability to climate change, yet many local authorities may lack institutional capacity or have difficulties gaining coordination among departments (Flyen et al. 2017; IPCC 2018). Institutional resources, for instance within municipal planning and engineering, are critical to the capacity to adjust to local climate challenges (Tompkins and Adger 2005; Næss et al. 2005). Lisø and Kvande (2007) emphasize the need for adaptive adjustments to climate change related issues in municipal planning, supervision and development of policy instruments. However, as local knowledge on climate challenges and climate change is often informal and undocumented (Eriksen et al. 2009), it will be important to develop more thorough and accessible documentation for municipalities. Further, inadequate municipal development of statutory risk and vulnerability analyses is an obstacle to create a society well prepared for worsening climate conditions (Flyen et al. 2014; Almås 2013; Aall et al. 2011). Næss et al. (2011) have noted the importance of more comprehensive collaboration between research, private industry and public sector at all levels. Even if there is considerable (informal) local knowledge present within local authorities' administrations, municipalities require assistance and climate services to achieve the level of knowledge necessary to prepare suitable climate adaptive measures and policy instruments. Especially the small municipalities lack the resources to gain knowledge on adaptation and need services from outside (Flyen et al. 2017).

Insurance Loss Data as Part of Climate Services for the Municipalities

"Climate services" denotes services helping stakeholders in decision making processes related to climate adaptation. This covers most forms of knowledge distribution and information about climate change (tools, data, documents, maps, webpages, social networks etc.), targeting decision-makers at all levels (Vaughan and Dessai 2014). Thus, climate services are aiming at obtaining well-informed strategy development and decision-making aiming at reducing the exposure of society to climate-related natural hazards, in addition to increasing the capacity to deal with natural hazard events. Unfortunately, public stakeholders often evaluate vulnerability by using fragmented and incomplete data sources (Labonnote et al. 2019). An important type of data not yet fully utilized is *insurance loss data* (claims data). 'Loss' is defined here as follows in a glossary of insurance terms developed by the US National Association of Insurance Commissioners:[2] '*Physical damage to property or bodily injury, including loss of use or loss of income*' after nature events such as floods or landslides. These losses to individuals are registered and calculated by their insurance companies. In other words, loss data is damage information on address level, gathered by the insurance companies concerning their customers.

[2]https://www.naic.org/consumer_glossary.htm#L. Read on January 4th 2019.

In Norway, almost 100% of private properties are covered by insurance against loss or damage (nonlife insurance), and 80% of the building stock is in private ownership. Thus, Norway has one of the most comprehensive insurance arrangements in Europe regarding compensation for damage to buildings caused by natural hazards (Opach and Rød 2018). The Natural Perils Insurance Act (JBD 2018) §1, state that "things in Norway insured against fire damages are also automatically insured against natural hazards". A part of the insurance premium is automatically transferred to The Natural Perils Pool. Thus, most privately owned buildings are covered against natural hazards. All insurance companies that sell fire insurance in Norway subscribe to the Natural Perils Pool arrangement. It is natural to assume that this diminishes or eliminates the competition between them. Rød (2013) maintains that due to this, restrictions on the availability of insurance-compensation data are less important.

Norway would benefit greatly of providing loss data as a climate services for the municipalities. The wide insurance coverage makes Norway a suitable case for studying how to use loss data to improve climate change prevention measures.

Compilation of Three Studies on Insurance Loss Data

The realization of the meaning of insurance loss data for the municipalities and governmental organizations to deal with impacts of climate change, has resulted in three research studies involving the finance industry organization Finance Norway. The organization represents 240 financial companies with 50,000 employees, and it advocates the views of the industry towards public authorities and various groups in the Norwegian society.[3]

This book chapter is a compilation of the results from three successive studies conducted between 2013 and 2018, examining the utility value of attaining access to insurance loss data for the case of 10 municipalities. In two of the studies, chosen Norwegian municipalities were provided with insurance loss data (climate-related damage) on asset level, to improve the quality of their work on mitigating economic loss from natural hazard events. The last study investigated attitudes towards sharing such data among the management of the 8 largest Norwegian insurance companies. Until now, there has been limited financial support and fragmented research on insurance and loss data for climate adaptation in Norway. However, the research centre Klima 2050[4] gave an opportunity to see the fragmented research in connection, and to write about the total results of this public-private cooperation.

[3]https://www.finansnorge.no/en/about-finance-norway2/. Read on January 16, 2019.

[4]www.klima2050.no.

Aims and Limitations

Based on the three studies on insurance loss data as a climate service, the paramount research questions were:

1. What is the *utility value* of attaining access to insurance loss data for Norwegian municipalities?
2. What are the *attitudes* among managers/directors in Norwegian insurance companies to sharing loss data with municipalities?

The studies focused on loss data from *private* insurance companies. Insurance loss data is case specific information on building damage caused by natural hazards and impacts of climate/climate change. The studies did not go into depth concerning insurance of municipal facilities or public properties.

Due to the qualitative nature of the study, the research has constraints related to the number of participating municipalities, however, the study represents both small and large municipalities. International comparison would be important for developing knowledge on the topic. There has not been time and budget for this type of extension in the projects, but these are important issues for further research.

Empirical Background and Existing Research[5]

Insurance in Norway

The Norwegian Natural Perils Pool is aiming at compensating damage caused by natural perils and to contribute to protective measures against such perils by the Act on Natural Hazards. The Pool administers a twofold compensation scheme for damages caused by *defined natural perils* on objects.[6] Which of the schemes to apply for compensating damage depends on whether the object is insurable (i.e. is suitable for fire insurance) or not. All buildings and movable property insured against fire damage are automatically insured against damage by natural perils if the damage in question is not covered by other insurance (e.g. motor insurance and other forms of comprehensive insurance schemes). This follows from the Act on Natural Perils Insurance (JBD 2018). All insurance companies insuring the abovementioned objects in Norway are participants in the Norwegian Natural Perils Pool. The Pool's scheme ensures compensation for damage incurred by natural perils. The Natural Perils Insurance Act does not include motor vehicles, boats, ships, roads, railways, etc.: compensation in such cases depends on the individual annual insurance coverage specified for these items. Claims for damage to objects unsuitable

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[5]Parts of this literature review has been presented in Hauge et al. (2018a, b).

[6]https://www.naturskade.no/en/naturskader-og-erstatning/compensation-schemes/. Read on January 4th 2019.

for fire insurance may be compensated by the Norwegian National Fund for Natural Damage Assistance, which can provide compensation for damages to objects that cannot normally be insured against damage by natural perils by means of ordinary insurance schemes. The decisive point is whether the object could have been insured, not whether it actually was insured. Many municipalities are self-insurers, as is the Norwegian State, and are not covered by the Natural Perils Pool. Some municipalities have however chosen to ensure parts or all of the building stock through insurance companies to avoid losses due to natural hazards.

The Norwegian Natural Perils Pool has administered this arrangement, and thus also collected loss data, since 1980. Damages to private property due to pluvial flooding are also included in the property insurance. Pluvial flooding, however, is not considered a cause of natural hazards, and is therefore not part of the definition of natural perils under this arrangement. Statistics collected by Finance Norway from their insurance members demonstrate that costs of pluvial flooding are about 3.5 times as much as the costs due to riverine flooding.[7] These losses are also covered by property insurance but have been the source of increasing concerns for future climate scenarios, involving more frequent heavy precipitation.

The last decade, more frequent events with heavy precipitation have been leading to an increase in damages and insurance claims. In addition, water and sewage infrastructures worn over time, add to the severity, extent, and impact of the damages. Repetitive damage in the same location, and questions of apportionment of liability, has led to frustration among local policyholders. Focus and arguments around cause and liability, as well as several Norwegian Supreme Court decisions have escalated tensions between urban municipalities (in particular) and property insurance companies as the cost of pluvial flooding continues to rise. In Norway, in the last ten years, insurance companies have paid annual compensation of around NOK 2 billion for damages to insured buildings caused by urban and river flooding. This represents a 114% increase from 2008 to 2017.[8] Prevention measures are urgent.

Insurance Loss Data in European Climate Policies

Use of loss data for better decision-making in climate change adaptation and disaster risk reduction is central to fulfilling the obligations of the *Paris Agreement*[9] and the *Sendai Framework for Disaster Risk Reduction.*[10] To support these agreements from the United Nations (UN), the Organisation for Economic Co-operation and Development (OECD)[11] has pointed out the need for private–public co-operation, and

[7] https://www.finansnorge.no/en/statistics/non-life-insurance/. Read on January 17th 2019.

[8] https://www.finansnorge.no/en/statistics/non-life-insurance/. Read on January 4th, 2019.

[9] https://unfccc.int/sites/default/files/english_paris_agreement.pdf. Read on January 4th, 2019.

[10] https://www.unisdr.org/files/43291_sendaiframeworkfordrren.pdf. Read on January 4th, 2019.

[11] http://www.oecd.org/daf/fin/insurance/OECD-Recommendation-Disaster-Risk-Financing-Strategies.pdf. Read on January 4th, 2019.

promotes the development of technologies and expertise in monitoring and assessing disaster risks by government. The OECD emphasizes the importance of including the private sector and non-governmental organizations, the scientific and academic communities, and taking advantage of private-sector capability and expertise in the development of risk assessment and exposure models.

A Science and Policy-report was issued by the European Commission Joint Research Centre on the current recording of loss data in the EU member states, aiming at providing evidence-based scientific support to the European policy-making process on disaster risk reduction. The authors state that the capacity of developing and developed societies to carry such losses is limited (de Groeve et al. 2014). Further, there is little awareness that estimates of future losses are hampered by low-quality in historical loss data. One solution stated by de Groeve et al. (2014), is to measure and describe losses better. Their recommendations also include: sharing experiences from operational data collection (local-level assessment and recording, aggregation process, uncertainty measures); exploring various tools and recently developed methods (e.g. economic loss accounting methods, sampling, remote sensing); and, comparing and harmonizing different structures of loss databases and their indicators. De Groeve et al. (2014) emphasise the need for further exploiting the potential of insurance as an incentive for risk reduction.

In March 2018 the European Commission published its Action Plan on "Financing Sustainable Growth",[12] following the recommendations of the final report by the High-Level Expert Group on Sustainable Finance,[13] Task Force on Climate-related Financial Disclosures (TCFD). The expert group recognizes that the financial system has a key role in addressing the challenges of climate change and address the need of for a comprehensive shift that foster transparency and long-termism. The shift should be aiming at reorienting private capital flows towards sustainable investments, including resilient critical infrastructure, and managing financial risks stemming from climate change. The insurance sector can play an important role as an absorber of risk and provider of risk expertise. The TCFD-report (p. 40) states that the financial sector should:

- *develop broadly accepted methodologies, datasets, and tools for scenario-based evaluation of physical risk by organizations, and*;
- *make datasets and tools publicly available and provide commonly available platforms for scenario analysis*.

[12] https://ec.europa.eu/info/publications/180131-sustainable-finance-report_en. Read on January 4th, 2019.

[13] Recommendations of the Task Force on Climate-related Financial Disclosures: https://www.fsb-tcfd.org/wp-content/uploads/2017/06/FINAL-TCFD-Report-062817.pdf. Read on January 4th, 2019.

Existing Research and Experience on Public Access to Private Insurance Loss Data

Regarding the use of loss data for climate change adaption, frameworks for cooperation between private insurance companies and municipal or governmental organizations still need further research (Zhou et al. 2013). Both parties have a potential advantage of collaboration, according to de Moel et al. (2009), and points out Austria as an example. In Austria, there is some collaboration between the central government and the insurance companies regarding flood maps for awareness raising and determining insurance premiums. There has also been some examples of collaboration in France and the UK. In France, researchers in Mission Risques Naturels (MRN) are also working on the use of insurance data for damage prevention.[14] In some of the cantons in Switzerland, where there is a public monopoly insurer for damages caused by natural hazards, this monopoly insurer often have rights to participate in disaster protection and land usage planning (Schwarze et al. 2011). After the heavy cloudburst in Denmark in 2016, all Danish municipalities were given the possibility to get free access to the Danish insurers' cloudburst data for their own municipality.[15] The motivation for offering the data was to give the municipalities a better decision basis in the required work on climate adaption plans for the municipalities.

For Norway, most of the research on loss data has been conducted to show that this data might be valuable for municipalities in climate change adaption, like the development of geo-visualization tools from the national natural hazard damage data. In the national "NASK register",[16] the compensations from Norwegian insurance companies for losses caused by extreme events as storms, floods landslides, storm surges, volcanic eruptions, and earthquakes, are registered. This data has been used in the development of ViewExposed,[17] a decision-support tool for local planners (Opach and Rød 2018), and of ClimRes,[18] a dashboard visualisation tool aiming at a user-friendly presentation of the damage data. For ViewExposed, the historical damage data was used for valuation of the integrated vulnerability index model that was also developed in the project. This vulnerability assessment enabled a ranking of the vulnerability of all Norwegian municipalities. The integrated assessment included exposure assessment of three natural weather-related hazards, and it was found that the exposure indices for landslide and storm correlated well. The flood exposure indices did not correlate well. The ClimRes had a more bottom-up approach, using only the historical damage data from the NASK register, in addition to water intrusion damage data due to pluvial flooding, that is available in the VASK register.[19] The previous experience (from ViewExposed) was that using exposure indices and

[14] http://www.mrn.asso.fr/publications/les-rapports-detudes/page/2/. Read on January 7th, 2019.

[15] https://www.forsikringogpension.dk/media/2370/skybrudsskadedata-2016.pdf. Read on January 7th, 2019.

[16] https://nask.finansnorge.no/hendelser.aspx. Read on May 6th, 2019.

[17] http://folk.ntnu.no/opach/tools/viewexposed/. Read January 16th 2019.

[18] http://folk.ntnu.no/opach/tools/climres/. Read on May 6th, 2019.

[19] https://vask.finansnorge.no/. Read on May 6th, 2019.

assessing the municipals vulnerability led to discussions about the applied methods rather than prevention measures. By only using the historical damage data as "objective facts", the aim was that a user-friendly spatial and temporal visualization would facilitate discussions in the municipalities about their preparation and adaptation for climate change-related events.

Torgersen (2017) also analyzed loss data in a case of a Norwegian municipality. He used data from the national "VASK register", where the insurance companies have registered water-related claims since 2008. Torgersen examined the correlation between the registered claims in the municipality and the precipitation data by using Principal Component Analysis. He also used Partial Least Square Analysis to investigate characteristics of the surroundings of houses on the exposure to urban floods. Torgersen (2017) studies show how greater data availability and cooperation among insurance companies, municipalities, and researchers can give new insights and improve traditional solutions. Thus, access to a higher-quality damage-data together with more research might spur knowledge-based implementation of flexible and sustainable measures to reduce the risks of urban flooding.

The valuable insights that can be obtained from analyzing insurance data, for explaining the variables of surface flooding events, is also investigated in the international systematic review article from Gradeci et al. (2019). The literature review shows that there has been published research literature on insurance data and analyses of flooding since 2000, and that the number of articles drastically increased from 2010. Even though there have been several research articles published since 2016 on the development of models from insurance loss data, these only include models for a few countries: Canada, Denmark, France, Germany, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, UK, and USA. These papers show that using innovative methods and developing models on loss data can be profitable for the municipalities in the planning of climate risk reduction. However, they do not consider in-depth the abilities of the municipalities to apply new methods and models in practice, investigate the cooperation needed between the private companies and the public organisations or look at the challenges regarding public sharing of the loss data. Bernet et al. (2017) points out that because of confidentiality, insurance loss data are difficult to collect from insurance companies. The data itself is often also spatially and temporally aggregated and lack precise data for the specific damage incidents. Insufficient loss data will make it difficult to model surface-water flooding events (Spekkers et al. 2013; Bernet et al. 2017; Torgersen 2017). Thus, there is a large research gap on public-private cooperation arrangements of access to insurance loss data.

Insurance Loss Data as a Climate Service

Climate service is the process of transforming existing knowledge and information into tailored products, services or tools to support decision makers in climate adaptation (Vaughan and Dessai 2014; WMO 2011; Hauge et al. 2017). Vaughan and Dessai (2014) highlights three aspects of this process: the generation, provision and contextualization of the information. In the current studies, the provision and contextualisation of loss data from insurance companies to the municipalities is investigated.

In much of the climate service literature, the insurance industry has been seen mostly as a potential climate service user, and not as a climate service provider (WMO 2011; Hattermann et al. 2018; Soares et al. 2018; NRC 2009). WMO (2011, p. 60) underlines the need of socio-economic information on the national and community level, in addition to climate information from climate research, for developing and implementing efficient climate services. This information is crucial for assessing vulnerabilities and risks in the communities. The insurance industry is pointed out by WMO (2011) as a main potential contributor from the private sector for providing important economic information. According to Street et al. (2018), there is a critical lack of available data related to damage and losses caused by extreme weather. Filling this gap is important to get effective climate services that can support disaster risk reduction.

Locally based instruments and tools for the municipal planning is crucial for climate adaptation (Flyen et al. 2017). Decision support products, services or tools should be tailored to the user needs for specific situations (Meadow et al. 2016; Miles et al. 2006; Street et al. 2015; Schwab and Storch 2018). In addition to user needs, the decision support tools should link information producers and users, and build connections across disciplines and organizations (NRC 2009). Vaughan and Dessai (2014) argue for co-production of climate services with all stakeholders involved. User evaluation is important to improve climate services. Internalisation of knowledge will enhance the contextualization of climate services (Hauge et al. 2017; Meadow et al. 2016), Hauge et al. (2018a, b) promotes learning in groups and networks as a way of improving climate services in the municipalities.

Environmental Psychology Contributes to Explain Efforts Towards Climate Change Adaptation and Mitigation

In the search for relevant research, little has been found on changes in attitudes on sharing of insurance loss data or co-operation arrangements/ frameworks for sharing of loss data. At this, research on changes in attitudes towards climate and environment in general is described here.

Within environmental psychology, social psychology theories are often used to explain challenges encountered by individuals and groups in terms of human behaviour, perceptions, and motivations in the face of climate change (Clayton et al. 2016; Goldstein et al. 2008). An environmental psychology perspective may therefore contribute in explaining changes in attitudes and efforts towards climate adaptation and mitigation. Stoknes (2015) recommends a focus on *social strategies* for communication in climate-related contexts, which harnesses the power of social networks and norms. People look to others to find out how they should behave. *Social norms* represent the summed knowledge (imagined or real) of what others would say or do in your situation. Even if many people state that the actions of their peers have little effect on their own habits concerning the environment, research indicates the opposite (Stoknes 2015; Sussman and Gifford 2013). Within a network, or between networks, people compete to perform better than their peers. People are not only trying to imitate or achieve the same as their peers, but also to outdo them (Griskevicius et al. 2010). These same status- and competition-related mechanisms may also be of importance in sector groups, where members may attempt to impress one another. People try to avoid social exclusion and social sanctions and need to be seen and praised for the good they do. Praise from other members in their group strengthens their attitudes and values (Cialdini and Goldstein 2004). Membership in a group of climate change adaptation experts strengthens individual members' identities as persons who care about climate change adaptation. Our attitudes are profoundly influenced by the groups that people want to belong to—the groups we recognize as high-status groups (Klöckner 2015; Tajfel 2010). Social networks appear to be central to ensuring that climate services are being used and developed (Hauge et al. 2017).

Methods Applied in the Three Referred Studies

Study 1—Pilot Project About Testing of Loss Data from the Insurance Industry for an Evaluation of Climate Change Vulnerability and Prevention of Climate Related Natural Hazards in Selected Municipalities

The first research study is the initial pilot testing of insurance loss data in municipalities from 2014, published academically in a Norwegian publication (Brevik et al. 2014) in addition to one international conference paper (Ebeltoft and Aall 2016). The research project was initiated by Finance Norway in 2013 and was carried out by the research partners Western Norway Research Institute and the Geographical Institute at NTNU (Norwegian University of Science and Technology). The project's overall goal was to assess whether having access to natural hazard insurance loss data could strengthen municipalities' capacity to prevent and reduce climate-related losses. Specific goals were to: (1) Identify possible advantages of having access to natural hazard loss insurance data; (2) outline the structure of a future system to use natural hazard loss insurance data; and (3) contribute to strengthening the trust between municipalities, state agencies and the private insurance industry on matters concerning the prevention and reduction of climate-related natural hazard losses.

Insurance loss data for the municipalities was provided by 8 insurance companies to 10 pilot municipalities. The focus of the project was on the damages related to sewer backup and surface water runoff.

The testing in the municipalities was documented in three manners: By a survey, from notes reported from the municipalities, and by interviews at the end of the project. The survey was distributed early in the testing period, to draw the municipalities' attention to the main research questions of the project. Another aim was to document the early phase challenges of importing and testing of the data (geocoding).

The notes came from 4 partners representing 5 municipalities. In the notes, the municipalities document the tests and analyses they had performed, with emphasis on their experiences with geocoding of data, evaluation of the data value, and recommendations for making the data more useful for the municipalities in the future.

The interviews took place at the end of the project period and involved the project manager in each of the 10 municipalities.

Study 2—Status and Possibilities in the Use of Loss Data in the Work with Climate Change Adaptation

The Norwegian Environment Agency ordered a report from Western Norway Research Institute as a sort of follow-up of the above-mentioned project. The report was published in Norwegian in 2017 (Aall et al. 2017). The first part of the project consisted of a systemization of available statistics about natural damage data on roads, railway, buildings, water and sanitary infrastructure, electrical grid, telecommunication infrastructure, maritime infrastructure, and agricultural property.

The second part of the study consisted of results from three qualitative interviews of city municipality employees. The municipalities were chosen from a climate change adaption network run by the Environment Agency. Through the participation in the network (after the initiative from the pilot that started in 2013) these municipalities had gained access to loss data from the insurance industry. The intention was to use the data in planning and decision processes in the municipalities. It was important both to assess the actual need of the data, based on the municipalities' experiences, and to document limitations in the existing data, in order to develop recommendations for a successful implementation of the data.

Study 3—Attitudes in Norwegian Insurance Companies Towards Sharing Loss Data

The third study aimed to collect and explain attitudes towards Norwegian insurance companies on sharing loss data, and to reveal the imperative requisites to obtaining such sharing of loss data. The findings are reported in an English report (Hauge et al. 2018a, b). The findings are based on qualitative interviews of 15 informants in the 8 largest insurance companies in the country, with both oral and written answers. In the invitation for research interviews, honest and open replies were requested, to ensure a reliable result of the study so that the study could help to indicate to the public authorities what to expect for sharing of loss data. Two companies chose to answer the interview guide via email. The other interviews were conducted face to face, recorded, transcribed, and translated. All texts were thematically categorized, themes and meanings were subsequently sorted into groups, analysed and discussed. All information is thoroughly anonymized. When working with the analysis, the most typical and clear quotations were selected to illustrate the findings. Some quotations from the interviews have been simplified or slightly rephrased, however with a focus on preserving the meaning of the statements.

Interviewees were managers and technical staff from the eight largest insurance companies in Norway, and most of the informants were men.

Results

Study 1—Pilot Project About Testing of Loss Data from the Insurance Industry for an Evaluation of Climate Vulnerability

Insurance companies hold essential loss data on asset level which can improve municipal understanding of climate risks. Access to the natural hazards data of insurance companies was found highly useful, for smaller as well as larger municipalities. Notes from one of the municipality-interviews:

> The loss data is to a great extent new for the municipality, and they have clear expectations to use the data to identify vulnerable areas they might not be aware of. Many of the cases that are part of the insurance data set are damages outside of the municipality's direct responsibility, and therefore not registered in the municipality. The municipality is also interested to proceed with the use of the data, however this depends on the data being geo-referred in a more effective way. (Municipality 1)

The *main conclusion* of the project is that providing Norwegian municipalities with access to the natural hazards loss data of insurance companies is of great use to the municipalities. Such a measure could potentially strengthen the preventive effort of municipalities with regards to natural hazards in the following ways:

- Generally:
  - Basis for better collaboration with the insurance sector and within the municipalities;
  - New insights into climate risks;
  - Improved understanding of how climate change may affect society.
- Land-use planning:
  - Improved knowledge base for localization of future development areas in order to select the areas with the lowest possible risk of natural hazards;

  - Improved knowledge base for the prioritization of preventive measures.

- Construction and maintenance of water and sanitation:
  - Improved knowledge base for prioritizing management, maintenance, rehabilitation, and reinvestment;
  - Improved knowledge base for collaboration between municipal water/sanitation and planning units.

- Public infrastructure in general:
  - Improved knowledge base for prioritizing preventive measures;
  - Improved knowledge base for risk and vulnerability analyses.

A nationwide database on loss due to natural hazard events could serve to boost trust and improve collaboration between municipalities and insurance companies, and within municipalities. The pilot project also showed that access to such data could provide new insights into previously unknown climate risks and strengthened suspicions of identified risks that had not been confirmed.

Another important question was whether municipalities have the institutional capacity and competence to make full use of the loss data, and, more importantly, whether getting access to such data would actually lead to higher prioritizing by the municipalities in terms of preventive efforts to reduce damage due to natural hazards. The project documented that Norwegian municipalities, small or large, may benefit from access to natural hazards data, regardless of whether they use advanced GIS tools. Still, a minimum of local interest and willingness to prioritize prevention of natural hazards must be in place.

The project documented that the quality of the natural hazard loss data need to be improved, especially in two areas:

- Information about when the damages occurred, as opposed to the time when the damage form was completed;
- Better information on where damages occurred. The damages must be related to an actual address or stated in the form of GPS coordinates, ideally also the altitude above or below ground.

Notes from one of the municipality interviews:

> Municipality X emphasized several aspects that reduced the usability of the loss data. On one side, the amount of nature damages was relatively low, and it was difficult to connect these to climate/ water. One the other side, many of the damages lacked classification; they were coded with "cause unknown". Altogether, only 30% of the data were possible to geo-locate with cause code. Even less, 9%, were considered to be climate related. (Municipality 10)

Therefore, a common standard for reporting damages needs to be developed. Supplementary measures are also needed, such as information, attitude change, and governmental requirements. Having a database of the damage data would not, in itself, lead to any changes.

Study 2—Status and Possibilities in the Use of Loss Data in the Work with Climate Change Adaption

A part of the study was done to detect the status of usage of loss data in the work with climate change adaptation. This recent study, conducted at the request of the Norwegian Environment Agency (Miljødirektoratet), investigated municipal needs for loss data. The report presents previous research in the area and an overview over existing sources of natural hazard damage data. The two databases of potentially the greatest interest for municipalities were found to be those reporting compensation from insurance companies for water damages (Vannskadestatistikken, VASK[20]), and natural damages statistics (Naturskadestatistikken, NASK[21]). They are both available from Finance Norway, and has previously been applied in analysing vulnerability to damages caused by water and natural hazards. According to Aall et al. (2017), these databases might serve as a good starting point for reporting damage data, but municipalities need a higher data quality. The damages must be correctly specified and categorized; also, higher geographical resolution on the data is necessary. Today, such data are available only on the *county and municipality levels* for the municipalities.

The report includes interviews with key personnel from three municipalities that participated in the study by Brevik et al. (2014) and that have been working with damage data in connection with climate change adaptation since then. The interviews confirm the usability of the data, but still some challenges are pinpointed in the notes from the interviews:

> Municipality X characterizes the data material as a useful supplement to other data sets they have. The use of these data in planning processes have been a bit random. The use includes area plans and smaller regulation plans where the municipality is developer. In municipality Y they have used the data in ongoing planning processes mostly as supporting data, through using the loss data as a static map-layer they may employ when needed. (…) In municipality Z they see the use of the loss data in planning processes, but they have experienced the data quality as a barrier.

These interviews confirm that high geographical resolution is needed to get valuable results from damage data, whether on the address or the GPS-coordinate level. Notes from the interviews with the municipalities who have had access to loss data the latest years:

> Lack of geographical precision in the loss data material is a challenge all the interviewees mention. The consequences were both increased administrative costs and that a part of the data set had to be deleted. Neither municipality X nor municipality Y expressed a need for competence and software. However, municipality Z had bought a new software to handle the loss data set. They all mention that a good geo data-department is a premise for handling the loss data from the insurance sector. Most municipalities, except the largest city municipalities in the country, will likely lack relevant competence and software.

[20]https://vask.finansnorge.no/. Read on January 21st, 2019.

[21]'Natural damage': damage directly caused by a natural event such as landslide, avalanche, storm, floods, storm surge, earthquake or volcanic eruption. https://www.naturskade.no/en/information/act/ Read on January 21st, 2019.

All three municipalities were large and urban municipalities, and all informants mentioned that a precondition for handling damage data from the insurance industry was a functioning geodata department in the municipality. For most municipalities in Norway, however, such competence is lacking. On the other hand, the informants generally maintained that if data quality is high, damage data will give possibilities to improve the knowledge about why, how, and when damages occur, and to help prioritizing the right measures. To some degree, all three municipalities report the advantages of using damage data, and one informant was certain that this benefit is important. One of the informants stated:

> The loss data do not solve problems. Loss data are something that give opportunities to increase the knowledge on why, how, and where the damage happens. This may be an indicator on the problems that occur. This knowledge is important, but first, the data must be good, easy to use, and trustable.

Study 3—Attitudes in Norwegian Insurance Companies Towards Sharing Loss Data

All except one of the companies said in the interview study that they were willing to share their loss data on asset level, and most of them said that they were positive towards this. After the publication of the report, and the media-attention it provided, the last company changed their mind, and stated that they were positive towards sharing. Some of the interviewees claimed that their view was contingent on the presence of a sector-wide positive attitude for sharing (as seems to be the case). Most of the interviewees preferred an establishment of a *requirement* to share loss data. However, their willingness to share data depended on the processing and management of the data.

> We are interested in sharing data because we have a genuine belief in a future-oriented, sustainable society, where we are a voice in the society: in the local communities and in the society at large. To contribute in a wise way. For us, this will involve limiting damages and all the things that are the ideal here. Definitely. But there is also the risk of sharing data with competitors. And there are the risks associated with protection of personal privacy, anonymization and things like that. These problems will have to be dealt with. (Company 1)

Even if they were willing, some were sceptical to the value of sharing their loss data. They said that the problem regarding prevention measures was a question of other needs than the municipalities' need for loss data. They maintained that technical personnel in the municipalities *know* what they ought to do, but they cannot get the politicians to set aside necessary funding. Further, that municipalities already possess considerable information that they do not utilize.

> The question is if there are there other ways of doing this that will generate the same benefits? With less risk, fewer problems with technical issues, personal privacy, security etc., but that can generate the same benefit for the municipality or county. (Company 8)

All the companies *demanded* that their loss data should not be made available to other rival companies. If other insurance companies had access, it might lead to price-fixing cartels and lack of competition. Several companies feared that foreign companies would gain easy access to the Norwegian market if they could obtain such loss data. Price is the most central element of competition in the insurance market. Log-in procedures and other means of protection were therefore extremely important to the companies. If too many stakeholders can obtain access to the data, filtering out undesirable use will become difficult. Access should be granted only to stakeholders who can utilize the loss data for prevention and climate change adaptation purposes.

> The insurance industry – it's a game between the companies, to be best in predicting damages. And since historical loss data is a very important parameter for predicting who will get damages, we, as a big company, don't want to share this with many small ones. This is a crucial point for us whenever we share data, that the information does not fall into the hands of our competitors. But apart from that, we are always positive to sharing information that can generate benefits for the society. (Company 4)

All companies were concerned with the protection of privacy. Several mentioned the implementation of the EU General Data Protection Regulation 2016/679 (GDPR), that entered into force in May 2018. They had difficulties in understanding that sharing personal loss data would be legal. This would require a legal basis and the data to be aggregated on a level where no specific individuals could be identified. Furthermore, it must also be arranged so that the insurance companies are not responsible for the information after it has been delivered.

> I think that the probably largest obstacle is simply the protection of privacy. (…) the possibility of just making all these data openly available. Nowadays we are very busy with ensuring existing and new rules for protection of privacy. When I was looking at this, I immediately though that it will be necessary to establish legal warrants somehow. Will it be systemized so much that we deliver loss data with specified addresses? We haven't made any juridical assessments, but I feel this would be the main challenge. (Company 3)

Interviewees thought the administrator should be a public, independent organization in which society has confidence. The Directorate for Civil Protection (DSB) was mentioned as one possibility. Some interviewees said that the most important point was for their organization to be able to implement an IT-structure that could ensure security.

All damage data are registered digitally in Norway. Most companies did not see the technical/ digital demands as requiring large investments. They add that, in any case, this is the direction in which they intend to take their company.

> This is a part of the development of the company and will be carried out no matter what. (Company 7)

Discussion and Conclusions

Summary of the Main Findings

As shown, the two first studies presented in this paper has demonstrated that the understanding of measures to prevent loss due to weather-related natural hazards related to both current and expected future climate conditions can be strengthened if the municipalities have access to insurance loss data. The municipalities need precise time, place and terrain height for flooding occurrence. A common standard for reporting damages needs to be developed (Brevik et al. 2014; Aall et al. 2017; NOU 2015). The last study on the insurance companies attitudes to sharing their loss data (Hauge et al. 2018a, b), shows that the insurance sector has increased their environmental effort and is prone to contribute to climate adaptation. All the insurance companies are willing to share their loss data with the municipalities and public authorities, dependent on how the data are treated, on what level, and with what stakeholders. Further digital registration of damage and loss data was part of the plan in all interviewed insurance companies.

Discussion of the Findings and Consequences

However, in order for sharing of loss data to happen, four major measures must be put in place: Firstly, the insurance companies must include 'climate change adaptation' as an additional reason for collecting loss data, and (at least in most cases) must make some changes in how the data are registered (e.g. by including terrain height for data related to flooding incidents). Secondly, an appropriate public body, for instance, the Directorate for Civil Protection (DSB), must be provided with sufficient economic resources to establish a database on damage and loss accessible for the local authorities, in close cooperation with the insurance industry. Thirdly, the challenge with commercial sensitivity must be solved with strict log-in procedures. The third of the presented research studies indicate that these issues may come into place. The fourth challenge is the protection of privacy. There have so far only been temporarily permissions to use personal insurance loss data.

A figure has been made to illustrate the most important issues that need to be solved, for sharing of insurance loss data to happen (see Fig. 9.1).

Figure 1.1 illustrates one potential process for utilizing insurance loss data for analysing the causes for damage and base measures for climate adaptation on these data. The figure also shows how other types of data from e.g. damage on railroad and road, would be important for the municipalities to analyse together with the insurance loss data. The speech bubbles contain all the important questions that have to be solved, and where in the process they occur, for sharing of loss data to happen. Using loss data on address level requires that insurance companies can continue to safeguard the commercial aspects and at the same time ensure client confidentiality.

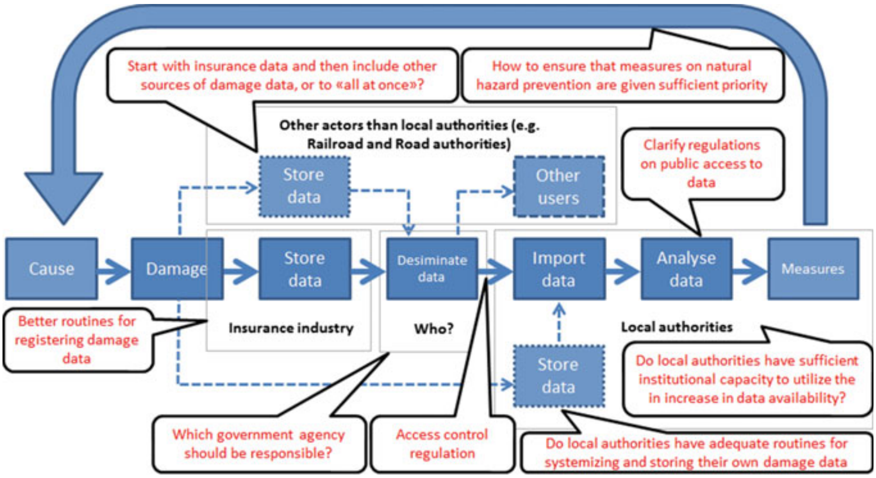

Fig. 9.1 Questions that need to be discussed regarding a possible arrangement whereby the municipalities are provided with access to the damage data from the insurance companies (Brevik et al. 2014)

Through regulating who should be granted access, and how much data should be made accessible at one time, these challenges can be dealt with. It is presumably necessary to clarify how to combine the considerations in the acts of personal data, open (public) files, archives, and insurance business.

The findings across the three studies show that it is valuable and possible to obtain public-private cooperation for climate change adaptation on sensitive loss data. It demands changes in attitudes in the insurance sector, and such attitude change is realistic; it has in fact occurred. Why did this attitude change happen? There has been attention and research on this matter in Norway since 2013. Reports, seminars and media covering made the stakeholders aware of the attitude issue. Especially the last report on attitudes in the insurance sector towards sharing loss data (Hauge et al. 2018a, b), contributed to making the attitudes visible, and strengthen the norms on corporate climate responsibility. After the launching of the report, also the last insurance company wanted to contribute with their loss data. According to an environmental psychology perspective (Cialdini 2003; Cialdini and Goldstein 2004; Stoknes 2015), social norms and group pressure are powerful tools to change climate attitudes. Theories about competition and the want to outdo peers in a group or network (Griskevicius et al. 2010), and how status- and competition-related mechanisms may occur in sector groups (Stoknes 2015), are also relevant explanations for the attitude change. Environmental psychology theories therefore contributes to explain the results/ the attitude change in the insurance companies that has happened the last years. The attitude change in the insurance sector is also an illustration of how the different spheres of drivers and barriers for responding to climate change, (1) practical, (2) political, and (3) personal, are embedded within one another (O'Brien and Sygna 2013). In this case, change of attitudes in the "personal sphere", and the visibility of the municipality needs in the "practical sphere", facilitated and made possible changes and action in the political sphere.

However, there are still barriers to overcome to obtain a permanent sharing of loss data. The insurance companies may *deliver* loss data on address level. However, address level as the *output* of the databank is more problematic, due to unsolved issues concerning the protection of privacy. Should the greatest weight be given to considerations for the individual who owns a property suffering from repeated damages, or the individual considering buying that property, or to climate change adaptation for the society?

In addition, the stakeholders must consider whether the sharing of loss data is the best way to assist the municipalities with climate change adaptation and prevention measures. Many of Norway's smaller municipalities would need to build competence on how to use the loss data in planning for climate change adaptation measures, or they will have to depend on collaboration with neighbouring municipalities or outside consultants. Some interviewees from insurance companies singled out local politics as the greatest obstacle to climate change adaptation measures, not the lack of information on damages. On the other hand, visualization of where damages occur, and the cost of these damages, is a powerful tool in persuading politicians to act.

Moreover: if the insurance companies provide the municipalities with detailed information on loss data, the municipalities will bear more responsibility in regress claims. The question is if small municipalities can manage such responsibility in exchange for obtaining access to loss data.

The first two research studies demonstrated that the main challenge for the municipalities was the low quality of the loss data. There were uncertainties concerning addresses and coding of cause of damage. Even if the third research study showed that the insurance companies are willing to provide the missing details and proceed with the digital development, the changes require efforts and agreement on a template.

Also, the value of the loss data depends on the combination of other relevant data held by public bodies, like landslide and flooding data, the Public Road Authorities' damage data, or the railway's damage data, and other data from different climate services. It is the total picture that could make a difference for sufficient information for climate change adaptation and damage prevention. Collaboration between the public authorities and shared digital systems and databases is at least as important (Labonnote et al. 2019) as collaboration between governmental departments and private business. This is especially important when it comes to nature hazards. How the municipalities handle surface water flooding events in cities is however depending on loss data on address level.

Practical Arrangements of Sharing of Insurance Loss Data

In Norway, the work on finding arrangements for sharing loss data proceeds after the studies, with Finance Norway and DSB (the Norwegian Directorate for Civil Protection) as driving forces. DSB's overarching task is to maintain a full overview of various risks and vulnerabilities in general.[22] In February 2018, Finance Norway and DSB agreed on a formal cooperation, aiming at (i.a.) preventing natural hazard events.[23]

Based on the cooperation between Finance Norway and DSB, work on establishing a national database on damage data (‘Knowledge bank’) started in 2018, involving the insurance agency Norwegian Natural Perils Pool in addition to DSB and Finance Norway.[24] DSB is now in the process of developing a knowledge bank with data to help the municipalities in their work with climate change adaptation and prevention of impacts of natural hazards. The goal is to achieve better overview and knowledge about undesirable events and disasters, and thus to strengthen work on societal safety, enhance disaster prevention, and reduce losses. The project is relevant to many stakeholders. There will be a special focus on municipalities and county governors, and their work on risk- and vulnerability assessment. Work in the first phase focuses on natural hazards. It will later be expanded to other types of risk. The Knowledge bank project aims to compile and make data available for civil protection to assist municipalities and county administrators in their work on preventing nature events through a better knowledge base for cost-benefit analysis, risk and vulnerability analysis. Insurance data on address level is among the data that DSB wishes to collect and make available. Other relevant data providers include the Norwegian Meteorological Institute (MET), the Norwegian Public Roads Administration (SVV), and the Norwegian Water Resources and Energy Directorate (NVE). The public-private cooperation has gained attention in the United Nations Office for Disaster Risk Reduction, and is referred to in two of their latest reports on sustainable finance and data challenges (UNDRR 2019a, b).

Constrains of the Research and Further Research

Qualitative interviewing is an excellent way of exploring reasons for attitudes, as it gives respondent opportunities for reflecting and discussing during the process of data collection. The results from the studies can be generalized analytically (by means of analytical generalization), meaning that the findings from one study can be used as a predictive guide to what may occur in other situations, given similarities in context and culture. Emphasis is thus placed on contextual information and transparency in argumentation (Brinkman and Kvale 2014). Examples of quotations from the interviews are therefore given in the text, so that the reader can judge the argumentation and findings.

However, to gain full understanding of public use of private insurance loss data, it is important to conduct international, interdisciplinary and comparative studies in

[22] https://www.dsb.no/menyartikler/om-dsb/about-dsb/. Read on January 16, 2019.

[23] https://www.finansnorge.no/aktuelt/nyheter/2018/02/samarbeid-om-klimakonsekvenser/. Read on January 16, 2019.

[24] https://www.dsb.no/nyhetsarkiv/nyheter-2018/klimasamarbeid/. Read on January 16, 2019.

order to generalize findings across countries. Comparative, quantitative studies may be challenging due to cultural differences in the insurance sector. The diverse forms of loss data in the insurance companies may also influence the applications of the data in the municipalities. Another important question is; what does it take for the municipalities to be capable of making use of insurance loss data?

The hope is that the research on loss data conducted in Norway may be of inspiration to research groups and public authorities worldwide. International research on public-private cooperation arrangements for sharing of loss data as a type of climate service for the municipalities is needed.

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References

Aall C, Øyen CF, Miles M, Hafskjold LS, Bruaset S, Almås AJ, Gjerde O, Groven K, Heiberg E (2011) Klimaendringenes konsekvenser for kommunal og fylkeskommunal infrastruktur. Delrapport 1: Kunnskapsstatus. [Consequences of climate change for municipally and regionally owned infrastructure. Partial report 1: status of knowledge.]. In: Aall C (ed). Vestlandsforskning, Sogndal, Norway

Aall C, Baltruszewicz M, Groven K, Almås A-J, Vagstad F (2015) Føre-var, etter-snar eller påstedet-hvil? Hvordan vurdere kostnader ved forebygging opp mot gjenoppbygging av fysisk infrastruktur ved naturskade og klimaendringer? [Prepared, wise after the event or status quo? How to evaluate costs for prevention against costs for reconstruction of physical infrastructure after natural hazards]. Vestlandsforskning, Sogndal

Aall C, Husabø I, Groven K (2017) Status og muligheter ved bruk av skadedata i arbeid med klimatilpasning [Status and possibilities with the use of loss data in climate adaptation] VF-rapport 12/2017. Vestlandsforsking, Sogndal

Almås A-J (2013) Climate adaptation and mitigation in the building sector: towards a sustainable built environment. Ph.D., Norwegian University of Science and Technology, NTNU

Bernet DB, Prasuhn V, Weingartner R (2017) Surface water 539 floods in Switzerland: what insurance claim records tell us about the damage in space and time. Nat Hazards Earth Syst Sci 17:1659–1682

Brevik R, Aall C, Rød JK (2014) Pilotprosjekt om testing av skadedata fra forsikringsbransjen for vurdering av klimasårbarhet og forebygging av klimarelatert naturskade i utvalgte kommuner [Pilot project on testing of loss data from the insurance business for evaluation of climate vulnerability and prevention of climate related natur hazards in chosen municipalities]. Vestlandsforsking, Sogndal

Brinkman S, Kvale S (2014) InterViews—learning the craft of qualitative research interviewing. Sage Publications, Los Angeles, CA

Cialdini RB (2003) Crafting normative messages to protect the environment. Curr Dir Psychol Sci 12:105–109

Cialdini RB, Goldstein NJ (2004) Social influence: compliance and conformity. Annu Rev Psychol 55:591–621

Clayton S, Devine-Wright P, Swim J, Bonnes M, Steg L, Whitmarsh L, Carrico A (2016) Expanding the role for psychology in addressing environmental challenges. Am Psychol 71:199–215

De Groeve T, Poljansek K, Ehrlich D, Corbane C (2014) Current status and best practices for disaster loss data recording in EU member states—a comprehensive overview of current practice in EU member states. JRC, Scientific and policy reports. EU, Joint Research Centre

De Moel H, Van Alphen J, Aerts JCJH (2009) Flood maps in Europe—methods, availability and use. Nat Hazards Earth Syst Sci 9:289–301

Ebeltoft M, Aall C (2016) Using insurance claims data to strengthen municipalities' effort to prevent climate-related natural hazards. In: ICUR2016, International conference on urban risks, Lisbon

Eriksen S, Øyen CF, Kasa S, Underthun A (2009) Weakening adaptive capacity? Effects of organizational and institutional change on the housing sector in Norway. Clim Dev Earthscan J 1:111–129

Flyen C, Mellegård SE, Bøhlerengen T, Almås A-J, Groven K (2014) Bygninger og infrastruktur - sårbarhet og tilpasningsevne til klimaendringer [Buildings and infrastructure—vulnerability and adaptability to climate change]. In: SINTEF FAG. SINTEF Byggforsk, Oslo

Flyen C, Hauge ÅL, Almås A-J, Godbolt ÅL (2017) Municipal collaborative planning as a key factor for climate resilience in the built environment. Int J Disaster Resilience Built Environ 9:58–69

Goldstein NJ, Cialdini RB, Griskevicius V (2008) A room with a viewpoint: using social norms to motivate environmental conservation in hotels. J Consum Res 35:472–482

Gradeci K, Labonnote N, Sivertsen E, Time B (2019) The use of insurance data in the analysis of Surface Water Flood events—a systematic review. J Hydrol 568:194–206

Griskevicius V, Tybur JM, Van Den Berg B (2010) Going green to be seen: Status, reputation, and conspicuous conservation. J Pers Soc Psychol 98:392

Hanssen-Bauer I, Førland EJ, Haddeland I, Hisdal H, Mayer S, Nesje A, Nilsen JEØ, Sandsven S, Sandø AB, Sandø A, Sorteberg B, Ådlandsvik B (2015) Climate in Norway 2100—a knowledge base for climate adaptation *M-406*. The Norwegian Centre for Climate Services, Oslo

Hattermann FF, Wortmann M, Liersch S, Toumi R, Sparks N, Genillard C, Hayes B (2018) Simulation of flood hazard and risk in the Danube basin with the Future Danube Model. Clim Serv 12:14–26

Hauge ÅL, Almås A-J, Flyen C, Stoknes P-E, Lohne J (2017) User guides for climate adaptation of buildings and infrastructure in Norway—characteristics and impact. Clim Serv 6:23–33

Hauge ÅL, Flyen C, Venås C, Aall C, Kokkonen A, Ebeltoft M (2018a) Attitudes in Norwegian insurance companies towards sharing loss data—public-private cooperation for improved climate adaptation. Klima 2050-report. SINTEF Building and Infrastructure, Oslo

Hauge ÅL, Hanssen GS, Flyen C (2018b) Multilevel networks for climate change adaptation—what works? Int J Clim Change Strat Manage (In Press)

IPCC (2018) Special Report on Global Warming of 1.5 °C Global warming of 1.5 °C. An IPCC Special Report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. United Nations

JBD (2018) The Natural Perils Insurance Act. In: Preparedness TMOJA (ed) LOV-2018-06-15-37. The Ministry of Justice and Preparedness, Oslo

Klöckner CA (2015) The psychology of pro-environmental communication. Beyond standard information strategies. Palgrave Macmillan, New York

Labonnote N, Hauge ÅL, Sivertsen E (2019) A climate services perspective on Norwegian stormwater-related databases. Clim Serv 13:33–41

Lisø KR, Kvande T (2007) Klimatilpasning av bygninger. SINTEF Byggforsk, Oslo

Meadow AM, Guido Z, Crimmins MA, Mcleod J (2016) From principles to action: applying the National Research Council's principles for effective decision support to the Federal Emergency Management Agency's watch office. Clim Serv 1:12–23

Miles E, Snover A, Binder LW, Sarachik E, Mote P, Mantua N (2006) An approach to designing a national climate service. Proc Natl Acad Sci 103(52):19616–19623

Næss L, Bang G, Eriksen E, Vevatne J (2005) Institutional adaptation to climate change: flood responses at the municipal level in Norway. Glob Environ Change Part A 15:125–138

Næss R, Solli J, Sørensen K (2011) Brukbar klimakunnskap [Useable climate knowledge]. Tidsskrift for samfunnsforskning 52:329–354

NOU (2015) NOU 2015: 16 Overvann i byer og tettsteder — Som problem og ressurs [Storm water run-off in cities and communities—a problem and a resource]. Departementenes sikkerhets- og serviceorganisasjon Informasjonsforvaltning, Oslo

NRC (2009) Informing decisions in a changing climate. The National Academic Press, Washington, DC

O'Brien K, Sygna L (2013) Responding to climate change: three spheres of transformation. In: Transformation in a changing climate, University of Oslo, Oslo, 19–21 June 2013, pp 16–23

O'Brien K, Eriksen S, Sygna L, Naess LO (2006) Questioning complacency: climate change impacts, vulnerability, and adaptation in Norway. Ambio 35:50–56

Opach T, Rød JK (2018) Developing a dashboard visualizing the compensation data on damages caused by extreme events. Kart og Plan 78:207–220

Rød JK (2013) Naturskadeforsikring og utbetaling etter 1980 [Insurance against natural hazards and payment after 1980]. In: Bye LM, Lein H, Rød JK (eds) Mot en farligere fremtid? Om klimaendringer, sårbarhet og tilpasning i Norge [Towards a more dangerous future? About climate change, vulnerability and adaptation in Norway]. Akademika, Trondheim

Schwab M, Storch HV (2018) Developing criteria for a stakeholder-centred evaluation of climate services: the case of extreme event attribution for storm surges at the German Baltic Sea. Meteorol Hydrol Water Manage Res Oper Appl 6:1–9

Schwarze R, Schwindt M, Weck-Hannemann H, Raschy P, Zahn F, Wagner GG (2011) Natural hazard insurance in Europe: tailored responses to climate change are needed. Environ Policy Gov 21:14–30

Soares MB, Alexander M, Dessai S (2018) Sectoral use of climate information in Europe: a synoptic overview. Clim Serv 9:5–20

Spekkers MH, Kok M, Clemens F, Ten Veldhuis JAE (2013) A statistical analysis of insurance damage claims related to rainfall extremes. Hydrol Earth Syst Sci 17:913–922

Stoknes PE (2015) What we think about when we try not to think about global warming: toward a new psychology of climate action. Chelsea Green Publishing, Chelsea

Street R, Parry M, Seemore JS (2015) A European research and innovation roadmap for climate services. EU, Publication Office, Brussel

Street RB, Buontempo CC, Mysiak J, Karali E, Pulquério M, Murray V, Swart R (2018) How could climate services support Disaster Risk Reduction in the 21st century. Int J Disaster Risk Reduction 34:28–33

Sussman R, Gifford R (2013) Be the change you want to see: modeling food composting in public places. Environ Behav 45:323–343

Tajfel H (2010) Social identity and intergroup relations. Cambridge University Press, Cambridge

Tompkins E, Adger W (2005) Defining response capacity to enhance climate change policy. Environ Sci Policy 8:562–571

Torgersen G (2017) Sustainable planning to reduce urban flooding—an interdisciplinary approach. Ph.D., NMBU Norwegian University of Life Sciences

UNDRR (2019a) Opportunities to integrate disaster reduction risk and climate resilience into sustainable finance. In: UNDRR (ed) Sendai Framework for disaster risk reduction 2015–2030. United Nations Office for Disaster Risk Reduction, Regional Office for Europe, Brussels

UNDRR (2019b) Socioeconomic and data challenges disaster risk reduction in Europe. In: UNDRR (ed) The European science & technology advisory group. United Nations Office for Disaster Risk Reduction, Regional Office for Europe, Brussels

Vaughan C, Dessai S (2014) Climate services for society: origins, institutional arrangements, and design elements for an evaluation framework. WIREs Clim Change 5:587–603
WMO (2011) Climate knowledge for action: a global framework for climate services—empowering the most vulnerable. Report No. 1065, World Meteorological Organization
Zhou Q, Panduro TE, Thorsen JB, Arnbjerg-Nielsen K (2013) Verification of flood damage modelling using insurance data. Water Sci Technol 68:425–432

Chapter 10
Evaluation of Climate Services: Enabling Users to Assess the Quality of Multi-model Climate Projections and Derived Products

Maida Zahid, Juliane El Zohbi, Elisabeth Viktor, Diana Rechid, Susanne Schuck-Zöller, Elke Keup-Thiel and Daniela Jacob

Abstract The core of climate services is to provide high quality climate-related information and data that are beneficial for the users. Between the provision of data and the application of climate services, a chain of providers and subsequent users exists. It is an ongoing challenge for providers to conclusively define what users perceive as beneficial regarding the quality of climate model output. This study aims (1) to understand the needs of users with regard to the quality of climate data and information, and (2) to enable providers to assess the quality of climate data input and derived products. From a large-scale survey, we distilled three main user groups: (i) Donna data (data user/product provider), (ii) Pete product (product user/product provider) and (iii) Nick non (potential-user). The survey results show that all three user groups struggle—amongst other things—with identifying reliable climate model output, that is relevant to their needs. They also desire guidance on how to evaluate the quality of climate model data to determine the suitability of the selected dataset for their purpose. Addressing this central need is breaking new ground. The evaluation of quality in the field of climate services in terms of climate model output is of high relevance to both climate model data users and providers of tailored climate information and not restricted to scientific standards and technical quality. We present a customized and tested tool ("QUACK") as one of the first hands-on, scientifically-based and at the same time user-oriented guidelines on how to assure data quality and to self-evaluate the processing of the data.

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Introduction

Climate change and the related impacts and consequences are more relevant today than ever. One example is the youth movement "Fridays for Future" which is demanding radical actions from decision makers in politics, administration and business. The pressure to incorporate the repercussions of every decision on our climate is immense. At the same time, decision makers are realizing that they are facing extraordinary risks and challenges due to the change in climate we are already seeing today and that we have to expect in the near future, caused by greenhouse gas emissions that have already been emitted. As a consequence, the demand for climate change data and information is high, because they can support the analysis of current and future vulnerabilities with regards to climate change for different topics and sectors. In order to assess the impact of climate change in a meaningful way, so that decisions can be based on this assessment, it is of utmost importance to have access to high-quality climate data and information. If the climate data used in climate impact assessment studies have quality issues, a consequence may be misleading and erroneous results (Hunziker et al. 2018). The quality of climate data and information is therefore crucial to make sound decisions.

Quality, however, is a very vague term. Everyone has a unique perspective of what high-quality means for them. The term quality can be defined in various ways, depending on the target audience (providers, users of climate services, and potential user groups). The Environmental Protection Agency (EPA) defines quality in terms of user/service-orientation: '*the totality of features and characteristics of a product or service that bears on its ability to meet the stated or implied needs and expectations of the user*' (EPA 2002). The Spatial Data Transfer Standard (SDTS) defined quality focusing on technical and scientific requirements. They suggested '*five categories of quality for spatial data: lineage, positional accuracy, attribute accuracy, logical consistency, and completeness'*. Information about the quality of spatial data provides a basis for decisions on the appropriateness of data for specific applications.

Quality assurance is a matter of concern for both the climate model data users and providers, because it is not an easy task. The National Weather Services and research projects have used different approaches, but the quality of the data cannot be ensured as there is a lack of a generally accepted methodology for quality assurance (Štepánek et al. 2013). Climate data providers may have given detailed information on the characteristics of data, but it is a challenge for the users to assess the level of data quality and its suitability for a specific purpose they want to achieve. Here, climate services can significantly support the users and providers and can play the role of a beacon shining a guiding light on scientifically sound, high-quality climate information.

Climate services can be described as "the transformation of climate-related data—together with other relevant information—into customised products such as projections, forecasts, information, trends, economic analysis, assessments (including technology assessment), counselling on best practices, development and evaluation of solutions and any other service in relation to climate that may be of use for the society at large." (EC 2015). Moreover, climate services play a critical role in national development planning, managing development opportunities and risks, and in mitigating or adapting to changes in climate. To provide authoritative information to all of these areas it is necessary to develop the best possible understanding of the quality of climate data and derived products.

There exist various types of climate services (see EC 2015). In this new emerging and growing climate services landscape, different players are active. The Climate Service Center Germany (GERICS) functions as a think tank for climate services to meet the range of climate-related information that decision-makers need in support of adapt to climate change impacts. GERICS develops prototype products in the area of climate services and works in close cooperation with science and practice partners from politics, economy, and administration. Besides this primarily user-centric and -tailored approach, there are national to European-scale services that aim to provide consistent information about climate change for larger user groups. The Copernicus Climate Change Service (C3S)—initiated by the European Commission—aims to support adaptation and mitigation policies of the European Union. The C3S is implemented by the European Centre for Medium-Range Weather Forecasts (ECMWF) on behalf of the European Commission. The majority of C3S service elements are implemented by about 200 companies and organizations across Europe, which are selected based on competitive Invitations To Tender. The backbone of the C3S is an online Climate Data Store (CDS) with a wide range of quality-assured climate datasets about the past, present, and future climate.

The core of all activities in the climate service landscape is to steer the development of climate services in the direction of usefulness and usability to ensure high quality in them. Therefore, it is crucial to analyze and understand the needs that the users/providers of climate information have. In this particular case, we would like to present a way of analyzing the results of a survey that was directed at understanding the user's and provider's needs regarding quality assurance and evaluation of climate data. The aim of the survey was to recognize what the users perceive as beneficial for their work regarding the quality of such climate data or information derived from it. The survey targeted climate model data users/providers such as climate scientists, impact researchers, climate service purveyors, and societal end users (public administrations, businesses, and individuals). The survey was conducted by GERICS in the frame of the C3S contract C3S_51_Lot4_FMI—Data Evaluation for Climate Models (DECM), which was coordinated by the Finnish Meteorological Institute (FMI). GERICS in its function as a subcontractor led the survey activities.

Quality assurance is an essential part of climate services, but how to evaluate the quality of climate model data has become a heavily discussed topic between users and providers recently. The climate data users require quality assured climate information for improved planning and decision making. This strong desire of users for quality assurance has given climate services a prospect to co-develop products on quality assurance involving users of these products. In the frame of the C3S contract C3S_422_Lot1_SMHI—Global Users in Copernicus Climate Change Service (GLORIOUS), coordinated by the Swedish Meteorological and Hydrological

Institute (SMHI), users of climate model data across the globe were supported in providing regional to local climate services. GERICS as a subcontractor co-developed a customized product for quality assurance with them, based not only on both scientific rigor and standards but also on practical relevance.

The successful climate services are those that not only understand and address the demands of users but also ensure high quality in the services provided. When taking climate data such as from the C3S Climate Data Store (CDS) to transform them into user-relevant information and products, it is essential to ensure high quality for the whole processing chain (while data extraction, during the data preparation, producing results, and end product). Often the quality assessment is restricted to technicalities and process evaluation. The challenge is to define quality indicators that not only cover both scientific soundness and technical quality, but also criteria like transparency or relevance and usability to users.

The strong interest of climate data users for quality assurance and their demand for guidance to evaluate the quality of climate model data and derived products on their own are the two main deriving factors that have led to this research work. Up to our knowledge, no appropriate and established tool for evaluating the quality of climate data and related products exists so far. So the main focus of this research is to understand and underline the concerns of users regarding the quality of climate data via survey and enable users/providers to evaluate the quality of climate data and derived products by themselves using a recently developed quality assurance tool. In this paper, firstly we present what users expect or need in terms of quality evaluation regarding climate model data through a survey, and secondly introduce a newly developed tool QUACK (Quality Assurance Checklist) for promoting high quality during the transformation of climate data for climate services. The outcome of the tool does not only reflect the quality of tailored climate information, but also enhances the credibility of the work along with the satisfaction of potential clients of the provided climate service.

Collecting the Missing Pieces: The Survey

A review of available information on user's needs regarding climate data evaluation was conducted in close collaboration with all C3S DECM subcontractors. The review concluded that there is an abundant amount of information already available concerning climate variables and climate change indicators, as well as about the technical documentation and guidance material regarding the raw data. However, there is only a little information available about the user's needs to be able to evaluate the quality of climate model data and their needs to strengthen their ability to judge the reliability of climate information. As a consequence—instead of collecting (again) information on required parameters of climate model data and products—the focus of this survey lay on the quality aspect and the demands users pose to be able to assess the quality of the provided data and gain trust in the products. Most questions were asked in a way to confirm already existing assumptions about the topic based on the database compiled previously, or to revise and refine the list of user requirements. The survey analysis provides findings regarding the use of climate model data and climate information products, the data structure and—most importantly—regarding the user's view on data and product quality and their needs in terms of guidance and support.

Thanks to the overwhelming support by the C3S DECM subcontractors and the C3S communication team, the survey was promoted widely to reach as many and diverse people as possible. The survey was advertised and disseminated through a variety of channels, such as networks, events, newsletters, in-house contacts, website posting (e.g. Research Gate, LinkedIn, etc.), news alerts, social media, and blog posts. The analysis of the results is based on the answers collected during a run time of about 8 weeks (12.05.2017–10.07.2017). During this time, it was possible to reach people all over Europe, with a large portion of participants in Eastern Europe (~40%), and even a small group based outside of Europe (1%).

Out of 905 participants in total, 481 users completed the survey. Only their replies were considered for the analysis. The survey split the participants into three classes: (1) Donna data, (2) Pete product, and (3) Nick non. The users were asked about their skills, experience, and subsequently categorized accordingly. Donna data users/providers work with raw and processed climate model data, whereas Pete product users/providers work with information products based on climate model data (e.g. written reports, tables, visualizations). Nick Non are potential users who are interested in climate model data and related products but do not use them yet for their work. Each of the three groups is represented well by the survey participants. They see the need for climate information but are facing obstacles with respect to actually applying climate information. This provided a good basis for the analysis regarding the differences between Donna data and Pete product users as well as regarding reasons by Nick non for not working with climate information.

Typical User Profiles

To develop user-centric climate services, it is essential to put oneself in the user's shoes. What does their environment look like, what are their habits, interests, emotions, thoughts, what are they struggling with and what are they really good at? Developing profiles for different typical user types can help with the understanding of the drivers and underlying motivations of their individual needs much better. Based on the survey, three different typical user profiles were designed.[1] Rather than defining the typical user profiles based on the institutions the users come from, they were grouped depending on their expertise and their actions.

[1] The detailed results of the survey are available upon request at the Climate Service Center Germany (GERICS) or Copernicus Climate Change Service (C3S).

1. **Donna Data**

Donna works at a university since 41% of the participating data users work for a research institution (university or other). The size of her organization varies between <50 employees (22% of all data users), 50–250 employees (19% of all data users), >250–1000 employees (23% of all data users), >1000–5000 employees (19% of all data users) and anything larger (10% of all data users). If Donna is not working in research and education (23% of the data users), she is most likely employed by the agriculture and forestry sector (12% of the data users) or in water management (10% of the data users).

Donna mainly uses climate model output for research and education purposes (51% of all answers by data users). The data is often related to the Representative Concentration Pathways (46% of all responses by data users), focusing on RCP8.5 (34% of all responses that chose RCP as the type of scenario they use) and RCP4.5 data (31% of all responses that chose RCP as the type of scenario they use). This data is usually provided by the CMIP or CORDEX initiatives (56% of all responses by data users), that are freely available (30% of all answers by data users) and of good scientific quality (27% of all answers by data users).

Donna wants to perform her own post-processing (64% of all responses by data users), but she would also make use of pre-calculated climate indices, statistically downscaled and bias-adjusted data (all three options each received >25% of the responses by data users). More often than not, Donna rates the spatial resolution of climate model data as being adequate for her purposes (61% of all responses by data users). She does, however, have many comments about the added value of an even higher resolution (see Fig. 10.1 for the main themes mentioned by data users).

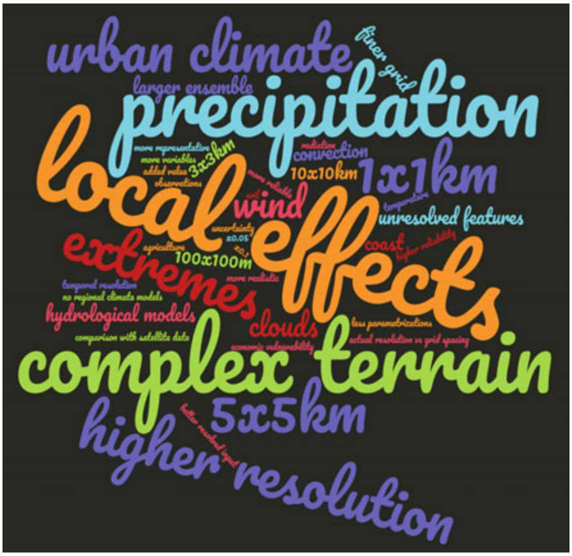

Fig. 10.1 Word cloud (created with wordclouds.com) presenting the different themes expressed by data users in the comments for the question “Is the currently available resolution of climate model data or model-derived climate information products adequate for the purposes of your work?”

Donna definitely needs information on the quality of climate model data (84% of all answers by data users), preferably provided in a quantitative way (69% of all answers by data users), focusing on the performance compared to observations (46% of all answers by data users) and other climate models (36% of all answers by data users). Donna needs guidance to find the most suitable climate projection for her purposes (19% of all answers by data users), and—even more importantly—to access and download the relevant data (22% of all answers by data users). She appreciates this guidance in the form of online help, such as webinars or step-by-step-tutorials, and offline help, e.g. manuals available for download (both 21% of all answers by data users each).

2. **Pete Product**

Pete works at a research facility (25% of all product users) or in the private sector (19% of all product users). He has less than 50 colleagues (30% of all product users) and works in the field of research and education (15% of the product users), agriculture and forestry (14% of the product users), or water management (11% of the product users). Pete uses climate model-based products primarily for research and education purposes (39% of all responses by product users), or for providing it to others in a non-commercial way (30% of all responses by product users). He usually obtains climate information from national meteorological and hydrological services (26% of all answers by product users) and uses idealized scenarios (42% of all answers by product users). In particular, he prefers scenarios with a 1.5 °C (22% of all responses that chose idealised scenarios) or 2 °C (28% of all responses that chose idealized scenarios) global warming, or a doubling of the current CO_2 concentration level (18% of all responses that chose idealised scenarios as the type of scenario they use). Pete needs freely available products (31% of all responses by product users) with good scientific quality (24% of all responses by product users) but also value a user-friendly interface (15% of all responses by product users).

Pete prefers using maps (25% of all responses by product users), graphs (23% of all responses by product users) and Tables (19% of all responses by product users) over fact sheets (17% of all responses by product users) or reports (15% of all responses by product users). He generally rates the spatial resolution of climate model data as being adequate for his purposes (69% of all responses by product users), but he also has a few comments about the added value of an even higher resolution (see Fig. 10.2 for the main themes mentioned by product users).

Pete needs information on the quality of climate model data (66% of all answers by product users) more often, provided in either a qualitative way (43% of all answers by product users) or a quantitative way (54% of all answers by products users). The information about the quality most relevant for Pete relates to uncertainties and limitations (21% of all answers by product users) the performance compared to observations (20% of all answers by product users) and the data source (17% of all answers by product users). He expects to receive information on the quality of the underlying climate model data in the form of an integrated design, as part of the product (by hatching, varying color shade, and saturation, text boxes, etc.; 43% of all answers by product users).

Fig. 10.2 Word cloud (created with wordclouds.com) presenting the different themes expressed by product users in the comments for the question "Is the currently available resolution of climate model data or model-derived climate information products adequate for the purposes of your work?"

Pete is looking for guidance to visualize climate information (22% of all answers by product users), to find the most suitable climate projection for his purposes (19% of all answers by product users) and to interpret climate information correctly (18% of all answers by product users). He appreciates this guidance in the form of online help, such as webinars or step-by-step-tutorials (21% of all responses by product users), offline help, e.g. manuals available for download (19% of all responses by product users), and use cases, i.e. examples for how the information on quality is used in specific cases (17% of all responses by product users).

3. **Nick Non**

Nick Non works in the private sector (34% of all potential users) with less than 250 colleagues (56% of all potential users). She/he works in the sectors research and education (16% of all potential users), cities (10% of all potential users), or infrastructure (10% of all potential users). The potential users could give reasons for not using climate model data or information products based on climate model data in their work (see Table 10.1) and provide comments on why they chose certain reasons.

Most potential users who stated no need for climate information by their organization work for a small company with less than 50 employees. One could put forward the assumption that small companies do not have enough manpower to specifically target this topic in detail. Potential users who struggle with finding relevant climate information expect this type of material to be found easily on the internet, e.g. on "regular weather websites" or the "National Meteorological Service's page". Participants, who are remarking on the fact that certain information is not available, wish for "all relevant indicators like snowfall and rain (time, volume, frequency), temperature and so on", seasonal rainfall predictions, information on heat waves and—on a more

Table 10.1 Potential users answering the question "You indicated that you do not use climate model data or information products based on climate model data in your work. Please specify the main reason(s) for this."

Answers	Responses by potential users	
There is no need for my organisation/company to use it	74	48%
I don't need it in my current role but other people within my organisation/company use it	23	14%
I don't know where to find relevant information	20	13%
There is too much uncertainty in climate model data	12	8%
The data or information I want is too difficult to access	10	6%
The data or information I want is not available	7	4%
The data or information I want is too expensive	7	4%
The data or information I want is not provided in a usable way	6	4%

Multiple answers were possible

technical side—the possibility to compare information of different climate models. Participants who criticize the usability of climate information demand graphs, that show climatological developments over extensive time periods ("thousands of years") in the past in order to put current values into context, and improved forecasts to overcome "limits in different disciplines and scales". The main barriers regarding data access listed are a lack of guidance to access the data, the need for a user account, or financial constraints. Of the twelve participants who chose the option "There is too much uncertainty in climate model data.", three indicated that even additional information explaining how to evaluate the level of uncertainty and its implications would not convince them to use climate information. The nine others indicated that they do not know how additional information would change their behaviour.

Outcome of the Survey: Guidance Needed on Evaluation of Quality of Climate Data

As a final question of the survey, the participants were asked about the main difficulties they encounter when dealing with climate model data and information products based on climate model data. They were encouraged to share suggestions on how these obstacles could be removed. Frequently recurring items related to the following keywords: data selection, limitations, reliability, interpretation, credibility, comparability, data provenance, assessing uncertainties. These terms are closely related to the responses given by both Donna data and Pete product users regarding necessary guidance material. Both user groups voiced the clear need for support with respect to the identification of the most suitable climate projection for their specific purposes. They all struggle (amongst other things and on their respective level of detail) with identifying reliable climate model output that is relevant to their needs. For them, it is a matter of being capable of data evaluation & quality control. Therefore, a central requirement brought forward by all users surveyed is guidance on how to evaluate the quality of climate model data to determine if the selected data suits their individual purpose.

Evaluation of Quality of Climate Data and Derived Products

The evaluation of the quality of climate model data in the field of climate services is an emerging topic. In the case of climate data, the quality is often looked upon as a question of scientific standards and technical aspects. However, for a meaningful evaluation of the quality of climate data, it is important to come up with a certain set of quality indicators that covers all aspects of quality i.e. scientific standards, significance, and utility to users. First steps in this context have been taken by proposing design elements of a climate services evaluation framework (Schuck-Zöller et al. 2017a, b; Vaughan and Dessai 2014; Kirchhoff et al. 2013; Lemos et al. 2012) addressing mainly the usability of climate services.

In terms of evaluation, there is a huge amount of different approaches, frameworks, and purposes to perform an evaluation in different fields. A good overview of different evaluation concepts delivers Wolf et al. (2013). It makes, for example, a difference, which aims the evaluation is the following: Is a project or product finalized and should be assessed ex-post? Or is the project still ongoing, the development of the product not yet finished and the management and development processes are to be assessed? This "formative evaluation" would often be performed in-house to learn about optimizing processes. For this type of evaluation, no standard framework is yet existing to be applied in climate services. Formative evaluation can be done by the product developers (=evaluands) themselves ("self-evaluation") in order to assure the quality of their development activities (Beywl 2003.). The contract C3S_422_Lot1_SMHI described in the following starts with an ex-post evaluation of data, that delivers the input for a second processing step. Thus the users of this original data want to evaluate ex-post data someone else generated. This has been identified as an important need during the surveys described above. Now, in the second step, Donna Data, Pete Product and—potentially—Nick Non want to further process their input data to provide outputs for their clients themselves. By doing so Donna Data, Pete Product and Nick Non are taking the role of providers and have to self-evaluate their own processing activities and outcome thereof.

As the role of users and providers of data and services change along this production chain, we decided to name them "users/providers", when talking about the two different steps of providing climate information: the generation of merely date (step one) or co-development of output that based on the further processing of the data in line with special client questions (step two).

The Earth observation community are pioneers in developing maturity matrices for their measurement and data records. Here, the focus lies mainly on activities that preserve and improve the information content, accessibility, and usability of data and metadata (Peng 2018). For example, under the 'Gap Analysis for Integrated Atmospheric ECV Climate Monitoring' (GAIA-CLIM) project, a measurement system maturity matrix has been developed to assess the capability maturity of the measurement systems in the following areas: metadata, documentation, uncertainty characterization, public access, etc. (Thorne et al. 2015; Peng 2018). The European FP7 project CORE-CLIMAX suggested and tested extensions of the approach in order to allow the applicability to additional climate datasets, e.g. based on in situ observations as well as model-based reanalysis. Based on the previous approaches, the World Data Centre for Climate developed a generic Quality Assessment System for Earth System data (Höck et al. 2015). This matrix serves as a self- evaluation of the data quality for five maturity levels with respect to the criteria data and metadata consistency, completeness, accessibility, and accuracy.

The existing maturity matrices have some limitations as they focus on measurements and specific raw climate data sets only. They cannot be applied to various kinds of climate data, in particular, climate models data, and tailored datasets as it is needed for climate services. However, quality for climate services relies on a strong scientific basis, serves the purpose of users and addresses the user's needs to cover various data sets.

Recently, the FORCE 11 community has developed FAIR Guiding Principles with an aim that all research objects should be Findable, Accessible, Interoperable and Reusable (FAIR) both for machines and for people. These are now referred to as the FAIR Guiding Principles. These high-level FAIR Guiding Principles precede implementation choices, and do not suggest any specific technology, standard, or implementation-solution; moreover, the Principles are not, themselves, a standard or a specification. They can act as a guide to data publishers and stewards to assist them in evaluating whether their particular implementation choices are rendering their digital research artefacts Findable, Accessible, Interoperable, and Reusable but cannot evaluate the quality of data (Wilkinson et al. 2016).

In short, up to our knowledge, no established tool for evaluation of the quality of climate data existed that could have been applied for the local and regional climate services provided by the Donna data and Pete product users/providers in 12 showcases in the frame of the C3S_422_Lot1_SMHI contract. GERICS as a subcontractor is responsible for the quality assurance activities and co-developed a new tool named as QUACK (Quality Assurance Checklist) together with the Donna data and Pete product users/providers to promote high quality in each showcase.

QUACK—Quality Assurance Checklist Tool

QUACK is an innovative and customised tool for quality assurance. It is based on both scientific rigour and standards, and user needs. It allows Donna data, Pete product, and Nick non to self-evaluate and document their performance regarding applying quality control measures in their showcases. QUACK is an innovative hands-on, scientifically-based tool and provides user-oriented guidelines on how to assure high quality when transforming climate data for climate services.

QUACK consists of two parts: an evaluation framework including checklist questions and guidance material. The second component is a reporting template. This allows to evaluate the quality at each step of the entire processing chain starting with the input data and then covering each processing step towards a climate service product.

The first step for the development of QUACK was to define suitable quality criteria. When defining quality criteria, it is common in the evaluation literature to follow an evaluation hierarchy structure to scale down from very general aspects of quality to such on a smaller and more detailed scale. Schuck-Zöller et al. (2017a) harmonized different elements of evaluation from literature in the evaluation cascade.

This evaluation cascade is the backbone for the newly developed quality assurance tool QUACK. It covers the levels of evaluation from general to detailed: **dimension**, **criterion,** and **indicator**. For each dimension, a number of evaluation criteria and related quality indicators were developed. The QUACK evaluation framework consists of 17 quality indicators grouped into 4 dimensions: *input data*, *processing, output*, and *outcome*. Each dimension includes different criteria and related quality indicators. To be able to specifically assess the level of quality for each indicator ("assessment method"), a checklist with questions was developed including guidance material. Figure 10.3 illustrates the QUACK evaluation cascade.

For determining the dimensions, we used the definition of the 'Organisation for Economic Co-operation and Development' (OECD 2002). We adapted the wording of the OECD dimensions to tailor the definitions to suit the showcase work of the C3S_422_Lot1_SMHI contract. This supports an intuitive application of the dimensions by the users. The dimensions of QUACK start with *input data* and *processing*, continue with *output* and finish with the *outcome* (see Box 1).

For each dimension, a number of evaluation criteria and related quality indicators were developed. We followed the initial work of an interdisciplinary working group, scientists from Helmholtz-Zentrum Geesthacht and Alfred-Wegener-Institute in Germany, who were working on knowledge transfer products, defining quality criteria and related indicators for the dimensions *output* and *outcome* (Schuck-Zöller et al. 2017b). Here, we applied this approach to assess specifically the quality of climate information data and products, and we expanded the list of criteria and related indicators for the first time to the dimensions *input data* and *processing*. We first selected the indicators appropriate for QUACK from the list of indicators (Schuck-Zöller et al. 2017a) and later involved the users and providers with their opinion to finalize the list of quality indicators. To be able to assess specifically the level of quality for each indicator, a checklist[2] with questions was developed at GERICS. Guidance material

[2]The complete evaluation cascade of QUACK including questions and guidance per indicator are available upon request to GERICS or Copernicus Climate Change Service.

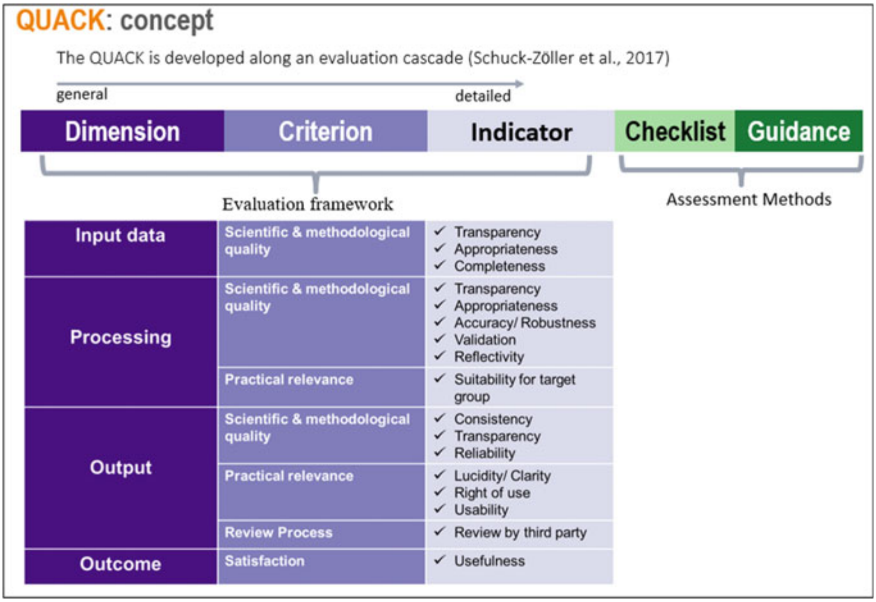

Fig. 10.3 Summary of the evaluation framework used in QUACK for outputs being co-developed between users and providers and thus caring for practical relevance already during the processing activities (C3S_422_Lot1_SMHI contract)

supports the users and providers of climate data in answering these questions with material showing good practices regarding quality and further help.

Box 1 Summary of the four evaluation dimensions of QUACK.

(1) **Input data**
collecting and checking the data that will be used for the showcase

(2) **Processing**
transforming input data into new climate impact indicators and *preparation of the data as input for a regional climate model or an impact model, and all other processing steps of the data, being reflected with users*

(3) **Output**
presentation of results

(4) **Outcome**
short and medium-effects of product (usability)

Besides the QUACK evaluation framework, a QUACK reporting template was also co-developed with users and providers. Figure 10.4 illustrates an example of a showcase that investigated the health impacts of heatwaves in Australia in

Copernicus Climate Change Service - C3S_422_Lot1_SMHI

Dimension: Input data

Criterion: Scientific & methodological quality

Quality indicator	Applied		Short description	Supporting documents	Comments
	Yes	No			
Transparency					
Are all data sources referenced? Please provide which category (observation, simulation, etc)of datayouusedand the source. **Example:** **Forcingdata:Precipitation, Station data, 1 h, 24 stations,national weather service** **Simulation:** **GCMdata,50kmresolution; ensemble of five models; RCP4.5 and8.5,providedby C3S_422_Lot1_SMHI**	X		Observation Data: - JRA55GlobalReanalysisSurface Air Temperature gridded dataset (daily); 1958–2014;resolution is 1.25° x 1.25°. - HadGHCND Global Surface Air Temperature gridded dataset (daily); 1950–2014;resolution is 1° x 1°. - AWAP high-quality Australian daily maximum and minimum temperature gridded dataset; 1910–2015;resolution is0.25° x 0.25°. Simulations: - CMIP5 model data; various resolution(from70kmto250km); ensemble of 18 models; HIST and RCP85 scenarios; data provided by ESGF and Copernicus CDS.	Caesar,J.,L.Alexander,andR. Vose (2006), Large-scale changes in observed daily maximum and minimum temperatures: Creation and analysis of a new gridded data set, J. Geophys. Res., 111, D05101, doi:10.1029/2005JD006280 Kobayashi,S.,Y.Ota,Y.Harada, A. Ebita, M. Moriya, H. Onoda, K. Onogi, H. Kamahori, C. Kobayashi, H. Endo, K. Miyaoka, and K. Takahashi , 2015: The JRA-55 Reanalysis: General Specifications and Basic Characteristics. J. Meteor. Soc. Japan, 93, 5-48, doi:10.2151/jmsj.2015-001 Jones,D.A.,Wang,W.andR. Fawcett, 2009: High-quality spatial climate data-sets for Australia, Australian Meteorological and Oceanographic Journal, 58, 233-248.	

Version: 2.0 1

Fig. 10.4 QUACK reporting template with an example of the Australian showcase reporting for the dimension—input data, criterion—scientific and methodological quality, and indicator—Transparency

C3S_422_Lot1_SMHI contract. The QUACK reporting template takes up the structure of the QUACK evaluation framework. It guides the users and providers through each dimension, criterion and related indicator. The documentation states if an indicator was applied including a short description. Any documents that describe the activities/methods, etc. for an indicator enhance the credibility.

The QUACK reporting template needs to be continuously updated during the progressing of the production of a climate service. Ideally, when the climate service product is ready, it can be delivered with the QUACK report stating the quality assurance for each step of the processing chain. The resulting QUACK reports not only reflect the quality of the showcases but also enhance the credibility of the work along with the satisfaction of potential clients of the showcases.

Benefits of QUACK

QUACK is a self-evaluation tool that supports Donna data and Pete product in judging if the climate data they would like to use are suitable for their purposes. For instance, while reporting on QUACK's first dimension 'input data' users will get an indication about potential insufficiencies or limits of the data in the context of the planned application. QUACK supports users to understand scientific quality standards and to determine subsequently the data's suitability. QUACK is also beneficial for the climate data and climate information providers to improve their provided datasets, and products through feedbacks from users and continuous dialogue. QUACK enhances trust and satisfaction down the line between the applier of QUACK and his/her clients by providing transparency about the procedure of quality assurance. Furthermore, QUACK fulfils the list of requirements that the DECM survey users favoured regarding the format of the guidance material.

Limitations

QUACK is most beneficial for climate model data users who are interested in further analysing and processing the data because it offers guidance at each step of the production chain of tailoring climate data for a specific purpose. Moreover, the tool is a self-evaluation tool meaning that the applier must be as honest and disciplined as possible and utilise it as far as possible to truly assure high-quality work. The reliability of quality based on QUACK also highly depends upon the level of understanding of the individual quality indicators by the tool users.

Since the assessment of quality is very context-dependent, QUACK does not claim to be a one-fits-all solution, nor does it provide a score or a certificate at the end. It is a starting point for self-reflection and triggers critical thinking regarding quality assurance in the field of climate service work. In each case, the evaluation has to be carried out specifically matching the circumstances. This can lead to differing priorities and results in each case.

Transferability

QUACK was successfully tested and applied by users and providers of climate model data for twelve showcases in the framework of the C3S_422_Lot1_SMHI contract. The input data covered climate model, seasonal forecasting data, hydrological data in combination with local data sets for different purposes in the sectors such as health, safety, water-security, transport, biodiversity, tourism, agriculture and food production. It could be demonstrated that QUACK can be applied for various modelling activities and serves sector-specific needs. The definition of quality indicators and assessment questions vary from case to case and may need to be adapted for the application in other fields.

Conclusion and Outlook

Quality assurance is fundamental for successful climate services. The underlying climate information in particular needs to be of high quality to ensure a reliable service (Vaughan and Dessai 2014). "High quality climate model data", however, can be defined in various ways. It depends on the perspective, i.e. on the entities taking up the roles of provider and targeted users.

The survey presented here gives insights into different user groups, their characteristics and their needs regarding quality. The groups are represented by three typical users: (i) Donna Data, representing the climate model data users, (ii) Pete Product, the user who is most interested in climate information products derived from climate model output, and (iii) Nick Non, a user who needs climate information but is not yet capable to use climate model data or derived products. The survey results taught us that three user groups show considerable differences when it comes to their requirements regarding the quality of climate model data, they share the essential need for guidance on how to evaluate the quality of climate model data to determine if the selected data suits their individual purpose.

The scientific community has set certain scientific standards for data that should always be met (e.g. DFG 2013), whether raw climate model data are used or climate information products based on climate model data are used. In the field of climate services, these scientific standards have to be combined with the user requirements regarding quality to ensure excellent services both from a scientific point of view and from the perspective of practical application. In doing so, one crucial aspect to consider is that all climate model data users require support in assessing the quality of climate model data beyond technical and processing issues, e.g. regarding the suitability, validation, reliability, consistency, traceability, etc.

As a first step to address their need and combine it with the demands of the scientific community, GERICS pioneered the development of the Quality Assurance Checklist (QUACK). QUACK was applied successfully in 12 showcases of the C3S_422_Lot1_SMHI contract. The lessons learnt from this experience are that the application of QUACK and the resulting level of quality assurance mainly depends on the experience users have with quality assurance, who is responsible for the QUACK reporting. Therefore, it is very important to foster regular discussions and feedback rounds among the providers of the original climate data and their users, to improve the quality of the QUACK reporting. The QUACK reporting can have varying degrees of detail as the application depends also on the design of the project for which the quality assurance is carried out. Yet, the QUACK tool aims to encourage the appliers to do quality assurance by themselves and thereby improve the quality of their work to establish certain comparability and transparency of quality assessments. As a consequence, the relevance and usability of the result become much higher.

The survey helped to learn more about user groups reading climate modelling data and derived products. But even though this survey reached a reasonable large crowd of diverse individuals, it can only describe these individuals to a certain degree of detail. And while the generalization of a colorful group of people is the main purpose of a survey, there might be issues raised during the analysis about certain answers and reactions that require a more in-depth examination.

QUACK is most beneficial for climate model data users who are interested in further analysing and processing the data. The tool assumes that climate data and climate information providers have a high level of experience and good skill in communicating their reflections regarding the quality of their product. The tool is a self-evaluation tool meaning that the provider must be as honest and disciplined as possible and utilize it as far as possible to truly assure high-quality work. The reliability of quality based on QUACK also highly depends upon the level of understanding of the individual quality indicators by the tool users. In each case, the evaluation has to be carried out specifically matching the circumstances. This can lead to differing priorities and results in each case.

Future prospects could include a continuation of the application of QUACK by different climate data users and providers to generate climate information for various sectors such as health, safety, water-security, transport, biodiversity, tourism, agriculture, and food production. This will not only help to gather additional feedback regarding the essential quality indicators of different sectors but will also improve the tool. Furthermore, it could be an option to operationalise the tool in the future and market the service of assessing the quality of climate data. But note that the QUACK dimensions 'input data', 'processing', 'output' and 'outcome' have been tested in C3S_422_Lot1_SMHI contract for the first time, therefore further research and development is needed for improving the tool before it is operationalized. The detailed monitoring and documentation for the dimension 'input data' as a part of quality assurance is well stated within this exemplary quality assurance tool. However, the choice of criteria and indicators for the dimension 'processing', 'output' and 'outcome' needs more investigation and mainly depends on the purpose of a project it will be used for. Quality assurance will remain a topic of central concern in the field of climate services to which this publication, and specifically QUACK, contribute in a user-centric way.

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References

Beywl W (2003) Selected comments to the standards for evaluation of the German Evaluation Society, English edition. Technical report German Evaluation Society (DeGEval)

DFG—Deutsche Forschungsgemeinschaft (2013) Sicherung guter wissenschaftlicher Praxis/Safeguarding Good Scientific Practice: Recommendations of the Commission on Professional Self Regulation in Science. Wiley-VCH Verlag GmbH & Co. KGaA. https://doi.org/10.1002/9783527679188.oth1

EC—European Commission (2015) A European research and innovation roadmap for climate services. European Union, pp 49. https://doi.org/10.2777/702151

EPA—Environment Protection Agency (2002) Guidance for quality assurance project plans, EPA QA/G-5, EPA/240/R-02/009, Washington DC, United States. https://www.epa.gov/sites/production/files/2015-06/documents/g5-final.pdf

Hunziker S, Brönnimann S, Calle JM, Moreno I, Andrade M, Ticona L, Huerta A, Lavado-Casimiro W (2018) Effects of undetected data quality issues on climatological analyses. Clim Past 14:1–20. https://doi.org/10.5194/cp-14-1-2018

Höck H, John V, Kaiser-Weiss A, Kaspar F, Schulz J, Stockhause M, Toussaint F, Lautenschlager M (2015) Maturity matrices for quality of model- and observation-based data records in climate science (EGU Poster 10158). http://meetingorganizer.copernicus.org/EGU2015/EGU2015-10158-1.pdf

Kirchhoff CJ, Lemos MC, Dessai S (2013) Actionable knowledge for environmental decision making: broadening the usability of climate science. Annu Rev Environ Resour 38:393–414

Lemos MC, Kirchhoff CJ, Ramprasad V (2012) Narrowing the climate information usability gap. Nat Clim Change 2(11):789–794. https://doi.org/10.1038/nclimate1614

OECD—Organization for Economic Co-operation and Development (2002) Glossary of key terms in evaluation and results based management. http://www.oecd.org/development/peer-reviews/2754804.pdf

Peng G (2018) The state of assessing data stewardship maturity—an overview. Data Sci J 17:1–12. https://doi.org/10.5334/dsj-2018-007

Schuck-Zöller S, Cortekar J, Jacob D (2017a) Evaluating co-creation of knowledge: from quality criteria and indicators to methods. Adv Sci Res 14:305–312. https://doi.org/10.5194/asr-14-305-2017

Schuck-Zöller S., Keup-Thiel E, Brix H, Buschbaum Ch, Cortekar J, Eschenbach Ch, Fischer-Bruns I, Frickenhaus S, Grosfeld K, Gutow L, Hiller W, Jacob D, Krause G, Meyer E, Meinke I, Nerger L, Rechid D, Schrum C, Schulz-Stellenfleth J, Stanev E, Treffeisen R (2017b) Towards a framework for the evaluation of climate service and knowledge transfer products within climate and coastal research—(poster). http://www.gerics.de/science/transdiscipline/index.php.en

SDTS—Spatial Data Transfer Standard. Guide for technical managers, p 14. http://mapi.gov.il/gisforum/tzevet_technology/stds-guide%20for%20technical%20managers.pdf

Štepánek P, Zahradnícek P, Farda A (2013) Experiences with data quality control and homogenization of daily records of various meteorological elements in the Czech Republic in the period 1961–2010. Q J Hung Meteorol Serv 117:123–141

Thorne P, Schulz J, Tan D, Ingleby B, Madaoona F, Pappalardo G, Oakley T (2015) GAIA-CLIM Measurement Maturity Matrix Guidance: Gap analysis for integrated atmospheric ECV climate monitoring: report on system of systems approach adopted and rationale. http://www.gaia-clim.eu/system/files/workpkg_files/640276_Report%20on%20system%20of%20systems%20approach%20adopted%20and%20rationale.pdf

Vaughan C, Dessai S (2014) Climate services for society: origins, institutional arrangements, and design elements for an evaluation framework. Wiley Interdisc Rev Clim Change 5(5):587–603. https://doi.org/10.1002/wcc.290

Wilkinson MD, Dumontier M, Mons B (2016) The FAIR Guiding Principles for scientific data management and stewardship. Sci Data 3. https://doi.org/10.1038/sdata.2016.18

Wolf B, Lindenthal T, Szerencsits M, Holbrook JB, Heß J (2013) Evaluating research beyond scientific impact: how to include criteria for productive interactions and impact on practice and society. GAIA Ecol Perspect Sci Soc 22(2):104–114. https://doi.org/10.14512/gaia.22.2.9

Chapter 11
The Need for Science-Based Information. A Requirement for Top-Down and Bottom-up Decision-Making Processes

Sebastian Müller and Marcela Scarpellini

Abstract For the first time, a global pact has been reached to set a common global limit on emissions which is quantifiable and therefore provides thresholds upon which to establish nation's emission reductions pathways. This pact is the Paris Agreement (2015), by which its signatories agreed according to Art. 2.1 lit. a to make efforts to halt the increase in the global average temperature to well below 2 °C above pre-industrial levels (in the following "**well below 2 °C limit**" or "**<2 °C limit**") and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels. This decision came from the recognition that these actions would significantly reduce the risks and impacts of climate change. The well below 2 °C limit is based on the recommendations of the Intergovernmental Panel on Climate Change ("**IPCC**")'s Fifth Assessment Report. Regional and national policies have been enacted as a response to this limit, but evidence between these national targets' actual contribution to keeping global temperatures below 2 °C is weak. This weakness is presumably associated with the fact that climate targets are often decided without properly taking climate science into consideration. If scientific information by which the alignment of policy strategies and plans with the <2 °C limit is missing, how can we claim that regions, countries and states' targets are in line with the Paris Agreement? Another weakness in established targets has to do with how economic players such as sectors and companies are incorporated into the equation. It seems to be a reasonable approach to set climate targets at different levels, from a top-down and a bottom-up approach in order to increase the likelihood of maintaining temperatures well below the 2 °C limit. The targets established at a top-down level need to bear relation to the targets established at lower levels. The manner in which they correlate can be provided by the well below 2 °C limit defined by the Paris Agreement. By targets at higher levels and at lower levels been set with one same reference point, the 2 °C limit, the likelihood of an appropriate correspondence between targets is highly incremented. The research question that will be explored in this article is if

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Climate Change Management, https://doi.org/10.1007/978-3-030-36875-3_11

using science-based information can assist in making the meeting point represented by the 2 °C limit, workable from two directions: top-down and bottom-up.

Introduction

> Thus, considering the alleged emergent and accelerating need for a science-based response to climate change. […] It is time for these youth to have the opportunity to address their concerns in a court of law, concerns raised under statute and under state and federal constitutions. They have argued their petition for a rule limiting Greenhouse Gas ("**GHG**") emissions based on best available science.[1] Judge Hollis R. Hill.

The petition in this case was rejected not due to the explicit request that rules and targets be based on scientific information—reasoning the Judge clearly agreed with—but because in the United States (**US**) a court cannot decide for a governmental department, how to technically regulate an issue.[2] It should be noted that the need for climate targets to be established on best-available scientific information was not contested by the Judge.

Similarly, in the Urgenda Case, the plaintiff: the Dutch based Urgenda Foundation, argued that the climate targets established by the Dutch State were unlawful and threatened Dutch citizens' rights since they contribute to world temperatures increasing to more than 2 °C. According to the Foundation this would go against what has been agreed upon in the Paris Agreement.[3] This lawsuit was based on scientific findings of future climate impacts, as was the court's decision.

These are only two examples that evidence the increasing demand for scientific information to be embedded within policy and laws defining climate targets. There is increasing precedent and pressure for scientific information to be involved in economic decision-making processes, especially in decisions pertaining to target setting and more specifically when it comes to climate targets.

The IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways gives context to strengthening the global response to the threat of climate change. Sustainable development and efforts to eradicate poverty ("**Special Report 1.5 °C**")'s Summary for Policy Makers, human activities are estimated to have caused approximately 1 °C of global warming above pre-industrial levels with a likely range of 0.8–1.2 °C. The

[1] Zoe and Stella Foster et al. v. Washington Department of Ecology, 75374-6-1, Wash. Ct. App.

[2] Court reasoning: The main question for the Court was to review the legality of the Department's rejection of the children's petition for rulemaking. The Court noted that the Department has the authority given by law to establish greenhouse gas emission standards, but it did not act in that regard until after the suit was brought when directed by the state Governor. Nonetheless, the Court because the Department is currently considering a cap on emissions, the Court cannot rule that they are failing to fulfil their duty to exercise that authority. The Court also cannot tell the Government how to decide on an emissions cap, therefore, the children's request to order the Department to use the best science available in the decision-making process was rejected.

[3] Urgenda Foundation v. Kingdom of the Netherlands, C/09/456689/HA ZA 13-1396.

Special Report 1.5 °C further indicates that global warming is likely to reach 1.5 °C between 2030 and 2052 if it continues to increase at the current rate.

With this clear statement on the link between human activity and its repercussions on climate dynamics, the manner and magnitude human activity will have on climate change should be reconsidered. From a methodological and mathematical perspective, actors at all levels should consider setting targets based on best available scientific findings if keeping temperatures well below 2 °C is to be more than a declaration of good intention. The scientific findings upon which targets should be set have been agreed upon by 90–100% of the scientific community (Cook et al. 2016). These scientific findings consist of forward-looking information, information which is not 100% certain due to the complexity of climate and weather predictions and interactions, but certain enough to signal that ambitious actions backed up by scientific information are necessary.

The process for target setting at a global, regional and national scale is taking quite a long time to deliver expected results. During this time, climate change and its impacts continue to exert its effects incrementally through increasing weather-related events, litigation for a companies' contribution to global warming, or the devaluation of company value. As such, climate change has proofed its potential for disrupting businesses at divergent scales.

The way the lack of ambitious targets will be resolved is still uncertain. As targets and regulation become obsolete in the face of the climate crisis, it seems that acting on best available and forward-looking scientific information might be, even amid excruciating uncertainty, the only certain step that will enable the best responses to be provided. At a corporate and financial level, the incorporation of scientific information consists of companies adjusting key corporate and financial decision metrics to incorporate climate-related information through climate impact scenarios by which they create effective transition indicators for corresponding institutions. In this endeavor, the first step is to generate a better data basis. This will consequently allow for the data generated to be converted into transition indicators. These indicators would help avoid companies being statically stuck with "green" or "brown" classifications, but rather serve for capturing the companies' competence for mastering the challenges arising from a world shaped by climate change.

These transition indicators are established at two levels: simultaneously from a top-down and a bottom-up approach, enabling the approaches to meet. This meeting point is already established and can be found in form of the number given by climate science. A very precise number. It is the <2 °C limit agreed upon in the Paris Agreement. Now, countries and companies just need to find a way to measure themselves against this limit.

Top-Down: Global, Regional, National and Sub-national Targets. Information Required Before Setting Targets

Having understood the urgency of the challenges brought by global warming, governments around the world are determined to change course by identifying and applying methodologies to shift capital towards less carbon dependant economies. The way they attempt to do so is by enacting policies, laws and regulations with three main and parallel intentions: (1) driving action; (2) tracking progress; and (3) raising ambition (Whitley et al. 2018). All of these efforts are intended to support Article 2.1 lit. c Paris Agreement, which clearly establishes the aim of the "global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by […] making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development."

Legislation

The well below 2 °C limit agreed upon at a global level acts as a top-down directive towards nations, to which they respond by setting themselves Nationally Determined Contributions ("**NDCs**"). The NDCs in turn serve as a bottom-up response to that global top-town policy (see also Elzen et al. 2016). Ideally, once countries NDCs' are reassessed, via the stock take mechanism established in Article 14 Paris Agreement they shall be aligned in a harmonic way as to ensure that nation's emission reduction pathways are conducive to keeping temperatures under 2 °C. Currently this is only theory as NDCs updated in December 2018, seem to be insufficient for keeping global temperatures below the 2 °C limit. The level of ambitiousness of current NDCs leads to the world warming up to approximately 3 °C above pre-industrial levels (The Emissions Gap Report 2016).

These same NDCs can serve as a top-down indicator for (federal) states and at an economic level for sectors and companies within specific countries, which might respond by setting themselves targets in line with the NDCs' emission reduction pathways. These targets in turn serve as a bottom-up response to the NDCs. The mechanisms by which NDCs are trickled down to lower levels such as states and are translated into economic guidance for sectors and companies, are usually implemented by countries' individual action plans, such as ex. Germany's Climate Action Plan 2050.[4] No specific reference has been established as how companies are expected to demonstrate alignment with the NDCs of the countries in which they operate. As the corresponding targets initially stem from sectoral targets, companies may try to establish their reductions in line with sectoral targets.

The problem is that current methodologies at all levels are lacking for measuring and tracking progress towards keeping global temperatures well below the <2 °C

[4]Climate Action Plan 2050. Principles and goals of the German government's climate policy. Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB).

limit (Peters et al. 2017). If the manners of tracking progress are lacking or weak, there is no way of guaranteeing that further and more ambitious reductions will bear a correlation with the measurable and quantifiable well below 2 °C limit.

We are currently at the stage in which governments are getting a comprehensive understanding of the climate situation in order to manage it as effectively as possible. According to the EU today, transparency is key, for which disclosures on the manners in which companies impact the environment is a focal point (see e.g. Directive 2014/95/EU, Directive on non-Financial Disclosures, "**NFRD**"). Therefore, in order to put these findings and initial efforts into action, the evaluation of current disclosure requirements is a first step. Requiring issuers to make sure they provide the right information to investors, the European Commission ("**Commission**") adopted a package of measures implementing several key actions announced in its EU Action Plan: Financing Sustainable Growth (COM(2018) 97 final, "**EU Action Plan**") in May 2018.

In late 2016, an amendment to the NFRD was enacted by the EU Parliament, requiring large undertakings to disclose material non-financial information, including considerations of environmental, social and governance factors that might help provide a better understanding of companies' development, performance, position and impact of their activity. Namely, the NFRD requires large public interest entities with over 500 employees (listed companies, banks, and insurance companies) to disclose certain non-financial information such as: (I) sustainability strategy, (II) material risks linked to the entity's operations, especially those which are very likely to have a material adverse effect on the matters on which disclosure is required, (III) management of such risks by the corporations and (IV) non-financial key performance indicators relevant to the particular business. Thus, the NFRD has introduced a new element to be considered when assessing the relevance of non-financial information by referring to information 'to the extent necessary for an understanding of the impact of (the company's) activity.' As part of the EU Action Plan the Commission committed to updating the Non-Binding Guidelines on Non-Financial Reporting, specifically with regards to the reporting of climate-related information.

Based on this background and recognising the need for increased transparency in the market around climate-related issues, the G20's Financial Stability Board ("**FSB**") established the Task Force on Climate-related Financial Disclosures ("**TCFD**") in December 2015 to develop recommendations for more efficient and effective climate-related disclosures. In June 2017, the TCFD issued its recommendations to encourage both financial institutions and non-financial companies to disclose information on climate-related risks and opportunities. The Technical Expert Group ("**TEG**"), which has been implemented by the EU Commission in 2018, is mandated to assist on adjusting the Non-Binding Guidelines on Non-Financial Reporting. The TEG brought the two strands together and aligned the TCFD recommendations with the requirements of the NRFD. According to the final report of the TEG "Report on Climate-related Disclosures" ("**TEG Report**") companies should—inter alia—disclose relevant information on the consequences of climate change for a company's business as well as information on the impact that the company's operations might have on climate change. Hence, the TEG Report keeps the dual focus on both the outside-in (how do climate risks and opportunities impact a company) and inside-out (how does a company impact on climate) perspective, in line with the approach of the NFRD.

When taking into account regulatory developments, mainly the NFRD recommendations of the TCFD, the work of the TEG and the Non-Binding Guidelines on Non-Financial Reporting—even if not binding in a legal sense—an implicit encouragement is made to companies to disclose relevant information on the consequences of climate change for a company's business with a strong suggestion of thorough consideration and disclosure on: the manner in which companies business operations are likely to have an impact on climate systems and how the changes brought by climate change from a physical, economic and political perspective might affect the company. The extent in which this specific requirement is disclosed will be subject to companies' assessment of climate change constituting a material risk. For which, an explanation of how a company reaches the conclusion of how they reach such determination, should be incorporated in the respective disclosures and duly substantiated. Specific guidance of aspects to be disclosed can be found in Article 19 lit. A NFRD bearing in mind that disclosures need to enable recipients to fully understand the context in which the company is operating and the manner by which it has carried out its analysis and conclusions on the risks and opportunities associated with climate change.

Even though neither the TCFD recommendations nor the Guidelines on Non-Financial Reporting are binding, they have the potential to steer current practice of disclosure towards demand for precise and relevant information. A key challenge when it comes to disclosure is the examination of the range of possible future pathways resulting from combining social and environmental systems (Rogelj et al. 2018). In order to aid this challenge, forward-looking methodologies, such as scenario analysis are being called upon by e.g. the Non-Binding Guidelines on Non-Financial Reporting. Scenario analysis provides a powerful tool for integrating what the future might look like into today's reality. Given the importance of forward-looking assessments of climate-related risk, scenario analysis is an important and useful methodology for a company to use, both for understanding strategic implications of climate-related risks and opportunities and for informing stakeholders about how the company is positioning itself considering these risks and opportunities (see also TEG Report, page 11).

A relatively new scenario framework facilitates the coupling of multiple socioeconomic reference pathways with climate model products using the representative concentration pathways. The scientific community has agreed on five pathways: the so-called "Shared Socioeconomic Pathways ("**SSPs**"). In short: this will allow for improved assessment of climate impacts, adaptation and mitigation (Kriegler et al. 2014). To better anticipate potential impacts of climate change, diverse information about the future is required, including future information on climate, society and economic developments as well as their influence on adaptation and mitigation measures. To address this need, a global Representative Concentration Pathways ("**RCP**"), SSP and Shared climate Policy Assumptions ("**SPA**") (RCP–SSP–SPA) scenario framework has been developed by the IPCC Sixth Assessment Report ("**IPCC-AR6**").

In addition to these developments regarding disclosure, the EU Action Plan has already delivered additional concrete and tangible steps that aim to understand the way environmental, social and governance ("**ESG**") factors are being integrated into investment decisions. For which the Directive on the activities and supervision of institutions for occupational retirement provision ("**IORP II**") e.g. introduces disclosure obligations on how institutional investors and asset managers integrate ESG factors in their risk processes. In addition, the Markets in Financial Instruments Directive ("**MiFID II**") and the Insurance Distribution Directive ("**IDD**") will include ESG considerations into the advice that investment firms and insurance distributors offer to individual clients.[5] What they intend to do is to gather results and make a value judgment of how useful the current level of detail and disclosure is, before suggesting amendments to similar laws such as the UCITS Directive 2009/65/EC, the AIFM Directive 2011/61/EU, the MiFID II Directive 2014/65/EU, the Solvency II Directive 2009/138/EC and the IDD Directive 2016/97.

Once a thorough assessment regarding the level of investment supporting the transition to a low carbon economy is completed, the need for establishing stricter climate targets will be evidenced and it is highly probable that regulatory change will be enacted quickly. Expected regulation will mainly consist of establishing stricter climate targets.

As climate change damages increase (Bouwer 2011), the search for culprits will follow. This is likely to trigger increased pressure on legislators and regulators to figure out a way of measuring alignment with the <2 °C limit or at least requiring environmental impacts and disclosures to be provided considering the broader context in which effects take place. This was e.g. the case of the EU Common Fisheries Policy ("**CFP**"), based on the principle of best-available scientific information. To this day, the impact of fishing on the fragile marine environment is not fully understood. For this reason, the CFP adopts a cautious approach which recognizes the impact of human activity on all components of the ecosystem (Borges and Lado 2019). Hence, the CFP is a set of rules for managing European fishing fleets and for conserving fish stocks. Designed to manage a common resource, it gives all European fishing fleets equal access to EU waters and fishing grounds. With mounting availability on climate science information and the added pressure of the climate crisis, it might very well be one of the ways in which the legislative approach manages to issue sensible and relatable direction from a bottom-up perspective.

[5] https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance_en.

Regulation

Besides international and national legislation, several Financial Supervisory Authorities are increasingly asking for regulation and specifically, transparency on climate-related issues in the financial world as a prerequisite for a stable financial system.

On October 11, 2018, the newly founded international network of central banks, supervisory authorities and international organizations "Network for Greening the Financial System" ("**NGFS**"), which includes e.g. the Bank of England and the German Federal Financial Supervisory (*Bundesanstalt für Finanzdienstleistungsaufsicht*, "**BaFin**") and the Deutsche Bundesbank, published a first report stating the need for short-term measures to reduce climate risks in the long term. It warns that the financial risks of climate change are system-wide and irreversible if left unchecked.

The UK's Financial Supervisory Authority (Prudential Regulation Authority, "**PRA**") goes even further and issued a draft on how banks should deal with the effects of climate change (PRA, Transition in thinking). This stipulates that board members of banks, insurance companies and investment companies must appoint a high-ranking person who is responsible for the identification and control of climate risks and who must report this to the Executive Board. Although the draft is relevant only to British actors, it could serve as a model for subsequent advances by other supervisory authorities.

The above identified existing and upcoming legislation and regulation will not only define the current top-down framework but will also be cornerstone of forward-looking scenario analysis in the RCP–SSP–SPA scenario framework for other forward-looking metrics.

Litigation

As described above, nations, regions and institutions enact their plans and targets via legislation and regulation at their respective levels. In cases which these instruments prove insufficient, slow, are deemed vague or lack enforcement, litigation might provide aid. A certain gap between legislative and regulatory enforcement might be filled by climate litigation. Climate litigation is a new field of law that deals with the legal application of existing laws and the incorporated legal principles to climate change and its consequences.

Litigation is also expected to aid laws and the re-interpretation of laws regarding mitigation and adaptation measures, which might intend to oblige governments to regulate (Zoe and Stella Foster et al. v. Washington Department of Ecology), increase the level of ambitious of current targets (Urgenda Foundation v. Kingdom of the Netherlands) and also seek culprits for past and future damages (Lliuya v. RWE AG).

Litigation as a means of pressuring governments and companies to increase the level of ambition for targets or for claims searching for compensation for damages related to climate change, is also increasing: 250 climate-related cases have being enacted in over 25 jurisdictions, a 20-fold increase from 1954–2017 (Nachmany et al. 2017). A general categorization, following the so-called Carbon Boomerang Report (Barker et al. 2017) for possible litigations suggests that litigation types fall into the following two categories:

- *Failure to mitigate*: which will encompass claims seeking to establish liability for emissions and/or associated climate change impacts. These claims will likely be either against large emitters (ex. Lliuya v. RWE AG) or against states failing to establish ambitious enough climate targets (ex. Urgenda Foundation v. Kingdom of the Netherlands).
- *Failure to adapt (including failure to disclose)*: which will consist of claims from commercial omissions or misrepresentation of risks derived from not taking climate change and/or exposure to climate change, thoroughly into account (ex. Abrahams vs. Commonwealth Bank of Australia). This category will also encompass claims for failing to take appropriate action to adapt to physical and transition risks within strategic business planning.

As regulation on disclosure around climate related affectations and climate risk is still incipient, we might see cases as the Abrahams v. Commonwealth Bank of Australia, increase in frequency. In this specific case, shareholders of the Commonwealth Bank of Australia sued the bank, alleging that it violated the Australian Corporations Act of 2001 with the issuance of its 2016 annual report, which failed to disclose climate change-related business risks—specifically including possible investment in the controversial Adani Carmichael coal mine.

Such types of climate litigation are expected to increase and would put pressure on governments and companies to raise the level of ambitious of their climate targets. The avenues and claims supporting climate litigation cases are expected to be diverse, referring to existing constitutional, human rights, corporate responsibility, environmental, civil and securities legislation. In parallel, legislation is expected to push the balance towards more ambitious targets. These two broad categories, legislation (including regulation) and litigation, serve to describe the current state of affairs regarding the treatment of climate change. At the same time, legislation (including regulation) and litigation serve to describe the incentives and sources of pressure that governments have for establishing a more ambitious response to climate change.

This section attempts to make the reader aware of the different levels and types of activities taking place at national levels regarding climate targets and action. It does not intend to be a comprehensive study of the entire current political and legislative developments, as that is not the focus of this paper (see e.g. Simlinger and Mayer 2019). The intention is to draw the reader's attention to the pressing need for measuring climate target's alignment with the well below 2 °C limit from a top-down approach.

Bottom-Up: Financial and Corporate Actors Going the Extra-Mile by Recurring to Science-Based Information

The fact that the previously described political and legal processes are expected to require rather long-time spans must not be understood and assimilated by financial nor corporate actors as a motive to slow down. In fact, the contrary, as the advantages of being ahead of the ball are significant (Wittneben and Kiyar 2009). As front runner companies' awareness on the opportunity to capitalize from climate change increases, the search for tools that allow them to communicate this clearly and directly is increasing.[6]

Besides market advantages and regulatory compliance, corporate and financial actors seem to be motivated to increase their understanding on climate risks and develop resilient responses to these risks. Many do so motivated by a thorough understanding of their corporate duties (Hutley and Harford Davies 2016) materialized by means of corporate principles, such as the prudent man principle and the principle of due diligence. These principles require companies' managers understand their own business and carry with it an obligation to thoroughly assess and understand the business environment surrounding of their undertaking in order to ensure resilient measures are in place to enable their business to thrive. Liability risks arise particularly from the obligation to disclose the findings of due diligences.

Such principles must be contextualized with the concept of materiality, which asks for the disclosure of risks that might affect a companies' capacity to generate value. In the context of climate change, this determination consists of understanding if the risks associated with climate-related happenings (e.g. in the form of transition as well as physical risks) might infringe on companies' business.

However, law does not define what is to be understood as a material risk, leaving the determination of what is to be deemed a material risk up to individual actors. Within e.g. the German system, referring to the German Accounting Standard, the term "risk" describes possible future developments or events that could lead to a negative deviation from predictions or targets. "Predictions", in turn, are statements about expected developments and events by the companies invested in. When predictions on which the company has based decisions on fail to materialize or materialize in a different manner to how they were expected to, risks are likely to represent concrete threats to a company. For which understanding the potential risks climate change could pose on a business requires a broad set of different predictions to be contemplated as a demonstration of due diligence. Secondly, it is a means of ensuring resilient responses are prepared if expected predictions fail to come through.

Considering that concepts must be understood in the light of new circumstances (Busse 2006), being this one of the main functions of legal methodology, leads us to understand how issues which might not have been regarded as material at a certain point in the past, might be regarded as material now. Likewise, issues that were

[6]This increase can be evidenced by climate tools providers and institutions such as: the 2dii, Carbon Delta, UNEP FI and right. based on science developing tools and methodologies for demonstrations corporate and financial endeavor's alignment with the Paris Agreement.

relevant in a specific economic and historic context might no longer be material. As a practical example of an issue that might currently be deemed material and which was not material until recently, we will refer to climate change. Considering it as a factor which is likely to have an impact on a company's capacity to create value, the relevance of this issue is increasingly affecting decision-making processes.

As a support to this statement and according to the NRFD, companies are required to disclose information on ESG matters in a sufficient manner as long as this information is deemed essential for providing an understanding of the company's development, performance, standing and the impact that its activities have or might have in the aspects that constitute ESG disclosures. According to which climate-related information can be interpreted as falling into the category of environmental matters considering that modifications in the climate system evidently impact the environment (Consultation Paper of the Non-Binding Guidelines on Non-Financial Reporting, p. 7).

According to the Consultation Paper to the Non-Binding Guidelines on Non-Financial Reporting, the NFRD has a double materiality perspective:

- The reference to the company's "development, performance [and] position" indicates financial materiality. Climate-related information should be reported if it is necessary for an understanding of the development, performance and position of the company.
- The reference to "impact of [the company's] activities" indicates environmental and social materiality. Climate-related information should be reported if it is necessary for an understanding of the external impacts of the company.

Disclosure following this dual perspective should be considered by companies if they determine that climate constitutes a material issue from either of these two perspectives. Referred to in literature generally as an outside-in and inside-out perspective (Porter 2006). An inside-out perspective asks for corporate managers to comprehend their business activities' impact on the environment, in this context the climate. An outside-in perspective asks corporate managers to understand how climate change (by means of its legal, social, economic and physical manifestations) might have an impact on the company's business environment. This information is usually more relevant for citizens, consumers and civil society organizations. However, it is nonetheless increasingly attracting investor's attention, since they need to better understand the impact of investee companies in order to measure and asses the climate impacts of their own investment portfolios (Consultation Paper of the Non-Binding Guidelines on Non-Financial Reporting, p. 7).

To better grasp the inside-out impact, managers must necessarily look deeply into their value-chains and understand the emissions associated with it (Porter and Reinhardt 2007). Understanding the risks that their value chain could be subject to under different global warming temperatures could offer preliminary guidance and at this point, constitute a thorough level of disclosure.

Considering climate change is likely to affect businesses from an inside-out as well as an outside-in perspective, understanding that these impacts will come from both changes in weather patterns and in regulation attempting to control the manner in which enterprises influence such weather patterns through their outputs (emissions), is thus advisable for management to understand what sections within their business will be affected.

Considering the current state of legislation and regulation and the vague compulsory climate targets established for sectors and individual companies, companies are left with imprecise guidance for determining what is a sufficient level of ambition when setting their climate targets. For which the 2 °C limit can serve as a meeting point, allowing companies—from a bottom-up perspective to contribute their fair share towards keeping temperatures under the 2 °C limit. This limit offers companies a threshold against which to set their targets and does not require national plans and legislation to be fully implemented before doing so.

The 2 °C limit represents the global top-down commitment which is to be attained by nations coordinating their emission reduction pathways, which with different levels of progress are trickled down to states, sectors and companies via national climate plans. This paper suggests that the 2 °C limit can be used by companies for guidance.

In setting themselves targets which are based on scientific information, which might be able to demonstrate the alignment to a 1.5 °C or 2 °C limit by means of using science-based models, companies might have a good means to demonstrate that they are limiting their emissions in line with climate science. Balancing their commercial purpose and obligations and simultaneously ensuring their operations contribute to keeping global temperatures under a certain degree. The reasons for financial and corporate actions to increase the level of ambition of their targets are not just altruistically motivated. There reasons motivating these decisions can be divided as follows:

1. **Reduction or avoidance of liability**: Companies and financial institutions are increasingly becoming aware of the requirement to disclose environmental aspects. Culprits are to be found by means which might follow the direction of attribution science. As a means of enabling a scientific association between anthropogenic climate change and loss and damage.[7] With studies such as the Heede study, which managed to trace emissions released historically by specific entities from the period comprehended between 1854 and 2010, helping shed some light (Heede 2014). As an example, Chevron is heading the list, being responsible for 4.54% of global emissions. This type of information might provide plaintiffs with good enough evidence to take major emitters to court under allegations of responsibility for contributions.
2. **Fair share of responsibility**: Corporate Social Responsibility ("**CSR**") is a well-known and widely used term in business. Even if there is little agreement about what it means and what it entails (Brei and Böhm 2013), companies are becoming more aware about the impacts that climate change will bring to their operations and vice versa, for which they are keen to prevent and reduce climate related risk as much as possible. The understanding about the correlation between emissions and global warming is finally entering corporate board rooms.

[7] Otto et al. 2014.

3. **First movers' advantage**: According to the Consultation Paper of the Non-Binding Guidelines on Non-Financial Reporting, climate-related information can be considered to fall into the category of environmental matters. Under the NFRD, climate-related information should, to the extent necessary, include both the risks to the financial performance of the company resulting from climate change and the risks of a negative impact on the climate resulting from the company's activities. This regulation and its accompanying non-binding guidelines ask companies to disclose their affectation to and from climate change, but still not requiring companies set themselves specific emission reduction targets. Companies setting themselves ambitious targets are trying to ensure that they are not exposed to regulatory pressures of e.g. carbon prices which are expected to rise over time or having to reach specific reductions in order to be in line with the Paris Agreement. As an example, Shell is being sued for its business model being misaligned with climate change and the plaintiffs are asking the court demands that they reduce their emissions sufficiently to be guarantee alignment with the Paris Agreement [Milieudefensie et al. v. Royal Dutch Shell plc. (2019)].
4. **Reputation**: Additionally, using science-based information as a way of determining appropriate targets is a powerful way to boost competitive advantage in the transition to a low-carbon economy. This allows companies to demonstrate transparency and external credibility to internal sustainability goals, seeing that these goals are built upon forward-looking scientific information, which due to the nature of climate, is bound to deliver strategies which are resilient and adaptive, thus providing real opportunity for the attainment of goals. In this point, it must be stressed that reputation is not only connected to immediate economic advantage. In the case of forward-looking risks, such as those brought upon climate change, commitments towards taking ambitious action, action which of course requires substation by implementing appropriate measures, take prominence. Later payoffs of current investments in measures destined to reduce emissions are uncertain but paired with the certainty that climate damages are to have, it seems advisable to start setting ambitious emission targets and putting in effort on determining the best ways to start achieving those targets. This assessment is based on the need to shift corporate mentality from short term and immediate returns towards expanding corporate responsibility to events that will take place in longer time spans. It requires corporate actors to bet and invest in a future in which next generations have a chance of existing on a liveable planet and understands corporations as integral to societal functioning but does not limit their existence to their capacity of generating value in the short term.

As a response to this understanding, concrete proposals are currently gaining acceptance. Proposals consist of the introduction of science-based information into decision making processes and target setting.

As an example of industries going the extra mile, the Principles for Responsible Banking, developed by 28 UNEP FI member banks from five continents intending to set the global benchmark for what it means to be a responsible bank, and provide actionable guidance for how to achieve this. Similar to the role that the Principles for Responsible Investment ("**PRI**") play for asset managers and the Principles for Sustainable Insurance ("**PSI**") for insurance underwriters, these principles aim to address the longstanding need for an umbrella framework to cover all aspects of sustainable banking.

One of the best-known indicators in this area is the so-called Science Based Target ("**SBT**") of a company developed by the Science Based Targets Initiative. It tells a company exactly when and how much it should reduce its emissions in order to be in line with the Paris Agreement. Identifying the target indicating the challenges of transitioning to 2 °C is the first step towards building trust with stakeholders to deal wisely with the challenges of operating in a world shaped by climate change. The approach is considered to be "an interesting research opportunity to follow organizations on their journey toward setting substantive climate change targets" (Dahlmann et al. 2017).

The proposal of PRI to use science-based information for target setting is clearly endorsed, thus demonstrating the financial industry's currency and awareness on the matter. PRI proposes that banks set themselves climate targets in line with a science-based target in conjunction with the Paris Climate Agreement Capital Transition Assessment ("**PACTA**") tool. There are several other methods and tools out there as e.g. Carbon Delta's Value at risk, being used by a working group with 13 investors, commissioned by UNEP FI or right. based on science's X-Degree Compatibility ("**XDC**") Model.

Science-Based Climate Information as the Key to Align a Company's Business with the <2 °C Target

Climate change and socioeconomic conditions are strongly intertwined through the wider socioeconomic impacts of the response to climate change (Knight and Ganguly 2018). The relationship between economic activities and their impact on climate change is evidenced by the fact that economic growth continues to be relatively coupled with increasing emissions (Hickel and Kallis 2019). Emissions which are unquestionably linked to increased levels of global warming. For which it is thus advisable to frame corporate activities through this lens, when requirements for specific levels and time spans regarding emission reductions are to be made.

In order to align corporate targets with global climate targets, understanding the relationship between emissions and the associated levels of global warming these emissions lead to by having a basic understanding of the science behind it is pivotal. This understanding serves for determining the appropriate level of ambitiousness of targets to be established. In order to make this understanding operational into concrete guidance, science must be integrated (Choi 2005) and connected with corporate language and figures in order to increase the likelihood of appropriate corporate strategies being taken up.

Having agreed on a global goal which is based on scientific information requires that targets set at lower levels also take that scientific information into account. At a global scale, if we for example assumed that global gross domestic product ("**GDP**") continues to grow 3% per year, decoupling must occur at a rate of 7.3% per year for keeping global temperatures under the <2 °C limit (Hickel and Kallis 2019). In order to translate global findings into directions for corporate action, science-based models which combine company data as well as climate data might proof a good first step towards providing an answer.

The hypothesis presented in this article, is thus the question of usability of the XDC Model as a methodology that can provide an insight for companies to understand if their climate targets are in line with the 2 °C limit. The XDC Model attempts to provide an answer by combining company data considering a range of socio-economic scenarios and corresponding climate projections. Climate impact scenarios take into account various affected sectors, climate change projections and future socio-economic developments and thereby provide data on how the world could look like if specific warming scenarios materialize. Since it is connected to a climate model and can be connected to further earth system models or socioeconomic models, it provides sophisticated options to understand how an economic activity exacerbates or relieves climate change (Helmke et al. 2019).

As an example of a science-based model which is able to respond to the requirement of combining the impact of business growth and performance on climate change the XDC Model incorporates: (i) climate scientific insights of e.g. the IPCC, (ii) company data on sales, growth, emissions or machine activity data and (iii) worldwide available comparative business parameters such as e.g. gross value added ("**GVA**"). The rationale behind the Model is as follows:

The XDC Model indicates for an economic entity (for example a company) how many °C the world would warm to by 2050 if all economic entities were as emission intensive as the entity under consideration. Results can serve for e.g. materiality assessments, since they provide substantiated evidence expressing the level of impact on and exposure to climate change under different scenarios and could therefore allow for risks to be reported accordingly.

If for example, a company has an XDC of 2.7 °C, this would mean that the earth would warm up to 2.7 °C, under the assumption that all companies were as emission-intensive as the company in question; following the computational logic behind the XDC Model. For further detail on the rationale on which the XDC Model is built upon (Helmke et al. 2019), please refer to the following steps:

Step 1: Company's value for Economic Emission Intensity (EEI)

Economic Emission Intensity ("**EEI**") refers to the amount of greenhouse gas emissions (expressed as tonnes CO_2 equivalents) per million Euro GVA.

As a first step a company's emissions are calculated, with e.g. 2016 being the base year the increased growth of these emissions is projected until 2050. The value for GVA is calculated for the same time period. GVA is defined as EBITDA plus Personnel Costs (Science Based Targets Initiative, 2015, pp. 38).

The rationale for combing these values is to provide a preliminary answer to the question: How much GHG are associated with the company's generation of one million Euro GVA, between 2016 and 2050. This correlation thus provides an indicator for the company's EEI.

Step 2: Global Emissions

The second step consists of the amount of emissions calculated in step 1 being scaled up along the value for global GVA for the period between the base year, e.g. 2016 up to 2050. In doing so, preliminary insight can be provided to answer to the question: What is the amount of emissions that would be released into the atmosphere under the assumption that all companies were to operate as emissions-intensively as the company under consideration?

Step 3: Climate Performance

In a third step, accredited findings in climate science are used to calculate the amount of global warming that would occur if the amount of emissions calculated in step two were to be released into the atmosphere. By doing this, insight can be provided on: the level of global warming that would result if every company were to operate as emissions-intensively as the company under consideration.

The calculation of global warming associated with an amount of GHG emissions and other climate pollutants consists of the following steps:

(1) Emissions
(2) Impact on atmospheric concentration
(3) Impact on radiative forcing
(4) Impact on global warming.

In order to determine the impact of emissions on climate the XDC recurs to the climate model Finite Amplitude Impulse-Response ("**FaIR**") (Smith et al. 2018). This model includes a comprehensive carbon cycle which spreads the anthropogenic CO_2 emissions among four reservoirs specifically soil, deep ocean, oceanic mixed layer and the atmosphere. Information on the amount of carbon accumulated in the reservoirs is updated every year depending on new emissions and taking into account reservoir-specific decay times of carbon.

Understanding the urgent need for alignment of targets at national, regional, sectoral and corporate levels with the well below 2 °C limit, leads the authors to conclude that the XDC Model can be a useful model to provide initial guidance and response to this question. The XDC Model allows companies to get an initial insight into their corporate targets' alignment with the <2 °C limit. The manner in which the XDC Model attempts to provide an answer to the question of alignment, is as described above, by means of evidencing the correlation of corporate emissions to the increase in global temperatures those emissions would lead to. This calculation takes place within the science part of the XDC Model, which recurs to the FaIR Model, which is the same model the IPCC used in its Fifth Assessment Report ("**AR5**") to establish the well below 2 °C limit.

The demand for the incorporation of scientific information is taking place at all levels, with Article 2.1 lit. c of the Paris Agreement establishing a concrete limit, which was established based on climate science. A target which is to be reached only by coordinated action, and which will ultimately by trickled down to companies, who have the advantage of being able to adapt and change course in shorter time spans. With the support of science-based methodologies providing the first steps for enabling the understanding required to put natural science and man-made economic and social progress on a harmonious level.

A global target agreed at a global level has been established, shaping the amount of emission reductions that must be collectively reduced. This global target sets the tone for actors at lower levels, mainly nations whose emission reductions should be conducive to keeping global temperatures well below 2 °C. Coordination and correlation of existing targets at a national level is still insufficient but does not act as an impediment for actors within countries to calculate targets that can be aligned with the <2 °C limit. As current methodologies exist that allow corporate actors to correlate their individual contributions to the global <2 °C limit, we see the <2 °C limit as a quantitative threshold which must be taken advantage of and can serve as reference for target setting from a top-down approach which is responded to by targets established individually bottom-up.

Limitations:

- The XDC Model, which is suggested by this paper as a methodology to allow actors at all levels to determine if their targets are in line with keeping global temperatures under the <2 °C limit, is still in ß development phase. Further developments need to be incorporated into the Model in order to provide a robust answer to a verifiable alignment with the <2 °C limit.
- Formal requirements of scientific information being incorporated into corporate and financial decision-making processes are mainly taking place at an academic level. Legislative and regulatory mandates are still vague and weak in this regard.

Future prospects:

- The code behind the XDC Model will be made open source, providing the research and academic community to improve the Model and its usability for financial and corporate decision-making processes regarding climate targets' alignment with the <2 °C limit.
- Provide clear guidance on how the XDC Model can be used to answer questions of materiality, when it comes to quantify climate-related risks in regards to their alignment or lack of with the <2 °C limit.

References

Articles and Reports

Barker S (Minter Ellison), Weber C (2° Investing Initiative), Thomä J (2° Investing Initiative, ADEME, CNAM) (2017) The carbon boomerang: litigation risk as a driver and consequence of the energy transition

Borges L, Lado EP (2019) Discards in the common fisheries policy: the evolution of the policy. The European Landing Obligation

Bouwer LM (2011) Have disaster losses increased due to anthropogenic climate change? BAMS

Brei V, Böhm S (2013) 'I L = 10L for Africa': Corporate social responsibility and the transformation of bottled water into a 'consumer activist' commodity. Discourse and Society, p 1

Busse D (2006) Interpreting law: text understanding—text application—working with text. Law and Language. Theory and Society. Düsseldorf university press 2008, p 239

Cook J, Oreskes N, Doran PT, Anderegg WRL, Verheggen B, Maibach EW, Carlton JS, Lewandowsky S, Skuce AG, Green SA, Nuccitelli D, Jacobs P, Richardson M, Winkler B, Painting R, Rice K (2016) Consensus on consensus: a synthesis of consensus estimates on human-caused global warming. Environ Res Lett 11(4):048002

Choi BCK (2005) Twelve Essentials of Science-based Policy. Preventing Chronic Dis J

Climate Action Plan 2050. Principles and goals of the German government's climate policy. Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB)

Dahlmann F, Branicki L, Brammer S (2017) Managing carbon aspirations: the influence of corporate climate change targets on environmental performance. J Bus Ethics 1

Elzen M, Admiraal A, Roelfsema M, van Soest H, Hof AF, Forsell N (2016) Contribution of the G20 economies to the global impact of the Paris agreement climate proposals. Clim Change 137:655

Heede R (2014) Tracing anthropogenic carbon dioxide and methane emissions to fossil fuel and cement producers, 1854–2010. Clim Change 122:229

Helmke H, Hafner H-P, Gebert F (2019) Controlling climate-relevant risks and opportunities with the XDC Model. Handbook of Climate Services

Hickel J, Kallis G (2019) Is green growth possible? New Polit Econ J

Hutley N, Harford Davies S (2016) Climate change and directors duties. Center for Policy and Development and The Future Business Council, p 4, Oct 2016

Knight Z, Ganguly G (2018) Managing financial system stability and climate change—a preliminary guide

Kriegler E, Edmonds J, Hallegatte S, Ebi KL, Kram T, Riahi K, Winkler H, van Vuuren DP (2014) A new scenario framework for climate change research: the concept of shared climate policy assumptions

Nachmany M, Fankhauser S, Setzer J, Averchenkova A (2017) Global trends in climate change legislation and litigation 2017. Grantham Research Institute in Climate change and the Environment, p 13

Peters GP, Andrew RM, Canadell JG, Fuss S, Jackson RB, Korsbakken JI, Le Quéré C, Nakicenovic N (2017) Key indicators to track current progress and future ambition of the Paris Agreement. Nature Clim Change 7(2):118

Porter M, Kramer M (2006) Strategy and society: the link between competitive advantage and corporate social responsibility. Harvard Bus Rev J 78

Porter M, Reinhardt F (2007) Grist: a strategic approach to climate. Forethought. Harvard Bus Rev 85(10):22–26

Rogelj J, Shindell D, Jiang K, Fifita S, Forster P, Ginzburg V, Handa C, Kheshgi H, Kobayashi S, Kriegler E, Mundaca L, Séférian R, Vilariño MV (2018) Mitigation pathways compatible with 1.5 °C in the context of sustainable development. Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty

Simlinger F, Mayer B (2019) Legal responses to climate change induced loss and damage. In: Loss and damage from climate change. Climate Risk Management, Policy and Governance

Whitley S, Thwaites J, Wright H, Ott C (2018) Making finance consistent with climate goals Insights for operationalising Article 2.1c of the UNFCCC Paris Agreement

Wittneben B, Kiyar D (2009) Climate change basics for managers. Wuppertal Institute for Climate, Environment and Energy

Jurisprudence

Abrahams v. Commonwealth Bank of Australia, 17 August 2017, Federal Court of Australia

Armando Ferrao Carvalho and other Applicants and the European Parliament Council

Assurance of discontinuance No.15-242. In the matter of Investigation by Eric. T Schneiderman, Attorney Generyl of the State of New York, of Peabody Energy Corporation http://ag.ny.gov/pdfs/Peabody-Energy-Assurance-signed.pdf

Lliuya v. RWE AG, OLG Hamm, 30 November 2017 - I-5 U 15/17

Milieudefensie et al. v. Royal Dutch Shell plc. 2019 Status: pending. Last revised on 13 May 2019

Urgenda Foundation v. Kingdom of the Netherlands, C/09/456689/ HA ZA 13-1396, Judgment of 24 June 2015

Zoe and Stella Foster, et al. v. Washington Department of Ecology, 75374-6-1, Wash. Ct. App

Laws, Directives, Regulations and Policy Plans

Action Plan: Financing Sustainable Growth (2018) https://ec.europa.eu/info/publications/180308-action-plan-sustainable-growth_en

Consultation Document on the update of the non-binding guidelines on non-financial reporting: https://ec.europa.eu/info/sites/info/files/business_economy_euro/banking_and_finance/documents/2019-non-financial-reporting-guidelines-consultation-document_en.pdf

Directive 2011/61/EU of the European Parliament and of the Council of 8 June 2011 on Alternative Investment Fund Managers and amending Directives 2003/41/EC and 2009/65/EC and Regulations (EC) No 1060/2009 and (EU) No 1095/2010

Directive 2014/91/EU of the European Parliament and of the Council of 23 July 2014 amending Directive 2009/65/EC on the coordination of laws, regulations and administrative provisions relating to undertakings for collective investment in transferable securities (UCITS) as regards depositary functions, remuneration policies and sanctions

Directive 2014/95/EU of the European Parliament and of the Council of 22 October 2014, amending Directive 2013/34/EU as regards disclosure of non-financial and diversity information by certain large undertakings and groups

Directive 2016/2341/EU of the European Parliament and of the Council of 14 December 2016 on the activities and supervision of institutions for occupational retirement provision (IORPs)

Directive 2016/97/EU of the European Parliament and of the Council of 20 January 2016 on insurance distribution (recast) Text with EEA relevance

Otto FEL, James R, Allen MR (2014) The science of attributing extreme weather events and its potential contribution to assessing loss and damage associated with climate change impacts

SBTi (2015) Sectoral Decarbonization Approach (SDA): A method for setting corporate emission reduction targets in line with climate science. Science-Based Target initiative. Available via Science-Based Target initiative. https://sciencebasedtargets.org/wpcontent/uploads/2015/05/Sectoral-Decarbonization-Approach-Report.pdf. Accessed 10 May 2019

Smith CJ et al (2018) FAIR v1.3: a simple emissions-based impulse response and carbon cycle model. Geosci Model Dev 11:2273–2297. https://doi.org/10.5194/gmd-11-2273-2018

Technical expert group on sustainable finance, Report on Climate-related Disclosures (2019)

Technical expert group on sustainable finance: Spotlight on taxonomy: https://ec.europa.eu/info/publications/sustainable-finance-taxonomy_en

Chapter 12
Provision of Climate Services—The XDC Model

Hannah Helmke, Hans-Peter Hafner, Fabian Gebert and Ari Pankiewicz

Abstract With global warming starting to shape economic realities, tools for measuring the impact of climate change mitigation activities and economic activities in general are required to be increasingly precise. Specifically, these tools will be expected to bring more clarity as to whether activities are compatible with a <2 °C-world or not. This fine but decisive distinction between what is climate-friendly and what is climate-friendly enough to support the transition to a <2 °C-world is a question being asked with increasing pressure by a range of stakeholders, such as policymakers, investors and financial institutions. The X-Degree Compatibility (XDC) Model determines the contribution of a single economic entity to global warming under various scenarios. It aims to deliver precise information that will allow for entities to understand their level of climate-friendliness in detail. Since the XDC Model is connected to a climate model and can be connected to further earth system or socioeconomic models, it provides sophisticated options for users to understand how an economic activity exacerbates or relieves climate change. Outputs are expressed in °C, enabling the user to associate results with different levels of climate change and use climate targets as a clear benchmark for assessing the effect of the economic entity's climate action. Generally, understanding a company's impact on climate change is valuable information for decision makers and can also give further

The XDC Model was fully conceived and developed by right. based on science. This article profited from the valuable input of Dr. Ari Pankiewicz from d-fine, which is an implementation partner of right. based on science. He has gathered experience in working with the XDC Model from several use cases.

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insights into what kind of climate-related risks the company may face. The XDC Model therefore delivers useful information when it comes to demonstrably steering a company into a <2 °C-world.

Requirements for Methods That Measure Climate Impact

A company's climate change impact is one aspect of its overall sustainability, or its total impact on the environment (United Nations n.d.). In most cases, it has been separated from corporate or financial risk management (Colas et al. 2019). As climate change is increasingly acknowledged as a risk factor that could materially affect a company's financial performance (Colas et al. 2019), the relevance of measuring not only a company's impact on climate change but also its exposure to climate change has recently started to spread within companies. While the traditional sustainability perspective is looking at climate change from the inside-out, understanding the impact of a company on climate as a part of the environment, another perspective is gaining more attention, one that complements the inside-out perspective by enabling a holistic view of climate change shaping corporate realities (Porter and Kramer 2006). This is the outside-in perspective: what is the effect of climate change on a company (Task Force on Climate-related Financial Disclosures (TCFD), 2017a)? Recently, the regulator within the European Union (EU) has started to require companies to report on both the outside-in perspective as well as the inside-out perspective [2014/95/EU, Article 19 (a) (d)]. This is an effort to foster a new form of collaboration between the sustainability and risk management of a company. One of the consequences is that the impact on and the exposure to climate change is increasingly expressed in metrics and targets because risk management is a quantitative exercise revolving around uncertainties, likelihoods and thresholds. Results will be used for managing climate-related risks through sustainability strategies that take such risks into account (Schulte and Hallstedt 2018).

Until now, this has been a vision and not a reality. While traditional sustainability metrics, such as the carbon footprint of the company, can be interpreted as the impact of the company on global warming, its significance with regards to expressing climate-related risks is increasingly challenged (Hoffmann and Busch 2008). Additionally, traditional risk management metrics, such as the Value at Risk, may capture short-term risks, but they are not set to grasp the risks that emerge with climate change over time (Dietz et al. 2016). Neither traditional sustainability nor risk metrics consider that the impact on climate change can be intertwined with the exposure to climate change. A company that has a high impact on global warming might e.g.—depending on the social attitudes towards global warming—be exposed to high reputational risks because of its high impact.

New models built to generate respective metrics and targets, such as the XDC Model, can make up for such shortcomings if they manage to respond to the following requirements:

– *Forward-looking*: Climate change is an issue triggered by past and present actions and will unfold in complex and non-linear ways in the future. The quantified climate-related risks and thus potential financial losses or gains relating to an economic activity in the future are the impact of a decision made today. Methods aspiring to capture climate-related risks and potential financial losses or gains are therefore expected to take the future into account.
– *Scenario-based*: The nature of climate change and its related risks and opportunities do not allow for the extrapolation of climate-related risk-factors into the future. In case of an infinite number of possible future conditions of a world shaped by climate change and therefore not a solid basis for probabilities, scenario analysis provides a comprehensive pathway for creating a profound understanding of risks and opportunities (Stirling 1998). Methods aspiring to capture climate-related risks and potential financial losses or gains are therefore expected to take the future into account by applying scenario analysis for dealing with climate-related uncertainty. Since scenario analysis is about understanding how possible futures could look like and getting a feeling for the nature and magnitude of future risks and opportunities, such an analysis must always cover several scenarios. Relying on just one scenario can be deemed negligent (Schneiderman 2015).
– *Open for sensitivity analysis*: There are various types of scenarios, ranging from qualitative stories about the future to quantitative representations of certain elements of the future. Scenarios of the type used in traditional risk management assessments are built by establishing quantifiable relationships between driving forces (Hassani 2016). Different levels of a key drivers' individual dispositions result in different corresponding responses through context factors and therefore show different outcomes. Scenario analysis requires input data by the user. The better the input data quality for important parameters, the more valid and thus useful the results. Measuring the sensitivity of the outcome of scenario analysis to variations of values for a single key driver helps to determine the required data quality for input data. Best-practice methods aspiring to capture climate-related risks and potential financial losses or gains therefore provide the user access to the underlying scenario framework. Resultingly, the user can determine the level of data quality that is appropriate for the purpose of the intended use of scenario analysis.
– *Science-based*: In context of this study, "science-based" is defined as based on the latest findings of climate science and studies of the impact of climate change on socioeconomic structures. Relevant scientific findings refer e.g. to the consequence of an amount of emissions released into the atmosphere for the climate system as assessed by Earth System Models (Steffen et al. 2016) or emission budgets associated with different levels of radiative forcing as projected by the Representative Concentration Pathways (RCPs) (Millar et al. 2017b). Further relevant scientific findings refer to climate impacts assessed by Climate Impact Models, such as those listed by the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP n.d.). Climate Impact Models can e.g. be used to determine the Social Cost of Carbon (Ricke et al. 2018). In the context of this study, science-based refers to the climate-related computational processes of the model exclusively and does not apply for

bespoke input data or assumptions that vary under different scenarios. The plausibility and scientific backing of the input data and thus the quality of the results is the responsibility of the user. Data sources and scenario-specific assumptions should therefore be made transparent when displaying results.

In order to have a meaningful and valid benchmark for interpreting results, impact, meaning the consequence of an economic activity on the climate system, and exposure, meaning the impact of climate change on socioeconomic systems, should be defined in a way that corresponds to the nature of the input data and thus the outcome of either Earth System Models or Climate Impact Models. Methods aspiring to capture climate-related risks and potential financial losses or gains are therefore expected to be science-based, meaning rooted in best possible representations of the kind of Earth Systems and Impact Models that provide the benchmark for interpreting model results. The criterion "science-based" especially applies to a method's ability to set an emission reduction target in line with a chosen climate target backed up by climate science (McSweeney and Hausfather 2018). A science-based climate target refers to an emission reduction target that is demonstrably in line with climate scientific findings of accredited scientific institutions, such as the Intergovernmental Panel on Climate Chang (IPCC), on limiting global warming to well below 2 °C. The delta of a company's planned emission trajectory to a company's science-based emission target is a relevant piece of information for several stakeholders. For example, investors have started to associate risk with investing money into a company that cannot provide a strategy for avoiding emissions which would not be available in a <2 °C-world (Leaton and Grant 2018).

– *Transparency*: Transparency of the discussed models' structure, assumptions and input data sources is key for comparability of results. The need for transparency comes from two perspectives: (1) the regulator, who is very likely to regulate an economic entities' impact on climate change due to the potential of severe levels of climate change towards undermining financial stability (see e.g. EU Action Plan) and (2) the market itself which is likely to acknowledge climate change as a material risk and therefore understands that a high impact on and exposure to climate change might represent a competitive disadvantage for an entity (Gitsham 2018).

The following sections will first present the structure and functionalities of the XDC Model and then match the above-mentioned requirements against the XDC Model.

XDC Model

The XDC Model determines the impact of an economic entity on climate change. Based on scientific findings and regulatory requirements, it calculates the climate metric known as the XDC. The XDC measures e.g. a company's contribution to global warming by expressing how many °C the earth would warm up to by 2050, if all companies operated as emission-intensively as the company in question. If, for example, a company has an XDC of 2.7 °C, this means, according to the calculation logic being the XDC Model, that the earth would warm up to 2.7 °C by 2050 if all companies were to operate as emissions-intensively as the company under consideration.

In summary, the calculation is based on how many emissions an economic entity needs in order to generate 1 million Euros of Gross Value Added (GVA) between a base year and 2050. Emissions considered include Scope 1–3 emissions as defined by the GHG Protocol (Ranganathan et al. 2004): Scope 1 emissions are defined as “direct emissions from owned or controlled sources”. Scope 2 emissions are defined as “indirect emissions from the generation of purchased energy”. Scope 3 emissions are defined as “all indirect emissions (not included in scope 2) that occur in the value chain of the reporting company, including both upstream and downstream emissions”.

Assumptions for the development of emissions and GVA between the base year and 2050 are to be set according to plausible references.

Familiar Concept: Science Based Targets

The XDC Model can be combined with the Science Based Targets (SBT) as a familiar concept, which has been initiated by the Science Based Targets initiative (SBTi) in 2015.

The SBTi is a collaboration between CDP, World Resources Institute (WRI), World Wide Fund for Nature (WWF) and the United Nations Global Compact (UNGC) with the aim of advancing science-based target setting into a standard business practice by 2020 (SBTi 2019c). Companies’ GHG emission reduction targets that are validated against the criteria of the SBTi are referred to as “SBT” (SBTi 2019b).

The basis for calculating a SBT is a global carbon budget which defines the amount of GHGs that can be emitted before global warming exceeds a specific temperature threshold (SBTi 2019c). Consequently, that raises the question on how to allocate the remaining budget amongst sectors and individual companies. The SBTi suggests various approaches:

The so-called Sectoral Decarbonization Approach (SDA) allocates the global carbon budget to different sectors based on different scenarios of the International Energy Agency (IEA). Within each sector, companies can derive their reduction targets based on their relative contribution to the total sector activity and their carbon intensity relative to the sector’s intensity in the base year. While the SDA is well-suited for homogenous and emission-intensive industries, it is not well suited for companies from heterogeneous sectors or not-covered sectors (SBTi 2015).

Advice regarding this approach has being provided, suggesting another approach be followed. An approach that consists of e.g. setting absolute targets by using contraction of absolute emissions. This means that all companies reduce their carbon emissions at the same rate, irrespective of their specific sectoral affiliation (SBTi 2019c). Alternatively, it could also consist of setting economic intensity targets based on the contraction of economic intensity (SBTi 2017).

While a SBT provides an existing and renowned framework for setting a <2 °C-compatible emission reduction target for a company, there are caveats when it comes to using resulting targets as a robust base for generating long-term climate strategies:

1. Latest research indicates that for setting credible science-based targets it is essential to take into account a bandwidth of plausible scenarios and assumptions of key parameters (Rose and Scott 2018; Kok et al. 2018).
2. Transparency about uncertainties within underlying models and assumptions that might have an influence on the outcomes, which in this case are resulting targets, is essential (Martinez-Moyano 2012).
3. A dynamic use of <2 °C-scenarios is necessary to factor in newest climate scientific findings[1] around e.g. the role of non-energy emissions from agriculture (Hirsch et al. 2017), the effect of disruptions on climate mitigation (Wilson et al. 2019; Schewe et al. 2019) or the role of socio-economic developments for a realistic representation of mitigation pathways (O'Neill et al. 2014).

The SBTi is aware of those caveats and as of today working on appropriate responses (SBTi 2019a).

With a SBT providing an existing framework for setting a <2 °C-compatible emission reduction goal for a company, the XDC Model complements that framework with additional information that serves as the basis for decisions on how to deal with climate-related risks and opportunities and steer a company towards a <2 °C-compatible business structure.

XDC Model Output: Standard XDC and Scenario Based XDC

The XDC Model's output can be divided into two main categories:

1. Standard XDC: This assumes standard assumptions for economic growth and emissions between the base year and 2050. The underlying assumptions assume the ratio between emissions and GVA remains the same until 2050. Due to using the same assumptions for every computed XDC, the Standard XDC serves the purpose of comparing one company to another or to another peer group, such as a sector. Although those assumptions can be regarded as a scenario, we believe they are too simplified for treating their results as a scenario outcome.
2. Scenario Based XDC: This allows individual assumptions for economic growth and emissions for each year until 2050 to be assessed. By doing this, XDCs based on different scenarios can be computed. Furthermore, the Scenario Based

[1]The need for a more dynamic use of climate-related scenarios for deriving decision-relevant metrics was an outcome of several workshops and presentations of the conference Scenarios Forum 2019 in Denver. https://www.scenariosforum2019.com/.

XDC allows for variation in Scope 1–3 consideration. A user can decide what percentage of Scope 1–3 emissions should be covered by the resulting XDC. Determining scenarios allows a user to consider emissions targets, strong business growth expectations, expansion plans or the effect of modern technology on decarbonization e.g. the supply chain.

XDC Model: Input Data Needed

Input data for determining a Standard XDC and a Scenario Based XDC with the XDC Model comes from different data sources, which are described in Table 12.1.

Parameters and corresponding assumptions for determining a Standard XDC or a Scenario Based XDC with the XDC Model comes from different data sources, which are described in Table 12.2.

Table 12.1 Input data and exemplary data sources for determining a Standard XDC or Scenario Based XDC with the XDC Model

Input data	Description	Exemplary data source
Scope 1–3 emissions	Specific to economic entity under consideration e.g. company or sector	Self-reported data; third-party data providers; Integrated Environmental Accounts
EBITDA	Specific to economic entity under consideration e.g. company or sector under consideration	Self-reported data; third-party data providers; OECD Database (OECD Data, n.d.)
Operating income corresponding to EBITDA for financial Institutions	Specific to economic entity under consideration e.g. company or sector under consideration	Self-reported data; third-party data providers; OECD Database (OECD Data, n.d.)
Personnel expenses	Specific to economic entity under consideration e.g. company or sector under consideration	Self-reported data; third-party data providers; OECD Database (OECD Data n.d.); Destatis (Genesis-Online Datenbank (2019)
Global GVA for base year 2016	59.0 € (trillion)	World Bank and OECD National Accounts (World Bank Open Data n.d.; OECD Data n.d.)
Atmospheric concentration CO_2-Equivalents (CO_2eq) for 2016 (base year)	490 parts per million (ppm)	National Oceanic and Atmospheric Administration (NOAA) annual Greenhouse Gas Index (AGGI) (2018)

Table 12.2 Parameters, corresponding assumptions and their exemplary sources for determining a Standard XDC or Scenario Based XDC with the XDC Model

Parameter	Assumption standard XDC	Assumption scenario based XDC
GVA growth until 2050 specific to economic entity	3.2% Compounded Annual Growth Rate (CAAGR) (World Economic Outlook Database 2019)	Specific to economic entity under consideration e.g. company or sector **Source**: Accredited research papers for decoupling growth from emissions; or users of the XDC Model (e.g. a company uses its climate target as input parameters)
Emission growth until 2050	No decoupling of economic growth and emissions, thus 3.2%	Specific to economic entity under consideration e.g. company or sector **Source**: Accredited research papers for decoupling growth from emissions; or users of the XDC Model (e.g. a company uses its climate target as input parameters)
Scope 1 emission consideration	100%	Specific to economic entity under consideration e.g. company or sector **Source**: The user of the XDC Model
Scope 2–3 emission consideration	50%	Specific to economic entity under consideration e.g. company or sector **Source**: The user of the XDC Model
Global GVA growth until 2050	3.2% CAAGR for Standard XDC (World Economic Outlook Database 2019)	User of the XDC Model **Source**: Any accredited research papers for global growth projections

Basic Steps of Processing

The impact of an economic entity on global warming is computed through three major steps. The three steps are described by using a company as an example of an economic entity.

Step 1: Economic Emission Intensity (EEI) of the Company

In a first step, we define Economic Emission Intensity (EEI) as the amount GHG emissions (expressed as tonnes CO_2eq) per million Euro gross value added (GVA). GVA is defined as EBITDA plus Personnel Costs (SBTi 2015). We use GVA as the factor to relate emissions to, because it measures the actual value that a company generates between costs and revenues without distortions stemming from taxation and interest rates.

In order to calculate the company's EEI, its emissions corresponding to the period between 2016 (base year) up to 2050, are linked to the GVA corresponding to the same period.

By doing this, insight can be provided on: How many greenhouse gases (GHG) is a company going to emit in order to generate one million Euro GVA, between the base year and 2050.

Formally, let e_k, $k = Base\ year, \ldots, 2050$ be the emissions for year k, gva_k, $k = Base\ year, \ldots, 2050$ the GVA for year k in million Euros. Then the average EEI for the period under consideration is

$$EEI_{Avg} = \sum_{k=Baseyear}^{2050} e_k / \sum_{k=Baseyear}^{2050} gva_k$$

Step 2: Global Emissions

In a second step, this economic emission intensity is scaled up along the value for global GVA for the period between the base year, e.g. 2016 up to 2050. By doing this, insight can be provided on: What is the quantity of emissions that would be released into the atmosphere if every company were to operate as emissions-intensively as the company under consideration?

Formally: Let $gva_{w,k}$ be the global GVA for year k, $k = Base\ year, \ldots, 2050$ in million Euros. Then the cumulative global emissions $e_{w,Cum}$ for the period from the base year to 2050 can be projected as

$$e_{w,Cum} = EEI_{Avg} \cdot \sum_{k=Baseyear}^{2050} gva_{w,k}$$

Step 3: Climate Performance

In a third step, accredited findings on climate science are used to calculate the amount of global warming that would occur, if the amount of emissions calculated in step two were to be released into the atmosphere. By doing this, insight can be provided on: the level of global warming that would result if every company were to operate as emissions-intensively as the company under consideration.

The calculation of global warming associated with an amount of GHG emissions and other climate pollutants consists of the following steps:

(1) Emissions and other climate pollutants, such as aerosols
(2) Impact on atmospheric concentration
(3) Impact on radiative forcing
(4) Impact on global warming.

In order to determine the impact of emissions on the climate we use the simple climate model Finite Amplitude Impulse-Response (FaIR) (Smith et al. 2018; Millar et al. 2017a). This model includes a comprehensive carbon cycle which disseminates the anthropogenic CO_2 emissions among four reservoirs namely soil, deep ocean, oceanic mixed layer (warm layer near the surface) and the atmosphere. It is used by the IPCC and referred to in several scientific publications (IPCC 2018; Mattauch et al. 2018; Thompson 2018; Schwarber et al. 2018). For every year the amount of carbon accumulated in the reservoirs is updated depending on the new emissions and the reservoir-specific decay times of carbon. Feedbacks of the carbon cycle to higher global temperatures are incorporated; especially the reduced absorption capacity of the reservoirs on land and in the ocean due to increased temperature. It is possible to include up to 40 different GHGs and other climate pollutants into the model (Smith et al. 2018).

Once we have determined the amount of the substances that reach the atmosphere, we can calculate the increase of their atmospheric concentration. A higher concentration results in higher radiative forcing. Radiative forcing is the net change in the energy balance of the Earth system; this is the difference between the incoming sunlight absorbed by the earth and the energy radiated back to space. Due to the greenhouse effect, a part of the energy radiated by the Earth is reflected by the atmosphere and radiated in all directions including the Earth's surface. FaIR calculates 13 separate forcing groups.

The final part of this third step to determine an economic entity's XDC is to calculate the temperature change that results from the combination of the individual forcing groups. Simpler models summarize the effect of radiative forcing on the climate to a single parameter, climate sensitivity. FaIR distinguishes between a slow response to the forcing coming from the upper ocean and a fast response from the deep ocean. The total temperature change is the sum of these two components.

All XDC calculations should be based on a range of plausible scenarios and plausible ranges of assumptions for key parameters. For the sake of simplicity, we don't test sensitivity to key parameter assumptions and use single scenarios to determine Scenario Based XDCs and Target XDCs in this study.

Example 1: Calculation of the Standard XDC for Enel S.P.A.

In order to make the process of calculating a company's XDC more concrete, we provide a description on how the Standard XDC for the Italian energy producing group Enel S.P.A. ("Enel") is calculated. As base year we take 2016. Enel reported for this year an EBITDA of 15.2 billion € and personnel costs of 4637 million € (Enel S.P.A. n.d.a). their corresponding GVA 2016 adds up to 19.9 billion €. We obtain emission data from the 3rd party data provider Engaged Tracking. They report for Enel in 2016 the following data:

Scope 1 80,000,000 t CO_2eq*
Scope 2 380,000 t CO_2eq*
Scope 3 63,000,000 t CO_2eq*

* For confidentiality reasons the original values were modified.
As stated above, only 50% of the Scope 2 and Scope 3 emissions are considered for the calculation of the Standard XDC.

The values for emissions and GVA are projected until the year 2050 with the assumption of an economic growth of 3.2% per year and a constant EEI which means that emissions also grow by 3.2% per year.

Summing up the values for each year, we calculate cumulative emissions and GVA of the company for the period 2016–2050. The cumulative emissions amount to 7020,921,824 t CO_2eq, the cumulative GVA is about 1250.9 billion €. This results in an EEI of about 5613 t CO_2eq per million € GVA. By multiplying this EEI with the World GVA of 2016 (59.0 trillion €, World Bank Open Data n.d.) we get the worldwide cumulative emissions for the period 2016 to 2050 under the assumption that every company worldwide has the same EEI as the company under consideration. This amount of emissions serves as input for the climate performance calculation of the XDC model. It is beyond the scope of this article to provide a detailed description of the calculation of the climate performance.

Based on the above-mentioned data points and assumptions, our climate model yields a Standard XDC of 6.3 °C for Enel. The calculation steps, which we just described for total emissions can be conducted for Scope 1, Scope 2 and Scope 3 emissions separately. Resulting Standard XDCs are Scope 1 XDC of 5.8 °C, Scope 2 Standard XDC of 1.1 °C and Scope 3 Standard XDC of 3.2 °C.

Example 2: Calculation of a Scenario Based XDC for Enel S.P.A.

This assumes that Enel wants to decarbonize its operations until 2050. Furthermore, they want to reduce the emissions per kWh energy generated by 15% until 2016 and by 25% until 2020 compared to 2007 (Enel S.P.A. n.d.b). We can compute a Scenario Based XDC to test whether this reduction strategy is in line with the Paris

Agreement. For this task we have to set some additional assumptions. In this study, we provide only a basic example to explain the rationale of Scenario Based XDCs, for which we meet the following strongly simplified assumptions:

- Annual growth rate of Enel's GVA equals 3.2%
- Reduction rates for Enel's emissions are equal for Scope 1–3 emissions
- Between 2017 and 2020 the emissions are reduced annually by 2.5% of 2007 emissions
- Between 2021 and 2050 additional emissions reductions of 2.6% per year (compared to 2007) so that by 2050 all operations are carbon-neutral.

By applying this reduction strategy Enel would save about 72% of emissions until 2050, compared to the emissions projected under the assumptions of the Standard XDC. The XDC values would decrease to 3.04 °C for Scope 1, 1.07 °C for Scope 2, 2.02 °C for Scope 3 and 3.54 °C in total. To interpret the results e.g. against the backdrop of the Paris Agreement, they have to be contextualized, as e.g. by comparing them with respective Target XDCs under a plausible bandwidth of 2 °C scenarios.

Contextualisation of XDC Results

In order to understand the meaning of a single XDC and be able to interpret it correctly, the user of the XDC Model is encouraged to work with more than one XDC result. XDC metrics that provide valuable context for this are e.g. Baseline XDC, Target XDCs or Sector XDCs.

This is because XDC values for economic entities are purely physical-climate-values dependant on the amount of emissions that would be generated until 2050 under the assumption that all economic entities behaved as emission intensive as the company under consideration. This means that they do not consider any alternatives to the role of a certain sector or company in a world shaped by climate change.

In this paper, we describe three helpful ways of contextualizing XDC values: First, by adding the Baseline XDC, second the Sector XDC and third, the Target XDC (IEA 2DS). For the latter two, we provide practical examples.

1. Baseline XDC

One useful type of Scenario Based XDC is the Baseline XDC. In the underlying baseline scenario, the development of GVA and emissions between base year and 2050 follows current trends and considers the expected results of e.g. relevant legislation and regulation which has been adopted but not yet fully implemented. It does not include any developments that depend on political or other decisions that have not yet been taken. Along the lines of proper scenario analysis, the Baseline XDC serves well as the starting point in a comparison between different Scenario Based XDCs. In order to understand e.g. the level of ambition of an emission target, a company's Baseline XDC can be compared with a Scenario Based XDC that assumes the company reaches its climate targets.

2. Sector XDC

In order to interpret a certain entity's XDC value, a comparison with its sector can be useful. Sector XDCs can be computed either by

a. Peer-group based approach: In this approach, aggregating data on GVA and Scope 1–3 emissions for a minimum number of relevant companies within a NACE (Nomenclature statistique des activités économiques dans la Communauté européenne) sector yields a Sector XDC. If the group of selected companies is representative for the sector and the choice of companies is unbiased towards any criterion, emission intensities are calculated for the group. An average emission intensity, weighted by the companies' GVAs, is calculated and used to determine the corresponding Sector XDC for a company,

or by

b. Country-based approach: In this approach, sector and country specific data from national inventories are used to define a sector. Ideally, emission and GVA data are available for each sector on a regional basis in aggregate form from government entities. However, availability for different types of data varies strongly between regions and countries. While GVA data is generally widely available from national accounts data and accessible via databases of e.g. the UN statistics division,[2] emissions data is less standardized. In Europe national Air Emission Accounts, containing country specific emissions data for various ISIC (International Standard Industrial Classification) sectors (with varying granularity) are compiled and available from the Eurostat online database.[3] However, other regions of the world do not report their emissions at such a granular level or use different classifications to group and count emissions. Emissions data based on the GHG inventory protocol of the Paris Agreement is available for many countries from the United Nations Framework Convention on Climate Change (UNFCCC) but mapping the data from the respective reporting format used in these reports to industry sectors proves difficult for most sectors. For this approach, only Scope 1 data is available.

It is crucial that the emission data used for determining a Sector XDC is comparable to the emission data being used for the economic entity under consideration which is to be compared to the Sector XDC. For example: calculating a company's Standard XDC with self-reported data and comparing it to a Sector XDC based on data provided by a 3rd data provider is potentially biased and thus might not render a valid analysis. This is why it is necessary to state the emission source as well as the assumptions for economic growth and the rate of decoupling between GVA and emissions that were applied for calculating an economic entity's XDC and a Sector XDC when comparing an economic entity to its sector.

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[2] http://data.un.org/Data.aspx?d=SNAAMA&f=grID%3A201%3BcurrID%3ANCU%3BpcFlag%3A0, Access date: 02/05/2019.

[3] https://ec.europa.eu/eurostat/en/web/products-datasets/-/ENV_AC_AINAH_R2, Access date: 02/05/2019.

Table 12.3 Standard XDCs, Sector XDCs and Target XDCs for selected companies

Company	NACE sector	Standard XDC (Base year 2016) (°C)	Standard sector XDC (Base year 2016) (°C)	Target XDC (IEA 2DS) (°C)
Enel S.P.A.	Electricity, gas, steam and air conditioning supply	6.3	6.6	3.8
Deutsche Telekom AG	Wireless telecommunications activities	1.6	1.4	1.2

Table 12.3 shows exemplary Standard XDCs of two companies in 2016 with high and low XDC values and compares them to the Standard XDC Base year 2016 and Target XDC (IEA 2DS) of their NACE sector. Table 12.2 shows the underlying data sources and assumptions on which the results in Table 12.2 are based.

All Standard XDCs, including Standard Sector XDCs were computed based on the assumptions as set out in Tables 12.1 and 12.2. Standard Sector XDCs were computed by following the peer-based approach and thus by aggregating data on GVA and Scope 1–3 emissions for at least 10 relevant OECD companies within each NACE sector.[4] Such Sector XDCs served as the base for calculating Target XDCs. Target XDCs cover Scope 1–3 emissions and refer to companies operating within the OECD.

3. Target XDC

While the overall goal of emission reductions should be aimed at achieving compatibility with the transition to a <2 °C-world, this is not necessarily the same as achieving an XDC of <2 °C. Feasibility of cutting CO_2 emissions differs from sector to sector, e.g. there exist feasible technological low-emission alternatives to coal power plants, while it is a lot harder to cut emissions from cement production to the same degree. Using a holistic approach, the excess of emissions caused by those industries with limited reduction potential needs to be compensated for by additional reductions in other sectors to achieve an overall <2 °C compatibility. Consequently, sector-specific Target XDCs need to be defined based on the sector's emission reduction potential in the context of the other sectors' reduction potential. In addition, regional differences regarding the capabilities to adapt low emission technologies may need to be taken into account.

Climate targets such as the <2 °C-target are set either by political agreements or by voluntary corporate commitments (Art. 2 (1) Paris Agreement). To assess whether planned emission reduction measures reduce actual emissions sufficiently to reach the target, climate models are used. Renowned climate models are e.g. MAGICC6[5]

[4]Standard Sector XDCs are based on the following number of aggregated companies: Electricity, gas, steam and air conditioning supply: 33; Wireless telecommunications activities: 33.

[5]http://www.magicc.org/, Access date: 06/05/2019.

from Potsdam Institute for Climate Impact Research (PIK) or Hector (Hartin et al. 2015) from University of Maryland.

Integrated Assessment Models (IAM), such as MESSAGE from the International Institute for Applied system Analysis (IIASA 2013)[6] or ETSAP-TIMES (Loulou et al. 2005) from the IEA quantify how technologies, markets and policy could evolve in order for socioeconomic futures to stay between those target budgets. The cost-effectiveness of different technologies is considered when laying out such futures. They do so by creating bespoke scenarios, such as the 2 °C-scenario called "IEA 2DS" developed and published by the IEA within their scenario framework Energy Technology Perspectives (ETP) (IEA 2017). 2 °C-scenarios usually consider mitigation and adaptation capacities by different sectors, countries and regions, which results in laying out cost-effective contributions to emission reductions in line with the overall achievement of the 2 °C target for various industry groups and regions at various points of time in the future. However, granularity in terms of sector differentiation, time and region varies between models published by various institutions (TCFD 2017b).

Using respective data and assumptions from such IAMs, one possible intuitive way to determine annual emission goals for a sector is given by using the sector's overall emissions budget b_s (this is the amount of emissions allocable to the sector according to the 2 °C-scenario) and the assumption of an exponential emission reduction via

$$b_s = \sum_{k=a_0}^{a_N} e_{a_0} \cdot (1-r)^{k-a_0},$$

where a_0 is the base year, a_N the target year (usually 2050), k is the index for the years and r is the annual percentage reduction in emissions starting from the amount e_{a_0} in the base year of the sector. Solving this equation for r then gives sector-specific annual emission reduction goals that are in line with the chosen IAM.

For the purpose of calculating Target XDCs, the XDC Model treats each sector like a business entity with GVA growth and emission reduction rate values obtained from the underlying 2 °C-scenario. The emissions that would be released if all companies were as emission intensive as the sector under consideration and as defined by the 2 °C-scenario, are the input emissions for the calculation of the Target XDC. They can be determined as

$$e_{s,p} = \sum_{k=a_0}^{a_N} EEI_{s,k} \cdot gva_{w,k},$$

where $e_{s,p}$ is the projected total emissions of sector s from the years a_0 to a_N, $EEI_{s,k}$ is the emission intensity in year k of sector s, and $gva_{w,k}$ is the projected overall GVA in year k.

[6] http://www.iiasa.ac.at/web/home/research/modelsData/MESSAGE/MESSAGE.en.html, Access date: 06/05/2019.

The calculation of the Sector's EEI corresponds to Step 1 of the XDC Model computation process. The calculation of $e_{s,p}$ corresponds to Step 2 which yields global emissions. Calculating the Sector Target XDC corresponds to Step 3 which determines the climate performance.

Besides direct emissions, indirect emissions also need to be considered when assessing a company's climate performance and calculating its Sector Target XDC. This is because companies often have a strong impact on their choice of energy supplier and at least some leverage on the behavior of their stakeholders along the upstream and downstream supply chain. The challenge with regards to incorporating indirect emissions into a sector's Target XDC lies in the attribution of a companies' indirect emission to their respective sectors. Scope 2 and 3 emissions can usually not be attributed to the same sector, to which Scope 1 emissions are attributed by using the company's NACE code. Scope 2 emissions can rather be distributed to the power sector, whereby Scope 3 emissions mostly stem from a wide variety of sources, which can again be attributed to a wide variety of sectors (Ranganathan et al. 2004). To avoid double counting, Scope 2 and Scope 3 emissions are currently considered with a factor of 50% only.[7]

As a consequence, for Scope 2 emissions, scenario-specific emissions reduction goals of the power sector are used. For Scope 3, an emission reduction rate is used that is aggregated from all sector-specific emission reduction rates as set out by the chosen 2 °C-scenario.

Using the sector-specific emission data as generated with the peer-group-based approach, the following formula yields the emissions used for a Sector Target XDC:

$$e_s = 1.0 \cdot e_{s,s1} + 0.5 \cdot e_{s,s2} + 0.5 \cdot e_{s,s3},$$

where $e_{s,s1}$, $e_{s,s2}$ and $e_{s,s3}$ are the respective Scope 1, 2 and 3 emission averages of the sector-specific peer group of companies.

And in terms of economic emission intensity, the computation goes as follows:

$$EEI_k = 1.0 \cdot \frac{e_{s,s1}}{gva_s} + 0.5 \cdot \frac{e_{s,s2}}{gva_s} + 0.5 \cdot \frac{e_{s,s3}}{gva_s} = \frac{e_s}{gva_s},$$

where gva_s corresponds to the average GVA of the peer group of companies.

Example 3: Target XDC Calculation

In order to illustrate the Target XDC calculation process with an example, this section shows how an OECD Target XDC for the power sector can be computed.

[7] In some cases, as e.g. for sectors with high Scope 3 emissions, it could make sense to cover more than 50% of Scope 3 emissions. Respective analyses are up for future research.

Using air emission account and national account data from Eurostat (n.d.) and OECD (OECD Data n.d.), we have computed the total GVA and total Scope 1 emissions for the power sector of the majority of OECD countries for the year 2016,[8] $gva_{OECD} = €238{,}923\,\mathrm{M}$, $e_{\mathrm{s1,OECD}} = 0.87\,\mathrm{GtCO_2eq}$. This leads us to the Scope 1 power sector EEI of these countries:

$$EEI_{s1,OECD} = \frac{e_{s1,OECD}}{gva_{OECD}} = 3.635 \times 10^{-3}\frac{\mathrm{tCO_2eq}}{€}.$$

Using the global GVA as of 2016, $gva_w = €59.6$ trillion, and an annual reduction[9] of $r_{s1} = 0.0691$ we get cumulative emissions from 2016 until 2050 of
$b_{e,s1} = \sum_a EEI \cdot gva_w \cdot (1 - r_{s1})^{(a-2016)} = 2879\,\mathrm{GtCO_2eq}$

We apply the climate performance calculation within the XDC Model to obtain a Scope 1 Target XDC of $xdc(b_{e,s1}) = xdc(2879\,\mathrm{GtCO_2eq}) = 2.59\ °\mathrm{C}$ for the OECD power sector.

Since country data cannot be used to calculate the Scope 2 and 3 emissions and GVA of a sector, we use the weighted average Scope 2 and Scope 3 EEI[10] of 25 companies[11] in the power sector which operate in the OECD:

$$EEI_{s2,peer} = \frac{6.46\,\mathrm{MtCO_2eq}}{117{,}068\,\mathrm{M}} = 0.055 \times 10^{-3}\frac{\mathrm{tCO_2eq}}{€}$$

$$EEI_{s3,peer} = \frac{390.15\,\mathrm{MtCO_2eq}}{117{,}068\,\mathrm{M}} = 3.333 \times 10^{-3}\frac{\mathrm{tCO_2eq}}{€}$$

The reduction rate of Sector 2 is $r_{s2} = 0.0691$ (based on IEA ETP 2016 Power Sector), and of Sector 3 is $r_{s3} = 0.0400$ (based on overall reduction rate). We get a power sector Target XDC of 1.12 °C for Scope 2 and 2.93 °C for Scope 3. Combining these values to a Scope 1–3 target XDC along the above-mentioned computation process we get a total Target XDC of 3.80 °C for the OECD power sector. This Sector Target XDC serves as Target XDC for every company in the Power Sector within the OECD.

[8]Based on values for the OECD countries AT, BE, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IT, LT, LU, LV, NL, PL, PT, SE, SI, SK; all data from Eurostat and OECD databases.

[9]The reduction factor is computed using the CO_2 budget of the IEA's 2DS (ETP 2016) for power industry, OECD.

[10]The average is weighted by the GVA of the companies.

[11]Data source emissions data: Engaged Tracking; Data source GVA: Factset Research Systems.

Strategy Development for Transitioning Towards a <2 °C-World

This chapter delves into how to set a 2 °C-compatible emission reduction pathway with the XDC Model and benchmark new investments against the company-specific emission reduction requirements set out by this pathway.

2 °C-Compatible Emission Reduction Pathway

Let C be a company with a Baseline XDC higher than its Target XDC. In order to achieve that Target XDC, C must reduce its cumulative emissions from 2016 (base year) to 2050 by a share € according to the following formula:

$$€ = 1 - \frac{b_t}{b_C}$$

where b_C represents the cumulated emissions corresponding to the Baseline XDC of company C and b_t represents the cumulated emissions of the Target XDC.

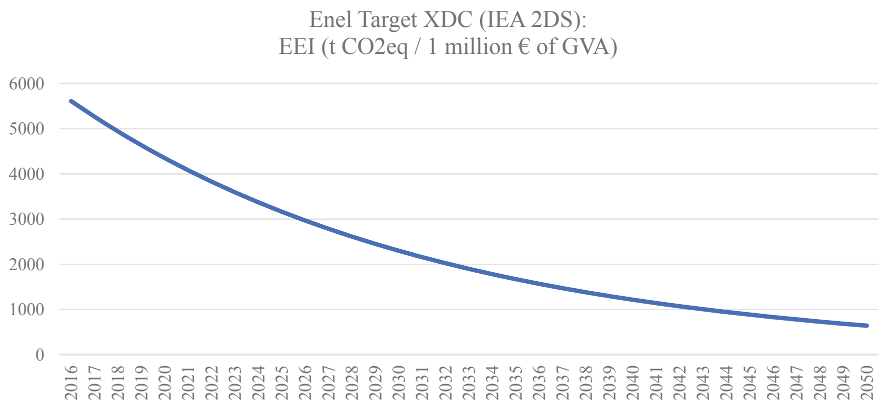
An emission reduction pathway for a company results from connecting the dots between its specific Baseline XDC and its sector specific Target XDC. The reduction pathway needs to be determined in a way that makes sure that the company's 2 °C-budget will be kept.

To hold the limit of the target budget b_t the company must reduce the amount of emissions e_0 in the base year a_0 by a yearly reduction rate r until the target year a_N. The following equation holds:

$$b_t = \sum_{k=a_0}^{a_N} e_0 \cdot (1 - r)^{k-a_0}.$$

For r there is no analytical solution available; therefore, approximation methods are required.

Since an XDC corresponds to an equivalent average EEI, a reduction pathway connecting the Baseline EEI with the Target EEI along r and thus without exceeding the company-specific 2 °C-budget, can be determined. The reduction pathway sets the benchmark for assessing whether a measure as e.g. the introduction of a certain "green" technology, can be regarded as "green enough" to be deemed 2 °C-compatible in the context of the company at hand.



Graph 12.1 Enel's relative emission reduction pathway expressed in t CO_2eq/1 million € of GVA for Scope 1–3 emissions according to Target XDC (IEA 2DS). In 2016, Enel needs 5613.00 t CO_2eq in order to generate 1 million € of GVA (Standard XDC). Assuming Enel reduces emissions exponentially, its EEI in 2050 has to decline to 643 t CO_2eq/1 million € of GVA in order to be in line with the emission reduction goal as set out by the IEA 2DS (ETP 2016) for the OECD power sector

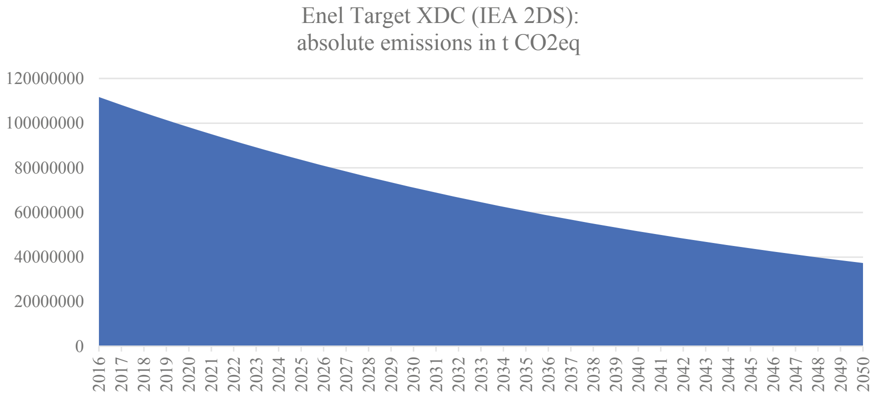
Example 4: Defining a 2 °C-Compatible Reduction Pathway

For the sake of simplicity, we use Enel's Standard XDC as its Baseline XDC. Graph 12.1 shows the reduction pathway of Enel's EEI between the base year 2016 and 2050 under the assumption of equal EEI reduction rates for each year. The EEI for each year describes the required rate of decoupling in order to be 2 °C-compatible according to the underlying set of assumptions.

Graph 12.2 shows Enel's corresponding absolute emissions reductions between the base year 2016 and 2050 in t CO_2eq. It should be noted that the IEA generally assumes considerable negative emissions in the second half of the century (IEA 2017). Consequently, emissions will not have to be reduced to zero by 2050. In order to take alternative views of the future into account, Target XDCs based on a plausible bandwidth of scenarios should be computed.

Example 5: Assessment of Climate Mitigation Activities

A climate change mitigation activity, also "measure" is 2 °C-compatible if it supports the required rate of decoupling between emissions and GVA as described by the sequenced EEI between the base year and 2050. In other words: in order to be 2 °C-compatible, a measure needs to generate sufficient GVA for the emissions it produces. What is deemed sufficient is described by the company's required rate of decoupling.



Graph 12.2 Enel's absolute emission reduction pathway for Scope 1–3 emissions according to Target XDC (IEA 2DS). The sum of each year's absolute emission as the surface below the curve represents Enel's 2 °C-compatible carbon budget for contributing to reaching the 2 °C climate target until 2050. The carbon budget is calculated based on scenario assumptions of the IEA 2DS (ETP 2016) scenario

To compute whether a certain measure, e.g. the implementation of a technology, is 2 °C-compatible, the following aspects need to be determined:

1. The measure's GVA potential: potential cost savings based on measure specific aspects such as energy consumption, maintenance or material efficiency minus the potential measure's investment costs.
2. The measure's emissions potential: potential Scope 1–3 emissions resulting from the measure, whereas Scope 2 emissions can be derived from energy consumption data.

The measure specific EEI is computed and compared to the average EEI requirements of the company's EEI pathway between start and end of life of the measure. The closer the EEI of the measure is to the company's average EEI in a 2 °C-scenario for the lifespan of the measure, the stronger will be the measure's support towards the company's achievement of the 2 °C target. In case the EEI of the measure is even lower than the company's average EEI in a 2 °C scenario for the lifespan of the measure, it supports a rate of decoupling of emissions from GVA, which even exceeds the necessary rate for the chosen 2 °C-scenario.

Assessing whether a measure supports the 2 °C target of a company or not consists of a long sequence of calculations. Within the scope of this study, it shall be stressed that due to its flexible setup, the XDC Model provides the possibility to understand a measure's contribution to reaching climate targets. A detailed description of how this can be done with the example of a technology for a car manufacturer is provided by Mathea (2018).

Evaluation of the XDC Model Against Requirements as Set Above

Having presented the structure and functioning of the XDC Model, followed by a set of context metrics and exemplary use cases, such as determining an emission reduction pathway and assessing whether a measure is 2 °C-compatible, the XDC Model can be benchmarked against the requirements for methods which determine the contribution of a single economic entity to climate change.

- *Forward-looking*: The XDC Model refers to the future in two ways: Firstly, it considers emissions and GVA between a base year, such as 2016, and 2050. Emissions and GVA are modelled for each year and can be adjusted to the effects of happenings on the amount of emissions and GVA in a certain year or a certain period of time. Secondly, future climate-related consequences of today's decision become apparent by being translated into levels of global warming, which is a relevant risk.
- *Scenario-based*: The XDC Model is scenario open, meaning not tied to only one scenario but can work based on different scenarios. Since it computes the impact of an economic entity based on input parameters GVA and emissions, which are cumulated for each year between a base year, such as 2016, and 2050, those input parameters can very simply be adjusted to different scenarios by the user. Since the XDC Model determines the impact of an economic entity through the simple climate model FaIR, temperatures corresponding to different amounts of emissions reaching the atmosphere can be determined. A beginner scenario might come in the form of different growth rates for GVA and Scope 1–3 emissions. A more sophisticated scenario may come in form of a detailed scenario framework aiming to model GVA and emissions and consisting of driving forces, context factors and a quantification of their relationships. The XDC of a company can thus be understood under different scenarios, enabling the user to understand the nature and magnitude of future risks and opportunities that can be derived from the impact of an economic entity to global warming.
- *Open for sensitivity analysis*: The analysis of climate-related risks and opportunities depends on data, which can be highly uncertain. Best examples are Scope 3 emissions of an economic entity or the value of a reasonable CO_2-price at a certain point in the near, mid and long term. Uncertainty does not allow for ignoring such factors, but requires methods incorporating a reasonable range of values for uncertain factors. The higher the uncertainty, the larger the range on which computations should be based on in order to derive valid and useful results. Because the XDC Model is connected to the simple climate model FaIR, which can determine temperature increases for any amount of CO_2eq reaching the atmosphere, a range of temperature increases can be determined for different levels of a chosen input parameter. In the context of the XDC Model, such parameters could be driving forces for GVA or emissions developments in the future. Depending on how sensitive the outcome is to changes of a certain input value, ranges of values that handle uncertainty in an appropriate manner, accredited findings in climate science. As a

conclusion, the XDC Model allows the user to conduct proper sensitivity analysis contributing to its ability to create sound results on the impact of an economic entity to global warming.
– *Science-based*: In the context of this study, we defined “science-based” as based on the latest findings of climate science and studies of the impact of climate change on socioeconomic structures. We stress that this definition applies to the climate-related computational processes of the model only and does not apply to bespoke input data or assumptions that vary under different scenarios. Since the climate model FaIR is an established and peer reviewed climate model, the XDC Model’s results can be used to derive an economic entity’s relation to the impacts of a certain degree of global warming on socioeconomic structures. We therefore conclude that the XDC Model is a science-based model, able to yield science-based climate metrics, such as a science-based emission reduction target of a company.
– *Transparency*: The XDC Model is accessible as an open source code and thus transparent in the way it computes the impact of an economic entity to global warming.

Outlook

Methodologies to understand the impact of a company on climate change and derive its exposure to climate-related risks are being developed and—in the case of the XDC Model—are ready to be used for exploring this new field of risk management. However, many questions remain to be solved.

Some of the most important questions refer to the consideration of the interdependencies of possible socioeconomic futures and climate change, which are relevant for the perception of climate-related risks and opportunities for a specific company:

- What does it mean to be a 4 °C-compatible company in a world in which the transition to a 2 °C-world is managed—driven by policy change motivated by a general mindset shift in which unsustainable practices would no longer be tolerated and sustainable practices gained support?
- What does it mean to be a 4 °C-compatible company in a world, in which the transition to a 2 °C-world is managed—driven by low levels of global trade and high social disparity?
- What does it mean to be a 1.5 °C-compatible company in a world shaped by levels of global warming of 4 °C, in which economy and international institutions are strong enough to cope with its consequences?
- What does it mean to be a 1.5 °C-compatible company in a world shaped by levels of global warming of 4 °C, in which economy is weak and international institutions are ineffective?

Such questions have not yet entered the conversation around climate-related scenario analysis in the practical world. In the academic world, the concept of the so-called Shared Socioeconomic Pathways (SSPs) point to how the XDC Model could provide insight on better and new conclusions.

The SSPs revolve around the interdependencies between different levels of global warming and socioeconomic pathways (O'Neill et al. 2015). They are built upon different elements, such as changes in demographics, human development, economy and lifestyle, politics and institutions, technology and environment and resources (O'Neill et al. 2015). IAMs can quantify the five different SSPs so that data is generated on e.g. the amount of emissions that would be released under a certain set of socioeconomic assumptions as comprised by one SSP (Riahi et al. 2016). Through this, corresponding climate physical effects can be determined so that challenges for mitigation and adaptation under the corresponding SSP can be derived (Riahi et al. 2016). A key insight from incorporating the SSPs into climate change and climate impact studies is that climate-related risks and opportunities of the same level of global warming as represented by an RCP vary significantly depending on socioeconomic conditions (Riahi et al. 2016; Diffenbaugh et al. 2007; Rogelj et al. 2018; Byers et al. 2018). Because of such findings, CMIP6 as the upcoming round of climate change scenarios, will incorporate SSPs in a more thorough manner into its results (O'Neill et al. 2016).

For further developing the XDC Model, this has two implications:

1. XDC results must be further contextualized with data on socioeconomic conditions. An XDC of 4.2 °C for a company given resilient socioeconomic conditions has to be interpreted differently from an XDC of 4.2 °C for a company given fragile socioeconomic conditions. For the latter, social costs of carbon might be higher, resulting in a hypothetically higher exposure of that company due to being held accountable for the damages that its impact on global warming results renders.
2. SSPs datasets must be incorporated into the computation of country-, sector- and company-specific EEIs. The quantification of each SSP through different IAMs provides the opportunity to base computations on bandwidths that cover a scientifically established and plausible space of uncertainty for several parameters, such as carbon prices. The user's possibility to generate robust results could be well improved by such a step.

Some questions also refer to the climate science behind the XDC Model. Besides improvements through the further incorporation of the socioeconomic dimension, the XDC Model will be improved through the way it connects an amount of emissions to a level of temperature. Climate scientific findings and climate change scenarios are dynamic and have to be adjusted to latest findings. With regards to the XDC Model, this applies to several sub-elements of the simple climate model FaIR, such as the role of short-lived climate pollutants or the magnitude of climate change feedbacks.

This study has presented the XDC Model as a method to compute the impact of an economic entity to global warming and derive its exposure to climate-related risks under various scenarios. Through several examples, it has stressed the flexibility of the model and its robustness when it comes to generating relevant metrics and information for assessing how climate-proof a company's strategy is. Further improvements and extensions of the model revolve mainly around further incorporating the socioeconomic dimension.

It can be concluded that the XDC Model can be of great assistance towards determining best possible strategies to detect and eventually deal with climate-related risks and opportunities in a world shaped by climate change.

References

Byers E et al (2018) Global exposure and vulnerability to multi-sector development and climate change hotspots. Environ Res Lett 13(5):055012. https://doi.org/10.1088/1748-9326/aabf45

Colas J, Khaykin I, Pyanet (2019) A climate change: managing a new financial risk. Available via Oliver Wyman. https://www.oliverwyman.com/content/dam/oliver-wyman/v2/publications/2019/feb/Oliver_Wyman_Climate_Change_Managing_a_New_Financial_Risk1.pdf. Accessed 6 May 2019

Dietz S, Bowen A, Dixon C, Gradwell P (2016) 'Climate value at risk' of global financial assets. Nat Clim Change. https://doi.org/10.1038/nclimate2972

Diffenbaugh NS et al (2007) Indicators of 21st century socioclimatic exposure. PNAS 104(51):20195–20198. https://doi.org/10.1073/pnas.0706680105

Enel S.P.A. (n.d.a) Annual report 2016. https://www.enel.com/content/dam/enel-com/governance_pdf/reports/annual-financial-report/2016/Annual_Report_2016.pdf. Accessed 02 May 2019

Enel S.P.A. (n.d.b) Decarbonization of the energy mix. https://www.enel.com/content/dam/enel-com/storie/doc_pdf/112-119_ENG_BDS2016_20170502_4WEB.pdf. Accessed 02 May 2019

European Union (2018) Communication From The Commission To The European Parliament, The European Council, The Council, The European Central Bank, The European Economic And Social Committee And The Committee Of The Regions—Action Plan: Financing Sustainable Growth. Available via EU. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0097&from=EN. Accessed 6 May 2019

Eurostat (n.d.) Eurostat, Luxemburg. https://ec.europa.eu/eurostat/data/database. Accessed 13 May 2019

Genesis-Online Datenbank (2019) Statistisches Bundesamt, Wiesbaden. https://www-genesis.destatis.de/genesis/online. Accessed 2 May 2019

Gitsham M (2018) Why climate change and other global problems are pushing some business leaders to embrace regulation. In: Sustainability. Harvard Business Review. Available via Harvard Business Review. https://hbr.org/2018/10/why-climate-change-and-other-global-problems-are-pushing-some-business-leaders-to-embrace-regulation. Accessed 6 May 2019

Hartin CA et al (2015) A simple object-oriented and open-source model for scientific and policy analyses of the global climate system—Hector v1.0. Geosci Model Dev 8:939–955. https://doi.org/10.5194/gmd-8-939-2015

Hassani BK (2016) Scenario analysis in risk management—theory and practice in finance. Springer, Switzerland

Hirsch AL, Wilhelm M, Davin EL et al (2017) Can climate-effective land management reduce regional warming? J Geophys Res Atmos 122:2269–2288. https://doi.org/10.1002/2016JD026125

Hoffmann VH, Busch T (2008) Corporate carbon performance indicators: carbon intensity, dependency, exposure and risk. J Ind Ecol 12(4):505–520. https://doi.org/10.1111/j.1530-9290.2008.00066.x

IEA (2017) Energy technology perspectives 2017—catalysing energy technology transformations. Available via ACS-GIZ. http://www.acs-giz.si/resources/files/Energy_technology_perspectives.pdf. Accessed 6 May 2019

IIASA (2013) MESSAGE. In: Models, tools, and data. International Institute for Applied Systems Analysis. Available via International Institute for Applied Systems Analysis. http://www.iiasa.ac.at/web/home/research/modelsData/MESSAGE/MESSAGE.en.html. Accessed 6 May 2019

IPCC (2018) Global warming of 1.5 °C. An IPCC Special Report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty, Chapter 2. Intergovernmental Panel on Climate Change. Available via Intergovernmental Panel on Climate Change. https://www.ipcc.ch/sr15/chapter/2-0/. Accessed 9 May 2019

ISIMIP (n.d.) Impact model settings & characteristics. https://www.isimip.org/impactmodels/. Accessed 6 May 2019

Kok K, Pedde S, Gramberger M et al (2018) New European socioeconomic scenarios for climate change research: operationalising concepts to extend the SSPs. Reg Environ Chang 19(3):643–654. https://doi.org/10.1007/s10113-018-1400-0

Leaton J, Grant A (2018) 2 degrees of separation—transition risk for oil and gas in a low carbon world. Available via CarbonTracker. https://www.carbontracker.org/reports/2-degrees-of-separation-transition-risk-for-oil-and-gas-in-a-low-carbon-world-2/. Accessed 6 May 2019

Loulou R et al (2005) Documentation for the TIMES model—Part 1. Available via IEA ETSAP. http://iea-etsap.org/docs/TIMESDoc-Intro.pdf. Accessed 6 May 2019

Martinez-Moyano IJ (2012) Documentation for model transparency. Syst Dyn Rev 28(2):199–208. https://doi.org/10.1002/sdr.1471

Mathea M (2018) Development of a methodological approach for evaluating technologies under the consideration of science-based climate metrics. Master thesis, Johannes Gutenberg-Universität Mainz

Mattauch L et al (2018) Steering the climate system: an extended comment. Centre for Climate Change Economics and Policy Working Paper No. 347. Available via London School of Economics and Political Science. http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2019/01/working-paper-315-Mattauch-et-al.pdf. Accessed 9 May 2019

McSweeney R, Hausfather Z (2018) Q&A: How do climate models work? Available via CarbonBrief. https://www.carbonbrief.org/qa-how-do-climate-models-work. Accessed 6 May 2019

Millar RJ et al (2017a) A modified impulse-response representation of the global near-surface air temperature and atmospheric concentration response to carbon dioxide emissions. Atmos Chem Phys 17:7213–7228. https://doi.org/10.5194/acp-17-7213-2017

Millar RJ et al (2017b) Emission budgets and pathways consistent with limiting warming to 1.5 °C. Nat Geosci 10(10):741–747. https://doi.org/10.1038/ngeo3031

O'Neill BC, Kriegler E, Riahi K et al (2014) A new scenario framework for climate change research: the concept of shared socioeconomic pathways. Clim Change 122(3):387–400. https://doi.org/10.1007/s10584-013-0905-2

O'Neill BC et al (2015) The roads ahead: narratives for shared socioeconomic pathways describing world futures in the 21st century. Global Environ Change. https://doi.org/10.1016/j.gloenvcha.2015.01.004

O'Neill BC et al (2016) The scenario model intercomparison project (ScenarioMIP) for CMIP6. Geosci Model Dev 9:3461–3482. https://doi.org/10.5194/gmd-9-3461-2016

OECD Data (n.d.) Organisation for economic co-operation and development, Paris. https://data.oecd.org. Accessed 2 May 2019

Porter M, Kramer M (2006) Strategy and society: the link between competitive advantage and corporate social responsibility. Harvard Bus Rev 84(12):78–93

Ranganathan J et al (2004) The greenhouse gas protocol—a corporate accounting and reporting standard (Revised Edition). World Business Council for Sustainable Development, World Resources

Institute. Available via GHG Protocol. https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf. Accessed 6 May 2019
Riahi K et al (2016) The shared socioeconomic pathways and their energy, land use, and greenhouse gas emissions implications: an overview. Glob Environ Change 42:153–168. https://doi.org/10.1016/j.gloenvcha.2016.05.009
Ricke K, Drouet L, Caldeira K, Tavoni M (2018) Country-level social cost of carbon. Nat Clim Change 8:895–900. https://doi.org/10.1038/s41558-018-0282-y
Rogelj J et al (2018) Scenarios towards limiting global mean temperature increase below 1.5 °C. Nat Clim Change 8:325–332. https://doi.org/10.1038/s41558-018-0091-3
Rose S, Scott M (2018) Company climate risk: developing a technical foundation for companies, investors, & others. Presentation held at UNFCCC COP24, Katowice, Poland, 13 Dec 2018
SBTi (2015) Sectoral decarbonization approach (SDA): a method for setting corporate emission reduction targets in line with climate science. Science-Based Target initiative. Available via Science-Based Target initiative. https://sciencebasedtargets.org/wp-content/uploads/2015/05/Sectoral-Decarbonization-Approach-Report.pdf. Accessed 10 May 2019
SBTi (2017) Science-based target setting manual. Science-Based Target initiative. Available via Science-Based Target initiative. https://sciencebasedtargets.org/wp-content/uploads/2016/10/SBT-Manual-Draft.pdf. Accessed 10 May 2019
SBTi (2019a) Foundations of science-based target setting. Science-Based Target initiative. Available via Science-Based Target initiative. https://sciencebasedtargets.org/wp-content/uploads/2019/03/SBTi-criteria.pdf. Accessed 2 May 2019
SBTi (2019b) SBTi criteria and recommendations. Science-Based Target initiative. Available via Science-Based Target initiative. https://sciencebasedtargets.org/wp-content/uploads/2019/03/SBTi-criteria.pdf. Accessed 10 May 2019
SBTi (2019c) Science-based target setting manual. Science-Based Target initiative. Available via Science-Based Target initiative. https://sciencebasedtargets.org/wp-content/uploads/2017/04/SBTi-manual.pdf. Accessed 10 May 2019
Schewe J et al (2019) State-of-the-art global models underestimate impacts from climate extremes. Nat Commun 10:1005. https://doi.org/10.1038/s41467-019-08745-6
Schneiderman ET (2015) Assurance of discontinuance No.15-242. In the matter of Investigation by Eric. T Schneiderman, Attorney General of the State of New York, of Peabody Energy Corporation. Available via New York State Attorney General. https://ag.ny.gov/pdfs/Peabody-Energy-Assurance-signed.pdf. Accessed 6 May 2019
Schulte J, Hallstedt SI (2018) Company risk management in light of the sustainability transition. Sustainability 10(11):4137. https://doi.org/10.3390/su10114137
Schwarber AK et al (2018) Evaluating climate emulation: unit testing of simple climate models. Earth Syst Dyn Discuss https://doi.org/10.5194/esd-2018-63
Smith CJ et al (2018) FAIR v1.3: a simple emissions-based impulse response and carbon cycle model. Geosci Model Dev 11:2273–2297. https://doi.org/10.5194/gmd-11-2273-2018
Steffen W et al (2016) Stratigraphic and earth system approaches to defining the anthropocene. Earth's Future 4(8):324–345. https://doi.org/10.1002/2016EF000379
Stirling A (1998) On the economics and analysis of diversity. SPRU Electronic Working Papers Series (28)
Task Force on Climate-related Financial Disclosures (2017a) Final report: recommendations of the task force on climate-related financial disclosures. https://www.fsb-tcfd.org/wp-content/uploads/2017/06/FINAL-2017-TCFD-Report-11052018.pdf. Accessed 6 May 2019
Task Force on Climate-related Financial Disclosures (2017b) Technical supplement: the use of scenario analysis in disclosure of climate-related risks and opportunities. https://www.fsb-tcfd.org/wp-content/uploads/2017/06/FINAL-TCFD-Technical-Supplement-062917.pdf. Accessed 6 May 2019
The NOAA Annual Greenhouse Gas Index (AGGI) (2018) NOAA earth system research laboratory, Boulder Colorado. https://www.esrl.noaa.gov/gmd/aggi/aggi.html. Accessed 2 May 2019

Thompson TM (2018) Modeling the climate and carbon systems to estimate the social cost of carbon. WIREs Clim Change 9(5):e532. https://doi.org/10.1002/wcc.532

United Nations (n.d.) Sustainable development goals. https://sustainabledevelopment.un.org/sdgs. Accessed 6 May 2019

Wilson C, Pettifor H, Cassar E et al (2019) The potential contribution of disruptive low-carbon innovations to 1.5 °C climate mitigation. Energ Effi 12(2):423–440. https://doi.org/10.1007/s12053-018-9679-8

World Bank Open Data (n.d.) The World Bank, Washington. https://data.worldbank.org. Accessed 2 May 2019

World Economic Outlook Database (2019) International monetary fund, Washington. https://www.imf.org/external/pubs/ft/weo/2019/01/weodata/index.aspx. Accessed 2 May 2019

Part II
Case Studies on Climate Services

Chapter 13
Climatological Global Solar UV Index: Measurement and Health Issues in Malta

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Abstract This study evaluated the knowledge, perceptions and behaviour of the Maltese population regarding ultraviolet radiation (UVR) exposure and sun protection attitudes. It also assessed whether the published Global Solar Ultraviolet Index (UVI) forecasts by the national local weather service are an accurate representation of the actual local UVR exposure. An analysis of long-term trends in the incidence of skin cancer in Malta was affected. This study revealed high local awareness levels in relation to UVI (96%), a relatively high familiarity with its significance (74%) and a relatively high follow-up of the published UVI forecasts during the summer months (72%). Notwithstanding this, 79% of the respondents claimed sun exposure during sun peak hours in summer. Furthermore worrying increasing trends in the reported cases of all skin cancer types over the past two decades were revealed. It was also established that 81% of locally published UVI forecasts were within ±1 UVI unit when compared to ground based integrated erythemally weighted ultraviolet radiation (UVER) data. This study demonstrated the importance for better focused sun protective campaigns and the relevance of a practical and easily communicable UVI concept using modern media applications so as to address the worrying situation of an ever-increasing trend in skin cancer incidence.

Introduction

UVR has been implicated to have significant impacts on human health. Appreciation of the negative effects of UVR has particularly been spurred by the discovery of the depletion of stratospheric ozone as a result of excessive anthropogenic release of chlorofluorocarbons in the atmosphere (Diffey 2002).

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Although minimal UVR exposure is required for the production of the essential Vitamin D, excessive UVR exposure can be a significant burden on human health especially on the skin (WHO 2006). In fact, skin cancer is the most significant complication of chronic UVR exposure (WHO 2006). There is general agreement among the scientific community that UVR plays a crucial role in the development of all skin cancer types as it is involved in the various mechanisms of the development of cancer (D'Orazio et al. 2013).

Skin cancer is the most commonly diagnosed cancer in the world amongst fair-skinned populations (IARC 2012a). Also according to the WHO International Agency for Research on Cancer (IARC) figures, both the incidence and mortality rates of all skin cancer types are on the increase globally (IARC 2012a). Although non-melanoma skin cancer (NMSC) is commoner than melanoma skin cancer (MSC), the latter is much more significant, due to its aggressive nature and its capability to spread to distant organs. In fact, although MSC constitutes only 5–10% of all skin cancer types, it makes up for 75% of skin cancer related deaths and is one of the most common causes of cancer related deaths among young people (de Vries et al. 2012).

In an attempt to increase sun awareness and to promote behavioural changes related to sun exposure the concept of the UVI was introduced by the WHO. Initially introduced in Canada in 1992, this unitless value which ranges between 1 and 11+ aimed to give a magnitude to harmful UVR (Kerr et al. 1994). Subsequently, Australia and USA, as well as other countries developed their own UVI. This was standardised in 1995 by the WHO and other organisations to serve as an indicator of erythema (inflammation of the skin) which is considered to be closely related to chronic skin damage that could lead to skin cancer. Another aim of the UVI was to serve as an international standard measure of long-term UVR reaching the Earth's surface. This would enable the assessment of any changes in the incident UVR arising from different causes such as anthropogenic causes (Allinson et al. 2012). Finally, in 2002 this concept was expanded by the WHO as a health awareness educational tool that should be promoted in sun protection campaigns.

The recognition of the ozone hole in the Southern Hemisphere and the increased awareness of the negative impacts of UVR, triggered the development of new instruments and methodologies by which UVI can be measured or predicted (Diffey 2002). In response to the WHO's recommendations, this concept was adopted by different countries in their sun protection campaigns. Such campaigns aimed to increase the knowledge of the negative impacts of excessive sun exposure thereby discouraging excessive sun exposure during sun peak hours especially in the summer months when the UVI levels increase drastically. The Australian and US campaigns have made extensive use of the UVI concept through different media sources, including UVI alerts via smartphone applications and internet widgets. Conversely, sun protection campaigns in Europe have as yet not followed the Australian and US approach in the promotion of UVI as a means of eliciting more sun protective practices. In fact, the primary focus of "Euromelanoma" campaign, which is the European initiative, is on the detection of MSC lesions at an early stage among high risk individuals. Since its introduction in 1999, this campaign has spread rapidly and is now active in 33 European countries with over 450,000 people having received free skin examinations (Euromelanoma 2019).

Although sun protection campaigns have been running for at least three decades, there are conflicting findings in published literature regarding sun protective knowledge and the use of sun protection mechanisms among the populations studied. Low use of sun protective mechanisms were reported globally, even in countries where studies have shown high levels of sun protection knowledge (Kasparian et al. 2009). Studies have also reported discrepancies by gender, age group and educational attainment in relation to sun protective attitudes.

Published literature also evidenced a wide variation in the familiarity and knowledge of UVI, showing that persons from European countries are less familiar with this concept when compared to Australian counterparts and that UVI forecasts are not influencing the sun protection behaviour (Italia and Rehfuess 2012). To date few studies assessed the preferred methods by which UVI forecasts and UVI alerts are being disseminated and analysed in terms of their effectiveness. In addition, these few studies have focused more on traditional media sources and have not assessed the use of more modern tools such as smartphone applications and internet widgets.

These findings have raised questions regarding the effectiveness of sun protection campaigns especially when increasing trends in all skin cancer types have been reported globally. IARC is predicting that skin cancer rates will double in the next two decades (IARC 2012a).

Climate change will also be impacting the incident UVR reaching the Earth's surface. Warming of the climatic system may result in the increase in atmospheric water content which in turn will pronounce stratospheric ozone depletion, leading to an increase in incident UVR reaching the Earth's surface (Williamson et al. 2014). Furthermore, warmer temperatures may also be associated with a higher number of sunburn episodes increasing skin cancer risks. Such risks have also been demonstrated to be accentuated in climatic conditions of higher temperatures and high humidity. This will provide a direct association between climate change and skin cancer risk. On the other hand, higher temperatures can also increase UVR induced Vitamin D synthesis which is also beneficial to health (Anderson 2012). Thus, the net balance of benefits and risks of a warmer climate is difficult to predict as it is a combination of various factors including stratospheric ozone depletion, subsequent increased levels of UVR and changes in sun exposure behaviours (Williamson et al. 2014).

The Current Maltese Scenario and the Aims of This Study

The Maltese Archipelago is located in the southern central region of the Mediterranean Sea, 80 km south of Italy and 284 km east of Tunisia and having a total area of around 316 km^2. The Maltese population in 2017 was 475,000 (NSO 2018a). Malta's climate is typical of the Mediterranean and is strongly influenced by the sea (Galdies 2011). The Maltese islands have a pleasant sunny climate with a daily average of around 12 h sunshine in summer going down to 5–6 h in mid-winter. This favourable climate attracts a substantial number of tourists each year (in 2017, more than 2 million tourists visited the islands, NSO 2018b).

The Malta Cancer Registry (MCR) reported that between 1993 and 2013 there were 8725 new cases of skin cancer which can be divided into 7622 cases of NMSC and 985 cases of MSC (MCR 2015). The incidence rate of MSC in Malta is 7.3 per 100,000 and is comparable with that of Spain which is 8.6 (IARC 2012b). When considering the mortality rates of MSC adjusted to the age standardized rates of European population per 100,000, the European average is 2.3. The Maltese mortality rate (1 per 100,000) compares well with those of neighbouring Mediterranean countries (IARC 2012a).

Awareness campaigns on the potential harmful effects of UVR and the promotion of the use of sun protection mechanisms have been held in spring and summer since the early 1990s (Scerri et al. 2002). However, to date the UVI concept is not being widely used as a tool for sun protection in these campaigns.

The only source of UVI forecasts in Malta is through a couple of weather portals including that of the Malta Meteorological Office (Malta MET Office). In local weather portals there is no data referring to ground based integrated erythemally weighted ultraviolet radiation (UVER) that could serve as a comparison and validation to the UVI forecasts.

UVI forecasts are reported daily in weather forecasts in traditional media sources (including television, radio and newspapers). However, no explanation regarding the implication of the UVI values or the recommended sun protection mechanisms that should be adopted are stated. Also, currently there are no forms of UVI alerts on media, even when very high or extreme levels of UVI are being forecasted.

Furthermore the following gaps in knowledge were identified, thereby highlighting the need for a comprehensive study to address these issues.

- Although the Malta MET Office consistently reports very high UVI forecasts, which exceed UVI 10 during the summer months, no studies have ever assessed the accuracy of these forecasts in relation to ground based UVER data. Consequently, it is still unclear whether these forecasts are an accurate representation of UVI especially during the summer months.
- No studies have investigated the knowledge and awareness of UVI and its impact on sun protection behaviour among the Maltese general population. Also, no studies had ever assessed the effectiveness of the limited communication methods that are being used and the ways the general public would like to be informed of high UVI.
- There is no published material referring to high UVI alerts in Malta. Additionally, no studies have ever assessed the preferred sources by which such alerts should be communicated to the general public.
- No local studies have assessed the impact of climate change on the skin cancer incidence rates in Malta.

With an emphasis on a changing climate and related changes in the statistical distribution of weather patterns associated with increased levels of UVR reaching the surface, the aims of this study were:

- To correlate the published UVI forecasts by the Malta MET Office with the ground based UVER measurements by means of broad filter radiometers (BFR).
- To assess the awareness, knowledge and behaviour of the Maltese population in relation to UVI and sun protection.
- To assess long term trends in the incidence of skin cancer in Malta

The methodologies used to investigate the above will be discussed in three different sections. The findings of this study will also be discussed in the respective sections.

UVR Measurements and Forecasts

The first attempts to measure UVR were made in the first two decades of the twentieth century by using potassium and cadmium cells. However, it was the detection of the ozone hole in the Southern Hemisphere and its potential negative impacts on health in the 1980s that induced further interest in measuring UVR more accurately. This focus on UVR measurement resulted in the manufacturing of different radiometers and also the development of alternative methodologies to estimate UVR (Diffey 2002).

The next section will discuss briefly the different methodologies by which UVR can be measured or estimated from which UVER can be calculated.

UVR Measurements Using Ground Based Instruments

In the last two decades of the twentieth century, a number of different instruments have been developed to measure and calculate the incident UVR reaching the Earth's surface. These ground based instruments vary in complexities and capabilities and can be categorised into three types which include spectroradiometers, multifilter narrow band radiometers (MNBRs) and broadband filter radiometers (BFRs).

Spectroradiometers, which are the most accurate due to their complexity, measure the intensity of the UVR as a function of wavelength. The measurements are done at 0.5 nm intervals at high resolution. UVR measurements can be achieved using either mechanical scanning or using microarray techniques (Kerr and Fioletov 2008). They provide reference data which permits the study of UVR under different conditions. Brewer and Dobson spectroradiometers are the most common types available.

MNBRs have four to seven filters at different wavelengths which are used to measure UVR at that particular wavelength using a resolution of 2–10 nm. The presence of filters permits simultaneous measurement of UVR at different wavelengths in a few seconds. MNBRs are easier to operate and cheaper than spectroradiometers but have significantly less resolution than the latter (Kerr and Fioletov 2008).

BFRs use one filter which allows the passage of radiation over a large wavelength range. The radiometer's detector which is composed of thermopiles measures the UVR wavelength range of that specific filter. Unlike spectroradiometers they cannot measure specific wavelengths but only a range which is determined by the inbuilt filter. BFRs are available with different filters of different wavelengths enabling the measurement of UVA, UVB and UVT. Radiometers with filters that replicate the erythemal action spectrum permit the measurement of UV erythemal irradiance (UVE). These types of instruments are specifically used for the calculation of the UVI since this is directly proportional to the erythemal irradiance (Kerr and Fioletov 2008). BFRs are most commonly used for measuring irradiance and for the estimation of UVI for public use. When compared to the other radiometers discussed so far, they are relatively inexpensive and due to their compactness can be easily transported from one place to another. However, unlike other radiometers, they can only measure one parameter thereby one cannot differentiate between different UVR wavelengths (Kerr and Fioletov 2008).

UVI Calculations Using BFRs

As already discussed, BFRs are available with various filters of different wavelengths enabling the measurement of UVR.

UVI is directly proportional to the UVE. Therefore in the case of BFRs which have filters that replicate the erythemal action spectrum, UVI can be calculated by multiplying the measured UVE in W/m^2 by the constant (k_{er}) equal to 40 m^2/W (WHO 2002).

The subsequent UVI data is better known as UVER and this is unitless.

UVR Estimation Methods

Apart from ground based instruments, there are alternative methodologies that can be used to estimate UVR and other atmospheric components from which UVI can be estimated or forecasted. Such methods which are very complex will only be discussed briefly in this section.

UVR can also be estimated using data which is supplied by monitoring instruments on board of satellites. For example, monitoring instruments like the US "Total Ozone Mapping Spectrometer" (TOMS), the Dutch/Finnish "Ozone Monitoring Instrument" (OMI) and the European "Global Ozone Measurement Experiment" (GOME) have global coverage and provide daily datasets of atmospheric components such as the Total Ozone Column (TOC) data, aerosols and cloud cover. These readings use the backscatter of the Earth's surface to space to measure these components. When these datasets are coupled with other temporal and geophysical data UVR estimates can be performed. This data is available online from the respective websites of the instruments mentioned above (Kerr and Fioletov 2008). The limitations of these estimates include overlapping factors that can affect the accuracy of the provided data.

UVR and the concentration of atmospheric components can also be estimated by the use of Radiative Transfer models (RTMs). This can be performed by using radiative transfer equations and simulating the atmospheric conditions using satellite based data and geophysical data. The radiative transfer equation is based on the energy transfer involved when radiation enters a medium, in this case the atmosphere. By taking into account the absorption, emission and scattering phenomena that take place in the atmosphere, in conjunction with the temporal and geophysical data of a particular place, it is possible to estimate UVR (Kerr and Fioletov 2008). These models provide widespread data in forecasting UVI. If UVR data from ground based instruments such as MNBRs is integrated with such models, it is possible to construct high resolution spectra. They are also frequently used for comparison purposes with BFR data for research studies. The limitations of such estimates include their complexity, which requires expertise in the field. For more accurate estimates, three dimensional transfer models need to be used to simulate the effects of scattered or broken clouds, uneven terrain features, snow cover and albedo. Such computations which are very complex also require expertise in IT systems (Kerr and Fioletov 2008).

Apart from estimating UVR data, it is also possible to use statistical models to make UVR forecasts. These statistical models use ground based measurements of UVR which are dependent variables, and relate them to other independent variables including meteorological and geophysical data. Independent variables which are taken into account include TOC, aerosols, dust, cloud and snow cover, albedo and humidity. However, for these forecasts to be computed it is essential to have past UVR datasets of ground based readings and also past meteorological and geophysical readings available. When all this data is entered into these statistical models one can forecast UVR from independent variables, which can be obtained from satellite data. These forecasts are frequently used for meteorological purposes and are available online. Inaccuracies of these forecasting models include factors such as pollution, which can vary significantly, especially in cities (Kerr and Fioletov 2008).

Correspondence Between Forecast and UVER Data

The first aim of this study was to correlate the published UVI forecasts by the Malta MET Office with the ground based UVER data using BFRs. The study period was between May and September 2015 where the highest UVR exposure levels are experienced during the year.

Forecast UVI Data

The Malta MET Office publishes UVI forecasts on their website https://www.maltairport.com/weather/7-day-forecast/ resulting from collaborative agreement with the Dutch based website TEMIS. This website uses a combination of satellite data which is integrated to RTMs to forecast clear sky UVI and TOC data at solar noon, for a particular location depending on its longitude and latitude. Solar noon forecasts are used since these correspond to the highest position of the sun above the meridian in which UVR/UVI levels are at their highest (van Geffen et al. 2005). This website provides six day UVI forecasts for a number of locations including that of the Malta MET Office (Latitude, Longitude, 35° 51′ 00″N14° 28′ 48″E). (http://www.temis.nl/uvradiation/archives/overpass/uv_Malta_airport_Malta_ENS_M8.dat).

The forecast UVI data between May 2015 and September 2015 pertaining to the Malta MET Office coordinates was downloaded from the archive section of the TEMIS website https://www.temis.nl/uvradiation/archives/overpass/uv_Maltaairport_Malta_ENS_M8.dat.

Since the TEMIS forecast UVI data assumes clear sky conditions, cloudy days were excluded from the study.

Determination of clear sky days were characterised using the Clearness Index (Kt). Antón et al. (2009) define this index as the ratio between the Total solar irradiance at ground level over a horizontal surface (E_G) and the corresponding atmospheric total solar irradiance also known as the Extraterrestrial irradiance (E^{TOA}).

$$K_t = \frac{E_G}{E^{TOA}}$$

The Clearness Index variations are attributed to the attenuation of solar irradiance due to cloud cover and aerosols. As a corollary this index is the fraction of the atmospheric solar irradiation that reaches the Earth surface. This expression has been widely used in similar studies such as those by Canada et al. (2000), as well as by Antón et al. (2009) to determine clear sky days.

Measurement of UVE Data

In this study the BFR with the filter that replicates the erythemal action spectrum used was the Kipp and Zonen UV-S-E-T model. This instrument was acquired by the Institute for Sustainable Energy and installed in its premises in Marsaxlokk (Latitude, Longitude, 35° 49′ 48″N 14° 32′ 24″E). This radiometer was connected to a Campbell Scientific CR1000 model data logger, which is programmed to take readings at specified time intervals of 1 min. UVE data between 27th May 2015 and 30th September 2015 was collected for the purpose of this study.

As per the Kipp and Zonen (2016) product instructions the UVE raw data was corrected for TOC and SZA using the appropriate software (UVIATOR) which is supplied by the manufacturing company.

The TOC and SZA data used for this correction was OMI-TOMS algorithm data. This data was retrieved from the NASA–EOS Aura satellite and is available from the NASA Aura Validation Data Centre website. Corrected UVE data using the UVIATOR software was used to calculate the UVER data.

Comparison Between Forecast UVI and UVER Data

As summarised in Table 13.1, this study found that 81% of the published Forecast UVI during the study period were within ±1 UVI unit when compared to the UVER data. Furthermore, almost half of the Forecast data (46%) were within the ±0.5 UVI unit. Also, 72% of all Forecast UVI data were within the ±10% of the UVER data. It was also demonstrated that 70% of the published Forecast UVI was higher than the UVER data.

This study found that in 70% of the cases, the Forecast UVI data was higher than the UVER data, while in 27% of the cases the opposite was applicable. Various authors such De Backer et al. (2001) and Gies et al. (2004) have highlighted the fact that forecast data should be an accurate representation of UVR exposure at ground level. However, in cases of disagreement between the two sets of data, it is important that the forecast UVI is higher than the ground based UVER reading to

Table 13.1 Comparison between UVER data and forecast UVI data

	Dataset (n) (in clear sky conditions)	% variation
Absolute variation between Forecast UVI and UVER data in UVI units	104	Variation within 0.5 UVI units = 46% Variation within 1.0 UVI units = 81% Variation within 1.5 UVI units = 98%
Variation between Forecast UVI and UVER data as a percentage of UVER	104	5% variation from UVER = 39% 10% variation from UVER = 72% 15% variation from UVER = 90%
Variation (±) between Forecast UVI and UVER data	104	Forecast higher than UVER = 70% Forecast lower than UVER = 27% Forecast is equal than UVER = 3%

ensure that the general public takes the recommended precautions as per the WHO (2002) recommendations.

The findings in this study confirm that the published UVI forecasts by the Malta MET Office are a good representation of the measured UVER/UVI exposure. Although statistical tests demonstrated that there is significant difference between the differences of the means of the two datasets (Paired t-Test; p-value is 0) and a modest association between the two datasets (Linear regression model, R^2 static is 0.626), as demonstrated in similar studies, variation between forecast and UVER data within ± 1 UVI unit is considered to be accurate for appropriate use of these forecasts.

Nevertheless, in those 27% of the cases where the Forecast UVI was lower than UVER data, the implication could be significant especially when the magnitude of the discrepancy is of 1 UVI or more. This is particularly relevant when the divergence occurs at the high end categories of the UVI (6+) especially in the summer months where additional sun protection mechanisms are necessary. Since these discrepancies were demonstrated in the summer months (June–September 2015), this could imply that the climatological forecast UVI data method in use is not accurate enough and a more robust methodology needs to be adopted.

A limitation of this study was that the findings could not be compared to previous local studies since no published studies have ever compared the Forecast UVI data published by the Malta MET Office with ground based UVER readings. These can serve as a baseline study against which further studies using diverse instruments with different sensitivities can be compared.

Also, the dataset used for the comparison of Forecast and UVER data was limited to one summer period between May and September 2015 due to the fact that the BFR used to measure UVE from which UVER data was calculated was only available during this timeframe.

Awareness, Knowledge and Behaviour in Relation to UVI and Sun Protection

The second aim of this study was to assess the awareness, knowledge and behaviour of the Maltese population in relation to UVI and sun protection. In order to achieve this, a telephone-based survey was performed.

After considering various sampling methods available, the sampling method used in selecting a stratified sample was a modified multistage random sampling method. In this case a two-stage sampling design was used. The first stage in multistage sampling is to divide the population into clusters and then take a sample from each one of the clusters. The advantage of such a sampling system is that one can take an independent sample from a number of clusters (Crawford 1997). The sample was taken from the latest Go Telephone Directory, which is the most comprehensive source of fixed telephone numbers of the Maltese population. The random sample

Table 13.2 Population study classified by gender, age group and highest education level attained

Gender	Number of respondents (n)	% Population of survey respondents (%)	Age distribution (%)	Highest education level attained (%)
Males	198	49.5	18–25: 14%	Primary: 11%
			26–40: 27%	Secondary: 43%
			41–60: 34%	Post-secondary: 27%
			61+: 25%	Tertiary: 19%
Females	202	50.5	18–25: 13%	Primary: 17%
			26–40: 25%	Secondary: 41%
			41–60: 32%	Post-secondary: 30%
			61+: 30%	Tertiary: 12%
Total	400	100	–	–

used in this study was stratified by gender and age on the basis of the most recent census of the Maltese general population taken in 2011 by the NSO. The level of education attained was also assessed. These stratifications permitted the assessment of possible trends by gender, age group and education in relation to the questions asked.

Based on the local population, a sample of 384 persons was necessary in order to have a confidence level of 95% and a margin of error of 5%. However, this number was rounded up to 400. The telephone survey was conducted between October 2014 and February 2015. Table 13.2 summarises the survey study population by gender, age distribution and highest education level attained.

Awareness and Impact of UVI Forecasts

This study found very high awareness levels in relation to UVI, high familiarity with the significance of a UVI of 9 and also a relatively high following of the published forecasts in the media during summer. In fact, 96% of the persons interviewed were aware of the UVI, 74% interpreted a UVI of 9 correctly and 72% claimed that they follow UVI forecasts in summer. These findings are in line with the findings found in Australia and US whilst significantly higher than those reported in other European countries.

However, despite the high familiarity with the UVI, only 26% of the study population replied that the UVI forecasts impacted on their work or leisure activities. In addition, 79% of those interviewed claimed sun exposure during peak sun hours, whilst more than half of them do so at least once a week. This finding shows that although a large proportion of the Maltese population acknowledge the significance of high UVI and is aware of the negative impacts of sun exposure, paradoxically this is not being translated into the expected behavioural change.

Results show that there is an association between the level of education attained and impact of UVI forecasts on work/leisure activities (p is 0.002). In fact, persons with primary and secondary education tend to be less affected by these forecasts, when compared to persons with higher education levels.

Preferred Sources by which UVI Forecasts are Communicated to the General Public

This study has also investigated the preferred sources of UVI forecasts and their effectiveness in clearly communicating these forecasts to the general public. Television (94%), internet and social media (55%), and radio (48%) were the favourite sources by which UVI forecasts are being communicated. However, the study population mentioned that UVI forecasts are most clearly communicated through internet and social media (92%), followed by television (67%) and radio (45%).

Preferred Sources by which High UVI Alerts are Communicated to the General Public

This study also assessed the preferred sources by which high UVI alerts should be communicated to the general public. The four different methods given to the study population included:

- During weather forecasts
- Spots during television programmes
- Internet widgets/Smartphone alerts via specialised applications
- Ongoing beach education.

Communication of such data during weather forecasts and spots during television programmes were the preferred method among the study population in comparison to other modern sources such as internet widgets/smartphone alerts and ongoing beach education. However, internet widgets and smartphone alerts were the preferred sources of UVI alerts communication among persons with tertiary education. Conversely, these methods were the least preferred sources amongst those with primary and secondary education. Also, internet widgets and smartphone alerts were the second preferred sources of UVI alerts among the 18–25 and 26–40 age groups, whilst they were the least preferred sources among persons in the older age group (61+).

These findings are in line with the results of other published studies. Since smartphones are still considered as relatively new sources of UVI forecasts/high UVI alerts and in view of the fact that currently no Maltese applications or widgets offer this service, this potential use of UVI forecast may have not been sufficiently publicised. Furthermore, as shown in the last Maltese census of 2011, on which the sample population of this survey was based, the local population is an ageing one and thereby may not be conversant with these new sources of UVI forecasts/high UVI alerts.

Knowledge in Relation to the Negative Impacts of Excessive Sun Exposure

This study also highlighted the fact that the Maltese population is aware of the negative impacts of excessive sun exposure. A very high percentage of the respondents (96%) were aware that excessive sun exposure can cause skin cancer, whilst 81% replied that this can have negative impacts on the eyes. When comparing these figures to those found in literature it became evident that awareness levels prevalent in Malta are very high when compared to those obtained in other European countries.

In contrast, this study also highlighted the fact that the majority of the Maltese population is not knowledgeable enough on the implications of a suntan on health. This was evidenced by the fact that 62% of the respondents were unaware that a suntan is always detrimental to health even if one avoids getting burned. This finding can be partly attributed to media influences that convey the message that a suntan "looks good" and "makes one more attractive". It can also be a result of a wrong perception that a suntanned body is healthy.

Use of Recommended Sun Protection Items During Summer

Another significant finding indicating that the general public is not giving serious heed to sun protection is the relatively low use of sun protection measures. As illustrated in Fig. 13.1, this study found that only 29% of those interviewed use sunscreen regularly, whilst only 28% of the respondents claimed to use a hat regularly in summer. These finding are especially significant since sunscreen and hat use are the most promoted sun protective items in local sun protection campaigns (Malta Health Promotion Unit website 2016).

The seeking of shade was the preferred sun protection method used by the study population, with 84% of the respondents claiming to seek shelter regularly. However, according to Tan et al. (2012) shade provided by beach umbrellas accounts only for a 75% reduction in UVR exposure. The remaining 25% UVR exposure is the result of UVR reflection from the sea, sand and other reflective surfaces. This sun protection method alone is not enough to prevent UVR exposure and should be used together with other sun protection items especially sunscreen (Tan et al. 2012).

Slightly more than half (56%) of the persons interviewed claimed to wear a shirt or cover themselves regularly when at the beach. Sunglasses, which apart from being

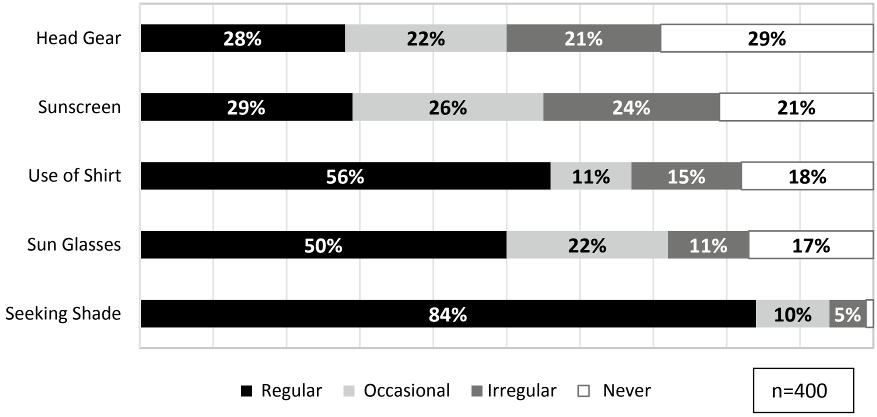

Fig. 13.1 Frequency of use of sun protective items in summer. (Key to answers: Regular—three times a week, Occasional—once a week, Irregular—less than once a week)

a sun protection item are also a fashion accessory, are used regularly by 50% of the respondents. However, it should be stressed that not all sunglasses have adequate protection against UVR (Tan et al. 2012). Consequently, as promoted in the Australian "SunSmart" campaign, proper labelling of effective sunglasses and fashion glasses against UVR can help people distinguish between different types of sunglasses.

Gaps Between Sun Protection Knowledge and Behaviour

This study emphasised the fact that although the Maltese population tends to be well informed on the negative implications of UVR, they still opt to stay in the sun during sun peak hours without resorting to the use of sun protective items especially sunscreen and hats. The discrepancies between knowledge and behaviour were investigated in various behavioural studies that aimed to analyse these observations. According to Diffey and Norridge (2009), people tend to underestimate the risks of excessive sun exposure and this would explain why they still engage practices that may compromise health, such as sunbathing. Conversely, Miles et al. (2005) argue that people tend to overestimate the effects of sun protective measures such as sunscreen, since from their UK-based study they observed that people did not consider sunbathing as a risk factor once they have applied sunscreen. Miles et al. (2005) in their study have concluded that in contrast to what is common practice in health awareness campaigns, rather than discouraging the positive perceptions of a suntanned body or raising the alarm on the possible development of skin cancer, more focus should be put on aesthetic skin damage such as wrinkling and pigmentation.

This study has also found that there is an association between sun protective knowledge, behaviour and gender. Females were significantly more knowledgeable about the risks of excessive sun exposure and stayed less frequently in the sun during sun peak hours in summer. Males used hats and shirts when at the beach significantly more than women did but opted to use sunscreen and sunglasses significantly less than females.

This study has also found an association between sun protection knowledge and behaviour and age groups. Although persons in the younger age group (18–25) were the most knowledgeable in interpreting a UVI of 9, a very high percentage (91%) claimed to stay in the sun during peak sun hours in summer, when compared to other age groups. Also, persons in this age group used significantly less headgear and/or shirts while at the beach and sought shelter significantly less than other age groups. The observation that young adults tend to be more exposed to the sun while using sun protective items much less than other age groups is consistent to those reported in literature. Wright et al. (2008) in their behavioural study argue that young adults are exposed more to the sun not because they are less aware of the implications, but because they like to have a suntan. Peer pressure and media influences tend to overcome their knowledge as well as parents' recommendations that a sun tan can be detrimental and can have potential negative health implications in future years.

Long Term Trends in the Incidence of Skin Cancer in Malta

The third aim of this study was to assess long term trends in the incidence of skin cancer in Malta on the basis of a changing climate.

The analysis of the skin cancer data supplied by the MCR show that there have been significant increases in all skin cancer types between 1993 and 2003 time frame and the period 2004–2013. Figure 13.2 shows the number of new skin cancer cases by type and year between 1993 and 2013.

Statistical tests performed have shown that all skin cancer types have significantly increased over these last 20 years. In fact, skin cancer data which was obtained from the MCR shows that the reported cases of total skin cancer cases between 2004 and 2013 timelines increased by 68% when compared to the 1993–2003 period. In the same period NMSC increased by 65%, whilst MSC more than doubled since the increase was equivalent to 117%.

When translated to the Maltese context, the introduction of the "Euromelanoma" campaign after the year 2000, could have had a positive effect on the detection of all types of skin cancers. Also, according to the 2015 "European Life Expectancy Report" the Maltese life expectancy between 2004 and 2012 has increased by 1.9 years for women and 1.3 years for men (EHLEIS 2015). Since NMSC is more commonly found in elderly adults, this increase in life expectancy could have also partly contributed to the significant increase in skin cancer. Also, although Aquilina et al. (2007) in their study have mentioned that a proportion of NMSC was still not being reported at the time of this study, according to MCR officials an increased surveillance in the last decade was implemented to ensure a more accurate reporting of these cases.

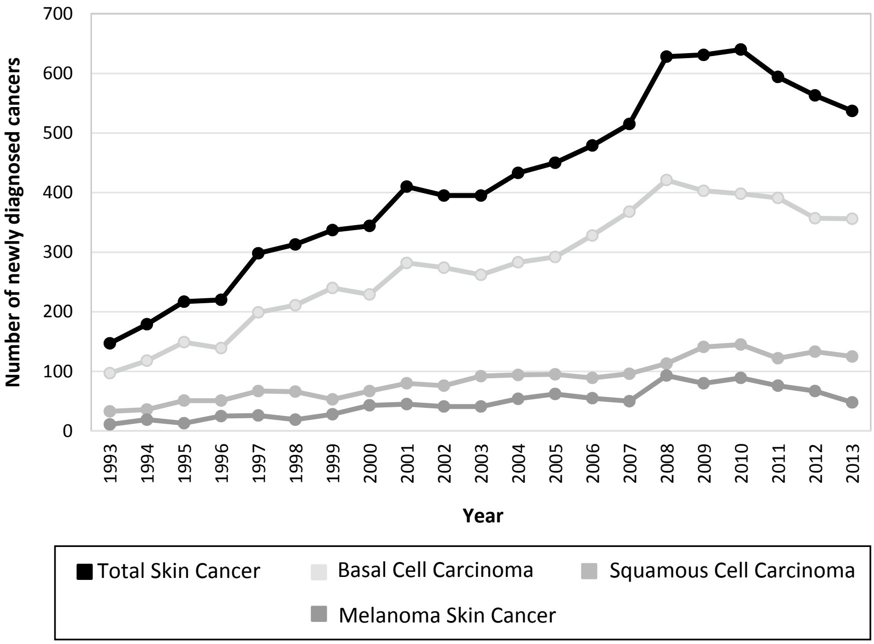

Fig. 13.2 Newly diagnosed Skin cancer cases by type and year (*Source* Malta Cancer Registry 2015) Total Skin Cancer cases include also other less common skin cancer types

However, although the above mentioned factors could partly explain the significant increases in the skin cancer incidence rates, according to Stratigos et al. (2012) these increases are mostly attributed to increasing trends of excessive sun exposure and low use of sun protection mechanisms (Stratigos et al. 2012).

Shortcomings of the Current UVI Concept and Recommendations for an Improved UVI Concept at Global Level

Although various studies are questioning the effectiveness of the UVI during the past 20 years, to achieve the much desired behavioural changes in relation to sun protection, only very few studies have put forward recommendations for an improved UVI concept.

As already mentioned, the possible reasons for the gap between high UVI familiarity, sun protection knowledge and behaviour is multifactorial and cannot be attributed to one single factor.

One of the few studies that identified recommendations for an improved UVI concept was the review paper by Italia and Rehfuess (2012). Also, Allinson et al.

(2012) proposed a number of recommendations in their article, which summarised the proceedings of the UVI working group meeting on the validity and use of the UVI held in Germany in December 2011, after identifying a number of shortcomings in both the UVI concept itself and the way it is being presented to the general public. According to these studies there are a number of reasons that are hindering the message from going through effectively. These are summarised below:

The UVI Concept Is not Clear Enough and Can Be Confusing

The above mentioned articles have reported wide variation in the understanding of the various categories of this concept. The significance of the UVI categories namely "high exposure", "very high exposure" and "extremely high exposure" is causing confusion in their interpretation and also in the subsequent recommended sun protective mechanisms that should be taken in the respective categories (Italia and Rehfuess 2012).

In view of this, the UVI working group recommended a study among the various target groups such as young adults, parents and the elderly, which will assess the possibility of the remodelling of the UVI concept into a two or three tier sun protection scheme, the results of which could be analysed at a larger scale (Allinson et al. 2012).

UVI Presentation Is Inadequate and Ineffective

Another shortcoming identified by Italia and Rehfuess (2012) is the way how UVI forecasts are being presented in the media. According to them, in many cases UVI values are given alone without their significance and the recommended sun protective measures, which should be taken for the different exposure levels. This situation is also applicable to the Maltese context as UVI values are given on their own without the recommended sun protective measures to be taken.

UVI Is not Being Promoted Enough

Italia and Rehfuess (2012) also highlighted the observation that UVI is not being promoted enough on the media. In most countries UVI forecasts are given exclusively during the weather forecast in the news bulletin during the summer months. This is also applicable to the Maltese context as UVI is mainly given in the weather forecasts during news bulletins on media such as television and radios, in the weather section on newspapers and on local weather portals.

The UVI working group also highlighted the importance of the use of modern media sources such as smartphone applications which till now have not been exploited enough when it comes to the promotion of UVI. Young adults who are more user friendly with such applications can be targeted. However, they emphasised that till now no studies have assessed the efficacy of such a media source even though this was applied in different campaigns such as the Australian "Sun Smart" campaign (Allinson et al. 2012).

UVI Promotion Should Be Part of Larger Sun Protection Initiative

Italia and Rehfuess (2012) have also stressed on the fact that UVI promotion should be one of a number of tools that should focus on raising awareness on the negative effects of UVR exposure and the promotion of sun protection. They remarked that the lack of use of the UVI concept could also mean that sun protection campaigns are failing to achieve the desired outcomes.

Recommendations for a More Effective Use of the UVI Tool Under a Climate Change Scenario

In view of the shortcomings of the current UVI system in inducing the much expected behavioural changes in relation to sun protection, the following recommendations are being forwarded as a means of improving the UVI concept.

Recommendations for a More Clearly Communicable UVI Concept

- As a result of the reported lack of clarity in the interpretation of UVI, it is suggested that the current five-tier UVI categories be replaced by the introduction of a three tier system (1–3). This would include the following exposure levels; "low exposure", "medium exposure" and "high exposure". This should lead to a better understanding and interpretation of the different exposure levels and the respective sun protection measures that should be applied at different levels.
- The use of attractive graphical content that clearly indicates the UVI value, the significance of that exposure level and the recommended sun protective measures to be used can help the general public to understand better the implications of a particular UVI value. The promotion of UVI by the use of graphical content customised for, and directed to, the different age groups can help the different groups understand this concept better.

- UVI should also be featured and promoted on a wide range of media sources including smartphone applications and internet widgets, in addition to the traditional media sources such as television, newspapers and radio. This initiative will allow the UVI concept to be more accessible to persons of all age groups and education levels. However, since no studies have ever assessed the effectiveness of media sources in the promotion of UVI as part of sun protection campaigns, a pilot study among target groups should help understand better how different media sources can be exploited to further this concept.
- The promotion of UVI as part of effective sun protective campaigns should include all stakeholders involved in the promotion of a healthier lifestyles through the reduction of UVR exposure. These stakeholders should comprise dermatologists, psychologists, other health care workers, health promotion officers, campaign marketing officials, scientists with interest in Earth systems, non-governmental organisations, educators and other persons directly or indirectly involved, in order to address the different aspects in this complex scenario. Campaigns should also include sun protection education in schools, which can help in bringing about a behavioural change at an early stage, the promotion of healthy sun protection attitudes during both leisure and work related activities, as well as a revised and clearer UVI concept.

Recommendations for Improved Local Sun Protection Campaigns

- Since this study has clearly highlighted excessive sun exposure and a low use of sun protective measures by the respondents, a study that assesses the effectiveness of the Maltese campaigns and their impact on specific groups is recommended. This study should target those who might be at a higher risk of developing skin cancer such as outdoor workers, persons whose lifestyle and hobbies regularly expose them to the sun and specific groups such as young adults and adolescents. This would enable the identification of potential shortcomings in the current campaigns and help establish methods on how these could be remodelled around the various risk groups targeted in these campaigns.
- Another significant finding in this study is that although there is a very high familiarity with UVI and a high awareness that excessive sun exposure can cause skin cancer and eye problems, this is not being translated into increased sun protection practices. Consequently, a behavioural analysis needs to be effected in order to shed more light on the various reasons as to why sun protection knowledge is not being translated into healthy sun protection attitudes. The findings from such a study can help all those concerned to re-design current sun protection campaigns in order to succeed in bringing the much desired behavioural change that can result in significant reduction in UVR induced disease.

- Since this study has established that those falling within the 18–25 age group are considered at a higher risk due to their sun exposure attitudes, a more aggressive sun protection education campaign in schools should be adopted. This should emphasise the advantages of using sun protective items and the negative implications of getting a suntan.
- Furthermore, the mandatory use of sun protective items such as hats and sunscreen during outside breaks and educational outings in primary and secondary schools, especially during spring and summer months (in summer schools) should be implemented. Such measures have already been tried and tested in the Australian and US campaigns and these should bring the desired cultural change of increased sun protection among future adolescents.
- The concept of UVI is not being sufficiently promoted in local campaigns. As recommended above, this concept should be incorporated in the reformulation of sun protection campaigns.

Recommendations to Introduce Climatological UVER Data by the National Meteorological Office

- The measurement of ground based UVR data by the national meteorological office using a BFR with the erythemal action spectrum from which UVER data could be calculated would enable the publishing of UVI data maxima on a daily basis especially during the spring and summer months. The availability of such dataset, apart from validating the forecast UVI data, can also serve as a source of ground based UVR data, which could be archived for future climatological analysis. Such initiative can be as a short term alternative preceding the introduction of more robust methodologies by which UVER can be calculated.
- The availability of a locally validated RTM methodology, which is supplemented with spectroradiometer data to measure UVR and other atmospheric variables such as TOC and cloud parameterisation could enable its use in the remodelled sun awareness campaigns in which real-time UVER data could be available on smartphone applications and internet widgets to enhance public awareness of UVI. A joint investment by the national meteorological office and the government agency in charge of sun protection campaigns could make this medium/long term initiative possible.

Recommendations Regarding the Increasing Trends of Skin Cancer in Malta Under a Climate Change Scenario

- In view of the reported lack of complete skin cancer data especially in NMSC figures, increased communication and surveillance between the officials of the MCR, dermatologists and medical practitioners involved in the diagnosis of skin cancer could enable the collection of more comprehensive skin cancer data. The availability of complete and accurate skin cancer data would enable the assessment of the current situation of these common cancers.
- Up till now, no published studies have categorised skin cancer patients according to criteria such as skin type, family history of skin cancer and increased sun exposure as a result of occupation or hobbies. Such data collection would enable the identification of trends in the general population of categories that are at a higher risk of developing skin cancer. This data could permit better targeting of sun protection campaigns in relation to sun protection and screening through initiatives like the "Euromelanoma" campaign, that are well within the sphere of wide climatological studies.

Future Prospects

Figure 13.3 represents inter-related and self-reinforcing recommendations based on the findings of this study. Although improvements in each category can lead to progress in that particular field, major advances can only be accomplished if a holistic approach is adopted throughout.

This approach should include the remodelling of the current sun protection campaigns, the availability of accurate ground based UVER data by the national Meteorological Office, a more practical and easily communicable UVI as well as more accurate skin cancer figures. The UVER data apart from being used to validate UVI forecasts could be easily adapted to issue UVI alerts using more accessible and innovative technology. This can also be combined with more focused and targeted sun protection campaigns that aim to convert the sun protective knowledge into action, in order to address the worrying situation of an ever increasing trend in skin cancer incidence.

Conclusions

This study demonstrated that a high awareness of the UVI concept is not being translated into increased sun protection practices notwithstanding that the study population is highly knowledgeable with regard to the negative impacts of excessive sun

Fig. 13.3 Summary of the recommendations based on the findings of this study

exposure. This could be partly attributed to the lack of exploitation of the UVI concept in these campaigns as well as the lack of use of modern media sources such as smartphone applications and internet widgets. Such media sources are more popular among the younger age groups, which as evidenced in this study are to be considered at a higher risk due to their sun related behaviour.

This study also established that the published UVI forecasts by the Malta MET Office are in agreement with the measured UVER/UVI exposure at peak time. In fact, 81% of locally published UVI forecasts were within ±1 UVI unit when compared to UVER data.

Furthermore worrying increasing trends in the reported cases of all skin cancer types over the past two decades were revealed.

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References

Allinson S, Asmuss M, Baldermann C, Bentzen J, Buller D, Gerber N, Green AC, Greinert R, Kimlin M, Kunrath J, Matthes R, Pölzl-Viol C, Rehfuess EA, Rossmann C, Schüz N, Sinclair C, van Deventer E, Webb A, Weiss W, Ziegelberger G (2012) Validity and use of the UV Index: report from the UVI working group, Schloss Hohenkammer, Germany, 5–7 December 2011. Health Phys 103(3):301–306

Anderson JG (2012) UV dosage levels in summer: increased risk of ozone loss from convectively injected water vapor. Science 337:835–839

Antón M, Serrano A, Cancillo M, García J (2009) An empirical model to estimate ultraviolet erythemal transmissivity. Ann Geophys 27(4):1387–1398

Aquilina S, Gauci AA, Boffa MJ (2007) Skin phototypes of a Maltese sample population. J Eur Acad Dermatol Venereol 21(9):1239–1243

Canada J, Pedros G, Lopez A, Bosca J (2000) Influences of the Clearness Index for the whole spectrum and of the relative optical air mass on UV solar irradiance for two locations in the Mediterranean area, Valencia and Cordoba. J Geophys Res Atmos 105(D4):4759–4766

Crawford IM (1997) Questionnaire design. In: Food and Agriculture Organisation of the United Nations, Marketing Research and Information Systems (Marketing and Agribusiness Texts—4), 1st edn. FAO, Rome

De Backer H, Koepke P, Bais A, de Cabo X, Frei T, Gillotay D, Haite C, Heikkilä A, Kazantzidis A, Koskela T (2001) Comparison of measured and modelled UV indices for the assessment of health risks. Meteorol Appl 8(03):267–277

de Vries E, Trakatelli M, Kalabalikis D, Ferrandiz L, Ruiz-de-Casas A, Moreno-Ramirez D, Sotiriadis D, Ioannides D, Aquilina S, Apap C (2012) Known and potential new risk factors for skin cancer in European populations: a multicentre case–control study. Br J Dermatol 167(s2):1–13

Diffey BL (2002) Sources and measurement of ultraviolet radiation. Methods 28(1):4–13

Diffey B, Norridge Z (2009) Reported sun exposure, attitudes to sun protection and perceptions of skin cancer risk: A survey of visitors to Cancer Research UK's Sun Smart campaign website. Br J Dermatol 160(6):1292–1298

D'Orazio J, Jarrett S, Amaro Ortiz A, Scott T (2013) UV radiation and the skin. Int J Mol Sci 14(6):12222–12248

EHLEIS, European Health and Life Expectancy Information Systems (2015) Health expectancy in Malta. http://www.eurohex.eu/index.php?option=reports. Accessed 20 Dec 2018

Euromelanoma (2019) Information about Euromelanoma campaign. https://www.euromelanoma.org/intl/node/68. Accessed 19 Jan 2019

Galdies C (2011) The climate of Malta: statistics, trends and analysis 1951–2010. National Statistics Office. https://nso.gov.mt/en/publicatons/Publications_by_Unit/Documents/B3_Environment_Energy_Transport_Agriculture_Statistics/The_Climate_of_Malta.pdf. Accessed 19 Apr 2019

Gies P, Roy C, Javorniczky J, Henderson S, Lemus-Deschamps L, Driscoll C (2004) Global solar UV Index: Australian measurements, forecasts and comparison with the UK. Photochem Photobiol 79(1):32–39

IARC (2012a) GLOBOCAN 2012: estimated cancer incidence, mortality and prevalence worldwide in 2012. http://globocan.iarc.fr/Default.aspx. Accessed 15 Dec 2018

IARC (2012b) EUCAN 2012: European cancer observatory data. http://eco.iarc.fr/eucan/Country.aspx?ISOCountryCd=930. Accessed 15 Dec 2018

Italia N, Rehfuess EA (2012) Is the global solar UV index an effective instrument for promoting sun protection? A systematic review. Health Educ Res 27(2):200–213

Kasparian NA, McLoone JK, Meiser B (2009) Skin cancer-related prevention and screening behaviors: a review of the literature. J Behav Med 32(5):406–428

Kerr J, McElroy C, Tarasick D, Wardle D (1994) The Canadian ozone watch and UV-B advisory programs. http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19950004680.pdf. Accessed 21 Dec 2018

Kerr J, Fioletov V (2008) Surface ultraviolet radiation. Atmos Ocean 46(1):159–184

Kipp and Zonen (2016) UV radiometers product information. http://www.kippzonen.com/ProductGroup/11/UV-Radiometers. Accessed 29 Dec 2018

Malta Cancer Registry (MCR) (2015) Incidence and mortality rates of skin cancer. https://health.gov.mt/en/dhir/Pages/Registries/cancers.aspx. Accessed 28 Dec 2018

Malta Health Promotion Unit website (2016) Campaigns. https://health.gov.mt/en/health-promotion/Pages/campaigns.aspx. Accessed 19 Jan 2019

Miles A, Waller J, Hiom S, Swanston D (2005) SunSmart? Skin cancer knowledge and preventive behaviour in a British population representative sample. Health Educ Res 20(5):579–585

National Statistics Office of Malta (NSO) (2018a) Maltese population statistics 2017. https://nso.gov.mt/en/News_Releases/View_by_Unit/Unit_C5/Population_and_Migration_Statistics/Documents/2017/News2017_111.xls. Accessed 19 Jan 2019

National Statistics Office of Malta (NSO) (2018b) Inbound tourism 2017. https://nso.gov.mt/en/News_Releases/View_by_Unit/Unit_C3/Tourism_Statistics/Documents/2017/News2017_191.pdf. Accessed 19 Jan 2019

Scerri L, Aquilina S, Gauci AA, Dalmas M (2002) Sun awareness and sun protection practices in Malta. J Eur Acad Dermatol Venereol 16(1):47–52

Stratigos A, Forsea A, Van Der Leest R, De Vries E, Nagore E, Bulliard J, Trakatelli M, Paoli J, Peris K, Hercogova J (2012) Euromelanoma: a dermatology-led European campaign against nonmelanoma skin cancer and cutaneous melanoma. Past, present and future. Br J Dermatol 167(s2):99–104

Tan S, Sinclair C, Foley P (2012) Running behind a tourist: leisure-related skin cancer prophylaxis. Br J Dermatol 167(s2):70–75

van Geffen J, van Der AR, van Weele M, Allaart M, Eskes H (2005). Surface UV radiation monitoring based on GOME and SCIAMACHY (14). In: Proceedings of the 2004 Envisat and ERS symposium (ESA SP-572), Salzburg, Austria. http://articles.adsabs.harvard.edu//full/2005ESASP.572E.178V/0000178.008.html. Accessed 4 Jan 2019

WHO (2002) Global solar UV index: a practical guide. Retrieved from http://www.who.int/uv/publications/en/GlobalUVI.pdf?ua=1. Accessed 19 January 2019

WHO (2006) Environmental burden of disease series, no. 13—Solar ultraviolet radiation: global burden of disease from solar ultraviolet radiation. http://www.who.int/uv/health/solaruvradfull_180706.pdf?ua=1. Accessed 18 January 2019

Williamson CE, Zepp RG, Lucas RM, Madronich S, Austin AT, Ballare CL, Norval M, Sulzberger B, Bais AF, McKenzie RL, Robinson SA, Häder D-P, Paul ND, Bornman JF (2014) Solar ultraviolet radiation in a changing climate. Nat Clim Change 4:434–441

Wright C, Reeder AI, Gray A, Cox B (2008) Child sun protection: sun-related attitudes mediate the association between children's knowledge and behaviours. J Paediatr Child Health 44(12):692–698

Chapter 14
Climate Change Risk and Insurance as an Adaptation Strategy: An Enquiry into the Regulatory Framework of South Africa and Ghana

Ademola Oluborode Jegede, Michael Addaney and Untalimile Crystal Mokoena

Abstract Climate change and its environmental, social and economic impacts continue to pose sustainability challenges for governments, organizations and individuals around the world. With Africa identified as one of the most vulnerable regions, adaptation to adverse effects of climate change has been recognised as increasingly necessary. Adaptation policies have therefore been developed by most African countries; where some countries have adopted targeted adaptation strategies while others have introduced more general policy initiatives. Insurance is a vital part of a comprehensive set of responses targeted at adapting to future climate change. Insurance, as argued, can provide resources needed to rebuild societies after experiencing adverse effects of extreme weather events, and can do so in ways that promote preventive, risk-reducing action. However, the extent of involvement of the insurance sector and adoption of climate insurance policies depends on the national regulatory frameworks governing adaptation. With a particular focus on South Africa and Ghana, this chapter links climate change risk to the potential of insurance as an adaptation strategy. It then interrogates the extent to which the regulatory environment can be harnessed in support of insurance as a climate change adaptation strategy in South Africa and Ghana.

Introduction

Climate change is recognised as one of the most complex issues of our time and it is responsible for increased natural disasters, for instance, floods, storm surges, droughts, and rise in sea level, which adversely affect the human race at large (Mayer 2018; Atapattu 2016). The increasing nature of these occurrences linked to extreme weather will in all probability exacerbate hunger and malnutrition, injuries, illnesses,

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water stress, forced displacements of vulnerable populations (IPCC 2018; Jegede 2016a, b). Therefore, climate change and its environmental, social and economic impacts pose sustainability challenges to governments and populations the world over. Disaster risk associated with climate change is rising due to importunate poverty and degradation of the ecosystem and the drivers of these risks are aggravated by climate change. As studies have shown, natural disasters affect up to some 200 million people annually across the world with the number of disasters increasing in recent decades (Jegede and Mokoena 2018; Guha-Sapir, Hoyois and Below 2013). Natural disasters increased three times from 2000 to 2009 as compared to 1980 to 1989 (Nagel 2015: 5). Consequently, there is an increasing focus on adaptation measures at international, regional and national levels to address the adverse effects of climate change (Abate 2016). The consequences of climate change within the context of disaster on the African continent is dire. Even though socio-economic factors contribute largely to the increased disaster losses currently, there is increasing evidence that climate related events such as increasing extreme precipitation at mid- and high latitudes, extreme floods and droughts in temperate and severe dry events in Africa.

Increase in drought and heavy precipitation (the latter often leading to floods) in that region and certain geographic regions, as well as extreme temperatures across the world are due to climate change (IPCC 2014). Of all the continents, Africa will be the most severely hit by the adverse impact of climate change due to the continent's weak capacity for adaptation (IPCC 2014). According to the IPCC (2014), Africa's major economic sectors are prone to climate sensitivity, with major economic impacts. This vulnerability is exacerbated by existing developmental challenges such as endemic poverty, poor infrastructure, complex governance and institutional dimensions, limited access to capital, poor energy and low technology, ecosystem degradation, disasters and conflicts. These in turn have contributed to Africa's weak adaptive capacity, increasing the continent's vulnerability to projected climate change. The impacts of climate change will therefore mount pressures on Africa's limited resources and threaten the attainment of sustainable development goals and aspirations. Admittedly, climate change adaptation measures have been developed by most African countries: while some countries have adopted targeted adaptation strategies, others have introduced more general policy initiatives. In the face of threats caused by climate change, a consensus is, however, emerging that additional safeguards are required to guarantee the health and safety of the most vulnerable groups, communities and property of the world, including the low-lying island nations, the urban and rural poor, women, children and indigenous peoples (Jegede 2016a, b; IPCC 2014).

A significant foundation for managing risk and a possible robust adaptation strategy is insurance and other alternative risk-transfer mechanisms that offer disaster safety nets for vulnerable groups (Jegede and Mokoena 2019). This is because disasters aggravate poverty as poorer victims usually sell their assets and livestock or engage low-yield farming to reduce their exposure to extreme weather events (Addaney et al. 2017). Without the infusion of finance, for instance, through insurance, for rebuilding or reconstruction after disasters, the events can have long-term adverse consequences on socio-economic development. There is consequently a heighten need to address weather-related risks by using approaches that enhances adaptation of the most vulnerable populations to the adverse effects of climate change. Yet, the introduction of insurance to the discourse of climate change suffers from a prior disinterest by the insurance industry to associate with climate change (Dlugolecki 2000). Nonetheless, the prevalence of climate change raises a great need to have assets insured against destruction by climate-related causes. It is, therefore, not surprising that various insurance designs are increasingly considered as part of a comprehensive set of responses targeted at adapting to future climate change.

Insurance is argued to provide resources needed to rebuild societies after experiencing adverse effects of extreme weather events, and do so in ways that promote preventive, risk-reducing action (Michaelowa 2006). To promote understanding and adoption of insurance as an adaptation option, this chapter interrogates the extent to which national policy environment, in particular adaptation policy, creates the platform for the development and adoption of climate risk reduction insurance schemes in two African countries: South Africa and Ghana. It further discusses the potential of climate change insurance in adaptation action and suggests how legal and policy barriers facing African governments and insurance companies could be overcome. The core argument is that national adaptation policies significantly shape the approaches of organisations and individuals toward climate risk insurance schemes particularly due to the absence of such provisions in policy debates and developments. Following this introduction, Section "Insurance as a Climate Risk Adaptation Strategy in Developing Countries" conceptualizes climate change insurance and risk reduction and how insurance can boost the adaptive capacity of developing countries. Section "Climate Change Risks, Adaptation and Insurance: Policy Responses and Emerging Strategies from South Africa and Ghana" discusses the legal and policy framework governing climate change risks, adaptation and insurance in Ghana and South Africa. Section "Conclusion" summarises and concludes the discussion.

Insurance as a Climate Risk Adaptation Strategy in Developing Countries

Warner et al. (2009) describe insurance as a contractual arrangement that promises economic protection against potentially great loss in return for a premium. For example, many homeowners purchase fire insurance to shield their property. Whether or not insurance is a suitable adaptation measure merits a consideration. The United Nations Framework Convention on Climate Change (UNFCCC 1992) defines climate change adaptation as actions taken to help communities and ecosystems to cope with changing climate condition. Adaptation involves practical actions that are taken in order to handle risks that are climate change related. Adaptations may also be understood to be adjustments or interventions, which take place in order to manage the losses or take advantage of the opportunities presented by a changing climate (Klein et al. 2007; IPCC 2001). Although climate change is a global challenge, it is geographically and locally different in terms of impact, vulnerability and adaptation (Addaney and Cobbinah 2019). Responses to adaptation have consequently been developed by African countries where some of them have adopted sectoral adaptation strategies while others have introduced more general policy mechanisms (Addaney 2019; Addaney and Cobbinah 2019). The authors also argue that lessening the growing losses associated with climate-related events such as floods, droughts and typhoons is crucial to alleviating poverty and in realizing the Sustainable Development Goals (Addaney and Cobbinah 2019). Hence, in so far as climate risk insurance involves responding to climate change effects by supporting poor and vulnerable people in finding climate-resilient development pathways (Schäfer et al. 2016), it is arguably a significant adaptation strategy. This section focuses on insurance as an adaptation response.

Linnerooth-Bayer and Mechler (2006) assert that climate change adaptation responses such as support for insurance instruments have been recognised at the international and local level in conjunction with the reduction of GHG emissions as a fundamental component of the response to climate change risks. The extreme weather events associated with climate change provide an impetus for the insurance community to better appreciate and promote tailored-made services. For example, article 4(8) of the UNFCCC calls upon State parties to the Convention to consider actions, including insurance, in order to fulfill the particular needs and concerns of developing States as a result of the adverse impacts of climate change (UNFCCC 1992). In addition, article 3(14) of the Kyoto Protocol encourages State parties to consider the adoption of insurance (Kyoto Protocol 1997). In particular, efforts toward managing climate risks such as proactive support for insurance instruments is emerging on the climate change adaptation agenda of many developing countries. For instance, during the early stages of the deliberations on a global insurance pool at the UNFCCC level, the Alliance of Small Island States (AOSIS) advanced the notion of an international compensation fund to be fully financed by industrialized (developed) countries as a mechanism to compensate low-lying states for the damages associated with sea-level rise (Linnerooth-Bayer and Mechler 2006). According to article 8(4)(f) of the Paris Agreement (2015), 'risk insurance facilities, climate risk pooling and other insurance solutions' are an important option in addressing the loss and damages associated with the adverse effects of climate change. This suggests that extreme weather-related events have implications for insurance services, in particular, the micro insurance service.

Micro-insurance is one of the forms of insurance relevant in the context of climate. Micro-insurance is characterised by low premiums and is typically targeted at lower income individuals who are unable to pay for traditional insurance policies. Its operation follows the normal insurance rules, including in relation to the payment of premiums. The insured, affected areas are provided with the much-needed cash to survive the impacts of natural hazards felt such as hurricanes, droughts, and floods (Scherer 2018). Warner et al. (2009) further argue that micro-insurance can cover an extensive range of risks which are usually related to health and weather risks, such as crop and livestock. They observe that weather insurance usually takes the form of a parametric transaction under which payment is done if a chosen weather-index such as 5-day rainfall amounts exceeds a certain threshold. The significant role of insurance firms to adaptation to climate change has also been recognized as a result of their risks assessment and cost distribution for natural hazards (Phelan et al. 2011; Johannsdottir et al. 2014). This makes insurance firms pivotal in influencing the risk-mitigation action of their policyholders (Adger et al. 2005; Mills 2012). The decision to address climate change adaptation by insurance firms and if addressed, the adoption of suitable measures and services, is significantly influenced by how adaptation is conceptualized and governed (Keskitalo 2010; Schwarze et al. 2011; Juhola 2013; Landauer, Juhola and Klein 2018). This makes it essential to explore the interaction between public adaptation policy and insurance services.

Yet, there is a scant attention of scholarship on how capacities and incentives for insurance firms to develop and implement relevant climate risks insurance can shape national adaptation policy (Agrawala et al. 2011). In particular, even if scholars have studied corporate adaptation responses (e.g. Berkhout 2012), the interface between national adaptation governance and adaptive actions of private actors and individuals are still relatively underexplored (Mees et al. 2012; Tompkins and Eakin 2012). The involvement of private actors such as insurance firms in addressing climate change adaptation has been attributed to several factors which essentially relate to the policy environment of a particular sector and/or its market structure (Grothmann and Patt 2005; Agrawala et al. 2011; Mees et al. 2013). These factors are, however, framed and shaped by the prevailing climate change adaptation framework. For example, Keskitalo et al. (2014) argue that a private insurance firm may be directly affected by public policies that target its primary products, or indirectly by policies that affect its behaviour on the market. National climate change response strategies and national adaptation policy design can therefore affect the responses that insurance firms develop and implement in specific sectors affected by climate risks and other extreme weather events.

Climate change insurance comes in hand as it has been noted that much investment for sound adaptation will need to come from households and firms of all sizes (Agrawala and Fankhauser 2008; Bowen and Rydge 2011). Brugmann (2012) argues that the effectiveness of adaptation responses will be dependent on catalysing market-based investments. This assertion is reinforced by the findings that the need for investment in adaptation far exceeds the financial resources available from public budgets (Hedger and Bird 2011). Schwab (2013: 46) identifies the failure of governments and businesses to develop and implement effective measures to protect populations as one of the most likely environmental risks over the next 10 years. Therefore, without a radical transformation in adaptation programming and development planning, private sector investments in climate change adaptation will continue to reduce. Agrawala et al. (2011) and Chu and Schroeder (2010) revealed a sketchy indication of big businesses investing in climate change vulnerability assessments, however, only few insurance businesses are beginning to invest in adaptation responses.

In developing countries, insurance markets can share and spread financial risk from climate change, such as through, helping to limit losses and manage risks in flood-prone areas (Rosenzweig et al. 2010). Risk-specific property insurance services, argues Mills (2012), can motivate individuals, communities and businesses to invest in adaptation responses or to avoid building in high-risk areas altogether. Other relevant insurance instruments include health and life insurance for individuals and property as well as micro-insurance or micro-finance mechanisms to support people living in poorer communities that are not covered by commercial insurance. This approach contrasts with traditional insurance markets which do not usually cover low income groups (Ranger et al. 2009; Hallegatte et al. 2010). Poorer populations do not access insurance due to their inability to afford the high transaction costs to companies administering pro-poor insurance policies. Hallegatte et al. (2010) attribute this to the fact that most low-income groups rely on local charity and government support when disaster occurs. Therefore, the insurance industry can therefore help shape adaptation initiatives through collaboration with building owners, farmers and governments in order to inform and encourage climate risk insurance as a form of adaptation action. For the insurance firms to fulfil their potential in facilitating climate change adaptation responses, national regulatory environment needs to create an enabling landscape for the insurance markets while public funding may also be required to protect the poor and most vulnerable households as well as to enable action by the insurance sector.

Climate Change Risks, Adaptation and Insurance: Policy Responses and Emerging Strategies from South Africa and Ghana

While climate risk insurance is of great significance in facilitating climate change adaptation, its application is determined by national regulatory environment in a country. Consequently, this section demonstrates the extent to which insurance can be harnessed as a climate change adaptation strategy in South Africa and Ghana.

Managing Climate Change Risks in South Africa: Linking Adaptation to Insurance

Climate change in South Africa not only exacerbates poverty and inequality, it also threatens the country's major resources like food security, water resources, infrastructure, health as well as biodiversity and ecosystem (Ziervogel et al. 2014). With the country's per capita emissions being the highest in Africa, climate adaptation and mitigation are of paramount importance. Relevant adaptive responses are urgently needed to deal with the country's socio-economic developmental needs and threatened ecosystem services. Climate change greatly affects one of the two key sectors (along with mining) which is agriculture. Zwane and Montmasson-Claire (2016) indicate that agriculture encounters a variation of climate change related risks such as changes in rain patterns, increased evaporation rates, higher temperatures, increased pests and diseases and changes in diseases and pest distribution ranges, reduced yields and spatial shift in optimum growing regions. This requires an urgent safety net amongst other adaptation measures that would cover climate change related contingencies especially for the majority of the destitute citizens who cannot deal with the consequences on their own. Studies reinforce that South Africa is already suffering the dire consequences of climate change as it aggravates hunger and malnutrition for multitudes, and is also capable of reducing the world's arable land by 20% by the end of the century. Finance is seen as one of the barriers to climate change adaptation measures (Zwane and Montmasson-Clair 2016) which can be remedied by having insurance in place.

South Africa is a state party to instruments of importance to climate risk adaptation. For instance, it is signatory to the UNFCCC (1992), the Kyoto Protocol (1997), and the Paris Agreement (2015), and has endorsed the Sustainable Development Goals (SDGs 2015). These international instruments, based on the provision of Section 233 of the 1996 Constitution of South Africa which enjoins the courts to apply international law, are relevant to South Africa as a framework for enhancing insurance as climate risk adaptation measure. Besides the incorporation of insurance in these instruments as earlier shown, insurance has been identified as a form of social security measure that is relevant to climate change adaptation (Jegede and Mokoena 2019). As argued, this is because it forms an integral part of the legislation such as Section 27(1) of the Constitution (1996) which provides for the right for everyone to have the right to social security, and the Social Assistance Act (2004) which entails insurance as a way to address human security needs (Jegede and Mokoena 2019). Along similar lines, official documents such as the National Climate Change Response White Paper (Department of Environmental Affairs 2011), National Adaptation Strategy (Department of Environmental Affairs 2016a, b), and reports such as the South Africa's 2nd Annual Climate Change Report (2016) on adaptation measures to address climate change indicate insurance as a viable option to address the consequences of climate change.

In discussing South Africa's adaptation strategy in urban settings, the White Paper emphasizes the need to develop mechanisms such as micro-insurance for the poor to recover after disasters. It identifies insurers as important development partners for the government including in the development of innovative climate change-related products (National Climate Change Response White Paper 2011: 44). While the South Africa's 2nd Annual Climate Change Report (2016) makes no mention of insurance, the National Adaptation Strategy (Department of Environmental Affairs 2016a, b) requires the government to create new strategic partnerships between the insurance sector and civil society with the view of supporting new innovative insurance mechanisms that can enhance adaptive capacity and allow people to proactively reduce their risk and increase their response capacity. Such partnerships are necessary for assessing not only loss and damage threats associated with climate change, but also to reveal opportunities for international support for loss and damage to these sectors from climate change (Department of Environmental Affairs 2016a, b: ix). Other stakeholders are enjoined to collaborate with the insurance industry to "build back better," i.e. to ensure that reconstruction after damage from a natural hazard results in adaptive infrastructure (Department of Environmental Affairs 2016a, b). The National Adaptation Strategy (2016: xv) identifies priority needs and opportunities for climate resilience in the transport and critical infrastructure areas (Department of Environmental Affairs 2016a, b: xvi).

The National Development Plan does not indicate where funding for climate change adaptation would come from, but it acknowledges that climate change impacts among others, agriculture, can be tackled through agricultural insurance markets as an adaptation strategy. This would obviously affect the multitude of indigent South Africans whose livelihood depends on agriculture. In particular, Benhin (2006) acknowledges that climate change impacts greatly on agriculture and indicate that farmers are adopting various surviving strategies which encompass insurance policies and other forms of income to address risks. Clearly this cannot be afforded by all farmers. There is a need for basic government funded insurance schemes to cover all farmers. The costly nature of insurance by farmers is affirmed by Elum and Simonyan (2016) who found that the dearth of awareness of insurance products and inability to afford the premiums are the main reasons why the majority of the farmers did not have insurance. Insurance companies together with the country's financial institutions hold a significant role in potential adaptation funding.

Adaptation measures without potential financers are as good as futile. Maddison (2007) identifies access to credit as well as insurance as significant adaptation measures which would better build resilience for the majority of South Africans. For example, the National Adaptation Strategy (Department of Environmental Affairs 2016a, b) cites Santam, an insurance company, as the example of a partnership between insurance company and local government and NGOs to reduce climate risks (Department of Environmental Affairs 2016a, b: 94). Santam demonstrates both the positive and negative role that climate change can have for insurance companies. On a positive note, the approaches of Santam can illustrate how insurance companies are geared towards helping to mitigate on-the-ground insurable risks to ensure sufficient disaster management capabilities in vulnerable areas. They help with insuring local fire stations in a manner that ensures the provision of equipment such as fire hoses and protective gear.

Santam has been able to secure its relevance through the Santam Partnership for Risk and Resilience (P4RR) programme, a national collaboration with the Department of Cooperative Governance and the South African Local Government Association, which focuses on 10 vulnerable district municipalities and 53 local municipalities. Over the next five years, the expansion of the P4RR programme stands to benefit more than five million people (Santam 2018). Santam is also partnering with communities to proactively manage risk associated with climate disasters. For example, after the floods in the eThekwini Metro, for example, clients took it upon themselves to assist with clearing storm water drains and protecting the drains from collapse in industrial areas. These actions allow insurers to efficiently help vulnerable communities and put businesses back in the position they were before disaster struck (Santam 2018). The downside to the potential in insurance activities as a climate change risk adaptation measure lies in the enormity of claim that can be involved when indemnified incidents occur. For instance, the claims associated with the fires that ravaged

Knysna and the surrounding areas as well as the heavy floods that wreaked havoc in Durban in South Africa is an amount in excess of R2 billion (Santam 2018). This development indicates that global temperatures and unpredictable weather events are likely to have a significant impact far beyond what private insurance can cope with. This does not only underscore the need for the involvement of government to address climate risks by injecting revenue to insurance for protection purposes. It highlights the need for government to ensure an appropriate regulatory space that can galvanise investments in insurance as a viable climate change adaptation strategy in South Africa.

Managing Climate Change Risks in Ghana: Linking Adaptation to Insurance

Ghana, like other developing countries has not been immune to adverse climate change consequences. The government of Ghana and other stakeholders play pivotal roles in reducing GHG emissions and adaptation to climate change. The efforts of national governments to address climate change and adverse effects in Ghana and other African countries are usually impeded by the lack of political will, inadequate finance (Allman et al. 2004; Davies 2005) and limited expertise. Another significant issue that hampers governments' response to the adverse effects of climate change is the increasing importance of other critical sectors of development that appear to have attracted consideration of government departments, agencies, local governments, and the private sector (Bulkeley and Betsill 2003, 2005). This importance stems from the certainty that these sectors can suitably address issues relating to climate change adaptation. Efforts to manage the risks associated with climate change are visible in all sectors of the Ghanaian economy including agriculture, flood management, transportation sector, urban planning, sea level rise and rising temperatures (with projected estimates of average temperature rise to reach 0.6 °C, 2.0 °C, and 3.9 °C by the years 2020, 2050 and 2080, respectively) (Government of Ghana 2013). Studies confirm that Ghana is gradually becoming warmer with average temperatures likely to increase by 2.0 °C, and 3.9 °C by 2050 and 2080 respectively (Government of Ghana 2013). The ensuing effects of climate change include droughts, contamination of water bodies, intense and frequent floods, erratic rainfall patterns and the eventual reduction in agricultural production, sea level rise, and water scarcity (Government of Ghana 2013). These impacts of climate change will aggravate poverty situations in the country where farmers depend heavily on rain-fed agriculture. For example, predictions in the IPCC's Fourth Assessment Report (Parry et al. 2007), point out that yields from rain-fed agriculture in selected countries in Sub-Saharan African (SSA) including Ghana may reduce up to 50% by 2050. In consistence with the situation in SSA, the Ghana NCCAS reveals that the agriculture sector which employs the largest portion of the labour force experiences the most from the adverse effects of climate change. The impacts of climate change and variability are not only manifested in the agricultural sector, but extended to economic, social and health sectors in Ghana.

The first national climate change policy, the Ghana National Climate Change Policy (NCCP), was adopted in 2013 to deal with the impacts of climate change on the country's development. The NCCP and the National Climate Change Adaptation Strategy (Department of Environmental Affairs 2016a, b) (a ten-year programme running from 2010 to 2020) influenced, to some extent, the creation of climate change awareness, especially among vulnerable communities and groups. Conversely, the potential role of risks insurance in climate change adaptation action is underexplored. Adaptation planning decisions are mainly guided by the policies of local government authorities who operate through mostly socio-economic and spatial planning policies (Korah et al. 2017). Just like South Africa, Ghana is a state party to all the relevant international instruments regarding climate risk adaptation. For example, it is a State party to the UNFCCC (1992), the Kyoto Protocol (1997), and the Paris Agreement (2015), and has endorsed both the Sustainable Development Goals (SDGs 2015) and the African Union Agenda 2063 (African Union Commission 2015). Although these international instruments and policy mechanisms are influential, unlike South Africa, Ghana is a dualist state and consequently international conventions do not have the force of law in the Ghanaian legal system unless they are expressly incorporated into domestic law (Oppong 2017). Nevertheless, these instruments can influence the development and adoption of climate change adaptation policy framework, particularly, in promoting risk insurance as an adaptation measure. For instance, the 1992 Constitution of Ghana, in article 36(1) enjoins the government to 'take all necessary action to ensure that the national economy is managed in such manner as to maximize the rate of economic development and to ensure the maximum welfare, freedom and happiness of every person and to provide adequate means of livelihood and suitable employment and public assistance to the needy' (Government of Ghana 1992). In addition, article 37(6) obliges the state to 'ensure that contributory schemes are instituted and maintained that will guarantee economic security for self-employed and other citizens of Ghana' (Government of Ghana 1992). With inspiration to Ghana's commitment to its obligations under international law, these constitutional provisions can influence the design and adoption of insurance as an adaptation measures to address climate change.

Amongst other reactions, the NCCAS, indistinguishable from South Africa, underscores that at the heart of Ghana's economy and society mostly lies climate sensitive sectors like agriculture. According to the NCCAS, about 70% of the country's population depends on agriculture for its livelihood. The vulnerable and indigent community especially the ones living in rural areas and depend on rain-fed farming are the ones that feel the awful repercussions of climate change. Owing to this, the NCCAS focuses on increasing the country's resilience to climate change impacts. The government adaptation measures in Ghana include *inter alia* the recommendation of crop variation and livestock breeding that adapts better to changing climatic conditions and building the capacity of extension officers in new farming technologies to enhance their support to farmers. The Constitution of Ghana, although it does not directly refer to climate change, expressly indicates a duty to protect the environment. Section 36(9) provides that, "the State shall take appropriate measures needed to protect and safeguard the national environment for posterity". The "appropriate measures" meant by the Constitution include the climate change adaptation measures. Section 36, Article 3 carries a more detailed responsibility of not only undertaking measures that promote agriculture but also its development. When this is critically examined, climate insurance measures can be recognised as one of such measures that currently fit under the scope of Section 36, Article 3. Sova et al. (2015) considered food insurance schemes amongst their suggestion of climate change adaptation strategies that could be undertaken in the Ghanaian agricultural sector.

Climate hazards like drought, excess rain or flood, bush fires and so on are prevalent in Ghana and greatly affect agricultural production. The country being the second largest cocoa producer in the world (with Cote d'Ivoire being the first) is expected to have a comprehensive safety net when it comes to protecting its agricultural produce. However, Mahul and Stutley (2010) indicates that, no insurance company had yet underwritten a retail market crop or livestock insurance products. Insurance companies at the time had limited or no exposure at all regarding agricultural insurance. Lack of definite ways of assisting or financing climate change adaptation measures leave small or poor farmers relying on ad hoc sponsor or donor support which creates uncertainties and grave frustrations. This begs for urgent viable measures that could deal with climate related financial risks. Micro-insurance is intended for the protection of the low-income persons and households against dire risks for low premiums (IPCC 2012: 322; UNFCCC 2008: 52). From the definition, it is clear that this type of insurance would be applicable to most small scale farmers. The challenge however, according to Weindl et al. (2015) is that micro-insurance may be difficult to cover weather related disasters as these usually affect a community and not individuals thereby requiring large amount of claims.

Despite the potential of insurance as an adaptation response, the National Climate Change Master Plan Action Programmes for Implementation (Climate Change Master Plan) (spanning 2015–2020) (2015: 87) reveals that there are currently no established systems for the transfer of risks associated with agricultural production systems. According to the Climate Change Master Plan, this has led to total losses of food and capital including financial losses when unexpected events strike and make it difficult for farmers to pay back loans. Therefore, through promoting financial support and insurance schemes as adaptation measures, it particularly seeks to develop and establish agriculture- and fisheries-based insurance schemes (Government of Ghana 2015: 74, 87). In discussing insurance as an adaptation strategy, the Climate Change Master Plan emphasizes the need to establish risk transfer systems and alternative livelihoods including insurance to enable vulnerable people to recover after disasters (Government of Ghana 2015: 23). It highlights that communities affected by climate-related disasters have to recover from the impact of such disasters, but that the cost of rebuilding and settlement could be prohibitive due to limited funding and the scale of the problems associated with such disasters. It thus encourages communities to take out insurance policies against climate-related hazards as a form of risk sharing (Government of Ghana 2015: 75).

The Climate Change Master Plan further identifies insurers as important development partners for the Government in many ways including the development of innovative climate change-related insurance products. It for that reason requires the government to collaborate with development partners, the insurance sector and civil society with the view of supporting new innovative insurance mechanisms that can enhance adaptive capacity and allow people to proactively reduce their risk and boost their adaptive capacity. These partnerships are indispensable for assessing not only loss and damage related with climate change, but also to divulge opportunities for international adaptation support. For example, the German Technical Cooperation (GIZ) in Ghana is presently supporting a pilot weather-indexed crop insurance scheme in the northern savannah zone of the country with emphasis on cereals. This pilot programme seeks to learn lessons in order to develop a risk transfer (insurance) scheme of wider scope and coverage for vulnerable farmers (Government of Ghana 2015: 9). As already observed, the fundamental role of insurance in producing support to disaster recovery and adaptation, as well as providing stimulants for practical risk reduction relating to the impacts of climate change cannot be downplayed.

Conclusion

This chapter, with a particular focus on South Africa and Ghana, attempted to link climate change risk to the potential of insurance as an adaptation strategy. It then further examined the situations and adaptation trends and types of insurance policies that can constitute a climate change adaptation strategy in the two countries. Against this backdrop, through the analysis and reflection on existing relevant legal instruments, official documents and literature on the development at the global level and domestic level (Ghana and South Africa), this contribution demonstrates the adverse effects of climate change as a multiplier of the threat to human life and property. Despite the existing legal and policy frameworks on climate change adaptation in both countries, the chapter shows that there is no clear articulation of insurance measures as an adaptation response. With insight from scholarly literature and emerging practices, it further argues how the existing framework may incorporate risk insurance as an adaptation measure in Ghana and South Africa. It observes that the insurance and risk-management industries can play a very critical role in the adaptation of communities, individuals and companies to the impacts of climate change, particularly in developing countries such as Ghana and South Africa.

While not a panacea, one promising avenue is represented by the tremendous potential for insurers and risk managers to become more involved in cushioning vulnerable populations and companies as part of a broader strategy to make them more disaster resilient. The challenge for the insurance community is to continue to identify and articulate the ways in which these strategies can moderate or prevent insurance losses, and to make the business case of how climate-related insurance can boost the adaptive capacities of individuals. The growing insurance risks associated with climate related disasters can be addressed, in part, through the inclusion of climate change insurance in national adaptation programme of action and other relevant adaptation responses. Lastly, there is the need to educate and train the relevant insurance industry actors (such as agents, brokers, executives, risk managers, trade associations, and underwriters), vulnerable populations and communities to be involved in the assessment and implementation of the opportunities associated with climate-induced disasters in both South Africa and Ghana.

References

Abate T (2016) Contribution of indigenous knowledge to climate change and adaptation response in Southern Ethiopia. J Earth Sci Clim Change 7(11)
Addaney M (2019) Adaptation governance and building resilience in the face of climate change in African cities: policy responses and emerging practices from Accra. In: Cobbinah PB, Addaney M (eds) The geography of climate change adaptation in urban Africa. Springer, London
Addaney M, Cobbinah PB (2019) Climate change, urban planning and sustainable development in Africa: the difference worth appreciating. In: Cobbinah PB, Addaney M (eds) Geography of climate change adaptation in urban Africa. Springer, London
Addaney M, Boshoff E, Oyetola B (2017) The climate change and human rights nexus in African, special edition on the environment and international law. Amst Law Forum 9(3):5–28
Adger WN, Arnell NW, Tompkins EL (2005) Successful adaptation to climate change across scales. Glob Environ Change 15:77–86
African Union Commission (2015) Agenda 2063: the Africa we want. https://au.int/sites/default/files/pages/3657-file-agenda2063_popular_version_en.pdf
Agrawala S, Fankhauser S (eds) (2008) Economic aspects of adaptation to climate change: costs, benefits and policy instruments. Organization for Economic Cooperation and Development, Paris
Agrawala S, Carraro M, Kingsmill N, Lanzi E, Mullan M, Prudent-Richard G (2011) Private sector engagement in adaptation to climate change: approaches to managing climate risks. OECD Environment Working Papers No. 39, OECD Publishing, Paris
Allman L, Fleming P, Wallace A (2004) The progress of English and Welsh local authorities in addressing climate change. Local Environ 9(3):271–283
Atapattu SA (2016) Human rights approaches to climate change: challenges and opportunities. Routledge, New York
Benhin JKA (2006) Climate change and South African agriculture: impacts and adaptation options. Discussion paper (DP)21, Center for Environmental Economics and Policy for Africa (CEEPA), University of Pretoria, South Africa
Berkhout F (2012) Adaptation to climate change by organizations. WIREs Clim Change 3:91–106. https://doi.org/10.1002/wcc.154
Bowen A, Rydge J (2011) Climate change policy in the United Kingdom (August Policy Paper). Grantham Research Institute on Climate Change and the Environment, London School of Economics, London, pp 251–269. https://doi.org/10.1787/5kg6qdx6b5q6-en
Brugmann J (2012) Financing the resilient city. Environ Urban 24(1):215–232. https://doi.org/10.1177/0956247812437130
Bulkeley H, Betsill M (2003) Cities and climate change: urban sustainability and global environmental governance. Routledge, London
Bulkeley H, Betsill M (2005) Rethinking sustainable cities: multi-level governance and the "urban" politics of climate change. Environ Polit 14(1):42–63
Chu SY, Schroeder H (2010) Private governance of climate change in Hong Kong: an analysis of drivers and barriers to corporate action. Asian Stud Rev 34(3):287–308
Constitution of the Republic of South Africa (1996)

Davies A (2005) Local action for climate change: trans-national networks and the Irish experience. Local Environ 10(1):21–40
Department of Environmental Affairs (2011) National climate change response white paper
Department of Environmental Affairs (2016a) South Africa national adaptation strategy draft for comments
Department of Environmental Affairs (2016b) South Africa's second annual climate change report
Dlugolecki AF (2000) Climate change and the insurance industry. Geneva Pap Risk Insur 25(4):582–601
Elum ZA, Simonyan J (2016) Analysis of Nigerian insurers' perceptions of climate change. South Afr J Econ Manag Sci 19:549–561
Government of Ghana (1992) Constitution of the Republic of Ghana. Government Press, Accra
Government of Ghana (2013) Ghana national climate change policy. Ministry of Environment Science, Technology and Innovation, Accra, Ghana
Government of Ghana (2015) National climate change master plan action programmes for implementation 2015–2020. National Climate Change Committee (NCCC) of Ghana/The Ministry of Environment, Science, Technology and Innovation, Accra
Grothmann T, Patt A (2005) Adaptive capacity and human cognition: the process of individual adaptation to climate change. Glob Environ Change 15(3):199–213
Guha-Sapir D, Hoyois P, Below R (2013) Annual disaster statistical review: the numbers and trends. Centre for Research on the Epidemiology of Disasters (CRED)
Hallegatte S et al (2010) Flood risks, climate change impacts and adaptation benefits in Mumbai: an initial assessment of socio-economic consequences of present and climate change induced flood risks and of possible adaptation options. OECD Environment Working Papers No. 27, OECD Publishing, Paris. http://dx.doi.org/10.1787/5km4hv6wb434-en
Hedger M, Bird N (2011) Climate change challenges for European Development Cooperation: issues towards 2020. EDC Policy Brief No. 15, EADI, Bonn
IPCC (2001) Climate change 2001: impacts, adaptation, and vulnerability. Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge
IPCC (2012) In: Field CB, Barros V, Stocker TF, Qin D, Dokken DJ, Ebi KL, Mastrandrea MD, Mach KJ, Plattner G-K, Allen SK, Tignor M, Midgley PM (eds) Managing the risks of extreme events and disasters to advance climate change adaptation. Cambridge University Press, Cambridge
IPCC (2014) Climate change 2014: impacts, adaptation, and vulnerability. Summary for policymakers. Contribution of working group II to the fifth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge
IPCC (2018) An IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development and efforts to eradicate poverty: summary for policymakers. IPCC, Geneva. Retrieved from http://ipcc.ch/report/sr15/
Jegede AO (2016a) The climate change regulatory framework and indigenous peoples' lands in Africa: human rights implications. Pretoria University Law Press
Jegede AO (2016b) Rights away from home: climate-induced displacement of indigenous peoples and the extraterritorial application of the Kampala convention. Afr Hum Rights Law J 16(1):58–82
Jegede AO, Mokoena UCA (2018) Connecting the dots: climate change, disaster and social security under the African regional human rights system. In: Bamgbose O (ed) The law and practice on disaster issues. Safari Books Limited, pp 345–368
Jegede AO, Mokoena UCA (2019) Thinking into the future: constructing social security law as an adaptation measure in South Africa. In: Cobbinah PB, Addaney M (eds) Appreciating difference: the geography of climate change adaptation in urban Africa. Palgrave MacMillan, pp 329–353
Johannsdottir L, Davidsdottir B, Goodsite ME, Olafsson S (2014) What is the potential and demonstrated role of non-life insurers in fulfilling climate commitments? A case study of Nordic insurers. Environ Sci Policy 38:87–106
Juhola S (2013) Adaptation to climate change in the private and the third sector: case study of governance of the Helsinki Metropolitan region. Environ Plan C 31:911–925

Keskitalo ECH (ed) (2010) The development of adaptation policy and practice in Europe: multi-level governance of climate change. Springer, Dordrecht

Keskitalo ECH, Vulturius G, Scholten P (2014) Adaptation to climate change in the insurance sector: examples from the UK, Germany and The Netherlands. Nat Hazards 71:315–334

Klein RJT et al (2007) Inter-relationships between adaptation and mitigation. In: Parry ML et al (eds) Impacts, adaptation and vulnerability: contribution of working group II to IPCC (AR4). Cambridge University Press, Cambridge, pp 745–747

Korah PI, Cobbinah PB, Nunbogu AM, Gyogluu S (2017) Spatial plans and urban development trajectory in Kumasi, Ghana. GeoJournal 82(6):1113–1134

Kyoto Protocol (1997) Kyoto Protocol to the United Nations framework convention on climate change

Landauer M, Juhola S, Klein J (2018) The role of scale in integrating climate change adaptation and mitigation in cities. J Environ Planning Manage 62(5):741–765

Linnerooth-Bayer J, Mechler R (2006) Insurance for assisting adaptation to climate change in developing countries: a proposed strategy. Clim Policy 6(6):621–636

Maddison D (2007) The perception of and adaptation to climate change in Africa. Policy Research Working Paper No. 4308, World Bank, Washington, DC

Mahul O, Stutley CJ (2010) Government support to agricultural insurance: challenging and options for developing countries—overview (English). World Bank, Washington, DC

Mayer B (2018) The international law on climate change. Cambridge University Press, Cambridge

Mees HLP, Driessen PPJ, Runhaar HAC (2012) Exploring the scope of public and private responsibilities for climate adaptation. J Environ Plan Policy Manag 14:305–330

Mees HLP, Driessen PPJ, Runhaar HAC, Stamatelos J (2013) Who governs climate adaptation: getting green roofs for storm-water retention off the ground. J Environ Plan Manag 56:802–825

Mills E (2012) The greening of insurance. Science 338:1424–1425

Michaelowa A (2006) Can insurance deal with negative effects arising from climate policy measures? Clim Policy 6(6):672–682

Nagel J (2015) Introduction: why gender and climate change? In: Nagel J (ed) Gender and climate change: impacts, science, policy

Oppong RF (2017) Ghana. In: Basedow J, Rühl G, Ferrari F, Asensio PM (eds) Encyclopedia of private international law. Edward Elgar Publishing

Parry M, Parry ML, Canziani O, Palutikof J, Van der Linden P, Hanson C (eds) (2007) Climate change 2007-impacts, adaptation and vulnerability: working group II contribution to the fourth assessment report of the IPCC, vol 4. Cambridge University Press

Phelan L, Taplin R, Henderson-Sellers A, Albrecht G (2011) Ecological viability or liability: insurance system responses to climate risk. Environ Policy Gov 21:112–130

Ranger N, Warner K, Surminski S, Arnold M, Linnerooth-Bayer J, Michel-Kerjan EO, Kovacs P, Herweijer C (2009) Adaptation to climate change: linking disaster risk reduction and insurance. United Nations International Strategy for Disaster Reduction Secretariat (UNISDR), Geneva

Rosenzweig C, Solecki W, Hammer SA, Mehrotra S (2010) Cities lead the way in climate-change action. Nature 467:909–911

Santam (2018) Risk management in a changing climate. https://www-acc.santam.co.za/about-us/media/specialist-business/risk-management-in-a-changing-climate/

Schwab K (2013) The global competitiveness report 2013–2014. World Economic Forum, Geneva

Schäfer L (2016) Making climate risk insurance work for the most vulnerable: seven guiding principles. United Nations University Institute for Environment and Human Security (UNU-EHS)

Scherer N (2018) How to advance the monitoring of climate risk insurance, news security beat. Retrieved from https://www.newsecuritybeat.org/multimedia/. Accessed 21 Jan 2018

SDGs (2015) OHCHR sustainable development goals and related human rights. http://www.ohchr.org/Documents/Issues/MDGs/Post2015/SDG_HR_Table.pdf/. Accessed 27 Feb 2019

Schwarze R, Schwindt M, Weck-Hannemann H, Raschky P, Zahn F, Wagner GG (2011) Natural hazard insurance in Europe: tailored responses to climate change are needed. Environ Policy Gov 21:14–30

Social Assistance Act 13 of 2004 of South Africa

Sova CA, Helfgott A, Chaudhury AS, Matthews D, Thornton TF, Vermeulen SJ (2015) Multi-level stakeholder influence mapping: visualizing power relations across actor levels in Nepal's agricultural climate change adaptation regime. Syst Pract Action Res 28:383–409. https://doi.org/10.1007/s11213-014-9335-y

Tompkins EL, Eakin H (2012) Managing private and public adaptation to climate change. Glob Environ Change 22(1):3–11

UNFCCC (1992) United Nations framework convention on climate change

UNFCCC Conference of Parties (2008) CMP decision on the adaptation fund (1/CMP.4). In: Fourteenth session of the conference of the parties (COP 14), Poznan, Poland, 1–12 Dec 2008

Warner K, Ranger N, Surminski S, Arnold M, Linnnerooth-Bayer J, Michel-Kerjan E, Kovacs P, Herweijer C (2009) Adaptation to climate change: linking disaster risk reduction and insurance. UNISDR/MCII

Weindl I, Lotze-Campen H, Popp A, Müller C, Havlík P, Herrero M, Schmitz C, Rolinski S (2015) Livestock in a changing climate: production system transitions as an adaptation strategy for agriculture. Environ Res Lett 10:1–12

Ziervogel G, New M, van Garderen EA, Midgley G, Taylor A, Hamann R, Stuart-Hill S, Myers J, Warburton M (2014) Climate change impacts and adaptation in South Africa. Wiley Interdiscip Rev Clim Change 5(5):605–620

Zwane M, Montmasson-Clair G (2016) A policy assessment: climate change adaptation and agriculture in South Africa: a policy assessment. Report compiled for WWF-SA, South Africa

Chapter 15
Climate Services for Resilient Climate Planning of the Natural Heritage—Serbian Experiences

Tijana Crnčević and Zlata Vuksanović-Macura

Abstract As a signatory of all relevant international documents that support climate change issues, the Republic of Serbia is conducting a continuous process of harmonization of the legal and planning framework. The expected adoption of the National Climate Change Strategy, together with the Action plan will accomplish an important step toward establishing the needed strategic framework to combat climate change and promote adaptation. In the context of climate change, throughout the planning process there is a need for accurate climate services coming from not only national but also international sources (WMO Climate Services, FAO climate change resources, UNESCO's climate change actions, etc.), covering data on rainfall, temperature, soil moisture and wind, as well as analyses and assessments within risk and vulnerability, together with projections and scenarios. Due to the increasingly visible effects of climate change, there is a need to enhance the level of protection of the natural and cultural heritage, and for the formation of appropriate databases. Thus, this paper gives an overview of the international and national framework regarding the climate services needed within the planning process and stresses their importance in achieving resilient climate planning of the natural and cultural heritage. Further, by presenting a selected case study, this paper outlines the main gaps as well as the advantages within the current framework in Serbia. The paper concludes by stressing that, within the planning process, climate services are playing a significant role in formulating adequate measures to cover mitigation and adaptation.

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Introduction

The issue of climate change at the end of the second decade of the twenty-first century has become a primary concern due to the impacts that have grown not only more frequent but also more extreme. According to the latest IPCC report, climate models project strong differences for regional climate characteristics for current global warming at 1.5 °C and for that at between 1.5 and 2 °C. The differences consider increases of mean temperature for the regions covered with land and for oceans and for hot extremes within the majority of inhabited regions (with high confidence), and in some areas for heavy precipitation or probability of drought and precipitation deficits (with medium confidence) (IPCC 2018).

Spaces designated under natural and cultural heritage, due to their unique characteristics, are especially vulnerable to the impacts of climate change. In this regard, the protection of space is the basic instrument that is aimed for in the preservation and sustainable management of these distinct areas. According to the UNESCO List, which also represents the basic global instrument, 1092 properties are under total protection or, in fact, 1090 because two have been delisted, of which 845 are cultural, 209 are natural and 38 are mixed (UNESCO 2019). The cultural sites of the Republic of Serbia included in the UNESCO List are: Stari Ras and Sopoćani; Studenica Monastery; Gamzigrad-Romuliana, the Palace of Galerius; and the Stećci Medieval Tombstone Graveyards and cultural sites in danger among medieval monuments in Kosovo. Fourteen additional national cultural and natural heritage sites, including national parks and natural resources, are entered in the Tentative List. The impact on terrestrial biodiversity is seen in several shifting ranges, including changes within the time of biological cycles, the migration of pests and invasive species, as well as the variation of the frequency and intensity of wildfires (UNESCO 2007a). The cultural heritage is endangered first by physical threats due to the rise in sea level and migration of pests, while archeological sites are threatened by the rise in soil temperature. A second danger to many cultural and social areas arises from the possibility of migration as a result of changes in the way of life and work of these communities (UNESCO 2006; Vuksanović-Macura et al. 2018).

When defining climate services, it should be stressed that its main aim is "the provision of climate information to assist decision-making" (Climateurope. Linking Science and Society 2019). Further, as stated, the provision of these services "must respond to user needs, must be based on scientifically credible information and expertise, and requires appropriate engagement between the users and providers" (ibid.). The recognized international resources within climate services include WMO Climate Services, FAO climate change resources, UNESCO's climate change actions, Red Cross/Red Crescent Climate Centre (RC/RCCC), and the National Oceanic and Atmospheric Administration (NOAA) Climate Services Portal (NCS Portal). To establish a Global Framework for Climate Services (GFCS) in 2009 after the World Climate Conference-3 (WCC-3) that was held in Geneva, Switzerland, a "global partnership of governments and organizations that produce and use climate information and services" was introduced (GFCS 2019). As outlined, the GFCS priority is to identify demand and to "ensure that this demand is met through access to scientific information" in four priority sectors (health, water, food security and agriculture, and disaster risk reduction) where within the next years the aim is to assist in developing the climate service and to reach the goal that in 10 years climate services are delivered to all climate sensitive sectors (ibid.). Regarding Sustainable Development Goals (SDGs), GFCS will have the most important role within its achievements and thus "climate information will be essential background information in monitoring the achievement of Transforming our World: the 2030 Agenda for Sustainable Development goals" (WMO and GFCS 2017: 9).

In the context of climate change and planning, climate services are playing an important role that "requires improved understanding of user needs" (Vincent et al. 2017). The reality of the issues of climate change and the attendant impacts is evident from the body of published scientific articles—more than 4000 scientific papers covering climate change were published up to the year 2014 (Perry and Falzon 2014). Thus, the research results covering the needs within climate services in planning have indicated that existing climate services are inadequate in terms of: (1) the spatial and temporal scale—existing climate information is not downscaled to the necessary resolution, with a lack of sub-annual to short-term (1–5 year) climate projections; (2) their accessibility and credibility—they are not tailored, packaged and communicated in a way that is useful for decision makers (Vincent et al. 2017). Thus, it is stressed that within decision making only 5–10 day and seasonal forecasts are currently being used and "findings highlight that there is a potentially high user demand for climate information that currently does not exist", and that there is "lacking access to data of high accuracy, relevance and quality including detailed climate projections and socio-economic information" (ibid.: 199). In this sense, the importance of climate services should be especially emphasized because, as was projected, accurate and updated hydro meteorological information, as well as an early warning in developing countries, could annually save approximately 23,000 lives and from US$3 billion to US$30 billion through disaster risk reduction (Rogers and Tsirkunov 2013). As is stressed, respecting "different needs for climate services in different stages of the urban planning process," there is the need to integrate climate services within "existing" urban planning tools (EU-MACS 2017).

In Serbia, according to the *Law on planning and construction* (2018), the main national responsible organization for providing climate service is the Republic Hydrometeorological Services of Serbia (RHSS), which issues appropriate conditions during the preparation of the plans and projects documentation. In this paper an overview is given of the main frames within the international and national frameworks, regarding the climate services needed within the planning process, with special reference to the natural and cultural heritage in the context of climate change. Further, the selected case study outlines the main gaps, as well as the advantages within the current framework in Serbia for climate services to achieve resilient climate planning.

Methodology

This research is based on the analysis and review of the relevant literature and documents, from the global, international level to the national level, encompassing Serbian experience, covering the issues of climate services and the planning of the natural and cultural heritage in the context of climate change. The survey includes an overview of the national database of spatial plans and a selection of plans for the area of special purposes that includes terrains with the status of natural and/or cultural heritage. The analysis of the selected plans for the area with special purpose included a search by relevant words, such as climate, climate change, climate variability and adaptation. This examination first enabled general insight into the use of the required terms, while additional reading provided the possibility of a more detailed analysis and interpretation (Milinković et al. 2019). The national database includes spatial plans developed for localities throughout Serbia, created in the period from 2011 to 2015, until the base was updated. In this way, the temporal and spatial coverage of monitoring these concepts and their development through the planning documents have been achieved. In addition, the plans collected in this database were created by different institutions, from different cities and with different professional backgrounds and capacities.

Among these plans, we have chosen the Spatial Plan for the Area of Special Purposes of Kopaonik National Park, located in the central Serbia on the northern part of the largest mountain range in the country. Because of its distinguished characteristics, Kopaonik has a status of National Park and protected area of outstanding values, covering a range of natural and cultural heritage, and it is on the UNESCO Tentative List. At the same time, Kopaonik is a ski center and one of the most popular touristic areas in Serbia, with developed non-seasonal facilities such as conference facilities, restaurants, mountain amenities, sport terrains and recreation areas (Miljanović 2015). On the other hand, intensive informal construction of vacation real estates and individual buildings, as well as deforestation caused by further development of skiing terrains and facilities, are the permanent threat to natural ecosystems and affecting micro-climate (Ćurčić 2017).

Climate Services and Planning from International Perspectives

A global, international framework that promotes the issues of climate change primarily refers to *UNFCCC 1992, the Kyoto Protocol 1997, the European Climate Change Program and European Emissions Trading Scheme* (Crnčević 2013). Within recent years the framework has been dedicated to formulating specific strategies and programs for reducing the impacts and adapting to climate change—*Action plan UNFCCC 2007, Cancun Adaptation Framework 2010, White Paper on Adapting to Climate Change*, as well as the *Sendai Framework for Disaster Risk Reduction.*

The adoption of the *Paris Agreement on Climate Change,* [1] together with 17 Sustainable Development Goals (SDG) have established that contemporary sustainable development is "conditioned" by climate change issues. Within the United Nations Framework Convention on Climate Change (UNFCCC), along with 17 SDGs to assist with adaptation planning in Least Developed Countries and other developing countries, a process has been established for the National Adaptation Plan (NAP). The process includes four key elements: laying the groundwork and addressing gaps, preparatory elements, implementation strategies and reporting, and monitoring and review (WMO and GFCS 2017). Within these elements are activities given to the NAP, primarily initiating and launching the NAP process; addressing capacity gaps and weaknesses in undertaking the NAP process; analyzing current climate and future climate-change scenarios; assessing climate vulnerabilities and identifying adaptation options at the sectoral, subnational, national and other appropriate levels; integrating climate change adaptation into national and subnational development and sectoral planning; prioritizing climate change adaptation in national planning and monitoring; and reviewing the NAP process. The GFCS is "an end-to-end system that uses observations, technology and scientific understanding as inputs to the development of climate services to meet user requirements" (ibid.: 13) and it consists of five components—"pillars" that interact: (a) User Interface Platform; (b) Climate Services Information System; (c) Observations and monitoring; (d) Research, modeling and prediction; (e) Capacity development (to support the systematic development of the institutions, infrastructure and human resources needed for effective climate services) (ibid.). Taking into consideration the premises of achieving resilient climate planning for natural and cultural heritage, of importance, after GFCS, is the priority area of disaster risk reduction which outlines the needed weather and climate service data and information products and services:

(a) "Prioritizing climate change adaptation in national planning (identify priority regions based on analysis of vulnerability to weather and climate extremes and other important factors and future projections);
(b) Developing a (long-term) national adaptation implementation strategy (identify the areas where current information on weather and climate is inadequate, strengthen the meteorological observation networks, data analysis and applications;
(c) Enhancing capacity for planning and implementation of adaptation (strengthen operational climate services, including analysis, forecasts and projection of climatic regimes and probabilities and scenarios related to extreme patterns, promote interoperability of health, socioeconomic and biological data with weather, hydrological and climate extremes and changes in their characteristics) and
(d) Promoting coordination and synergy at the regional level and with other multilateral environmental agreements" (WMO and GFCS 2016: 30).

[1] Paris agreement was adopted at the 21st Conference of the Parties of the United Nations Framework Convention on Climate Change (UNFCCC).

When we consider climate services, the main benefits of their use should first be outlined in: delivering science-based information that covers all sectors and levels (global, regional, local) and time periods (past, present and future); providing projections, economic analyses, trends and services through various modes—web portals, climate statistical tables and maps, mobile-phone applications or by applying "users' dialogue" within workshops, seminars, open days, feedback sessions and practical exercises for revising, checking and improving products and services (WMO 2017).

Particular emphasis should be put on the role of national meteorological and hydrological services in the provision of climate services, as well as in supporting the adaptation process: protecting life, property and the environment; participating within the process of sustainable development; arranging long-term observation and collection of meteorological, hydrological, climatological and other related environmental data; supporting endogenous capacity-building; meeting international commitments; and contributing to international cooperation (ibid.).

The need to take into account the existence of "certain pressures" and consequently of the necessity for innovating the established systems and criteria for protected areas was pointed out by Bishop et al. (1995). Corresponding to that, it should be emphasized that "the issue of climate change does not represent only current 'pressure', but also the necessity of the policy of protecting the natural and cultural heritage of the 21st century" (Crnčević et al. 2015: 38). Within the management of protected areas, the problems that managers have should be stressed in their efforts to focus on adaptive measures with a lack of knowledge, resources and institutional structure for collaboration within departments and within communities (Perry and Falzon 2014). Areas considered as natural heritage have an important role in reducing CO_2—15% or 312 gigatons are stored in protected areas throughout the world (in 39 national park in Canada over 4 billion tons and in the Brazilian Amazon 8 billion tons). The role of these sites is also important within the impacts of climate change as they serve as natural buffers, providing space for floodwaters to stabilize soil against landslides and to block storm surges (ibid.). On the other hand, protected areas can handle out the impacts of climate change and in this context stand out as a source of clean water and food—"thirty-three of the world's hundred largest cities derive their drinking water from catchments within forest protected areas" (ibid.: 33).

The current practice of planning an area under protection stands on principles that ensure the authenticity, integral protection of natural and cultural heritage, controlled use of potentials and a minimum intervention and maintenance on a permanent basis (UNESCO 2007b). The focus is on the protection of Outstanding Universal Value (OUV)[2] and its features where monitoring and evaluation are important in order to be able to adjust activities. Thus, it can be summarized that the premises of contemporary planning are to achieve climate resilient planning where resilience is defined as elasticity. This "refers to the ability of a system to survive impact and

[2]Cultural and/or natural significance which is so exceptional as to transcend national boundaries and to be of common importance for present and future generations of all humanity. As such, the permanent protection of this heritage is of the highest importance to the international community as a whole (UNESCO 2013).

recover functioning to its original or desired state after a disturbance" (Pérez et al. 2010). In that sense, it is assumed that when a system is resilient it can absorb distresses—flood, drought, fire, without any major long-term turbulences regarding its functioning (ibid.). Taking these ideas into account, two processes can be identified that are connected to resilience: resistance compromises the ability of an "ecosystem to absorb disturbance without structural change" while recovery describes "the speed of return to the predisturbance ecosystem structure" (Côté and Darling 2010: 1).

Within adaptation/resilient planning for natural and cultural sites, the dynamics of climate change should be considered and provide for the review of the zoning system together with laws and regulations that influence the process and the ability to adapt (Perry and Falzon 2014). Additionally, it is necessary to provide continuous monitoring as well as vulnerability assessment processes because, as stated, the effectiveness of certain activities has proven to be successful during recent years: "increasing the resilience of a site by reducing non-climatic sources of stress, re-designing boundaries and buffer zones to facilitate the migration of species, preventively draining a glacial lake to avoid the occurrence of an outburst flood, improving dykes to prevent coastal flooding, supporting traditional methods to protect a site from sand encroachment, etc." (UNESCO 2006). Further, as was estimated by the United Nations, coastal wetlands protection against hurricanes saves US$23.2 billion per year (Perry and Falzon 2014).

However, the worst scenario occurs when the OUV of the subject area is irreversibly affected and where the impact of climate change represents only one of the factors. This has required the World Heritage Committee to reconsider the implications that they will include in the Convention (UNESCO 2006). The fact that climate change impacts now threaten World Heritage emphasizes the necessity to adapt all processes and procedures related to the Convention, such as its nominations, periodic reporting and reactive monitoring, and in that sense "design appropriate measures for monitoring the impacts of Climate Change and adapting to the adverse consequences"(ibid.: 3).

The significance of the exchange of information as well as the establishment of a database for spaces on the World Heritage List was indicated in 2011 in the document called the Sintra Contribution (2011). Because through the planning process all those included are making decisions, therefore, in the context of climate change it is essential to provide adequate information that will enable all included in the process to achieve "climate-smart decisions" (WMO 2017). The role of the GFCS within the achievement of SDGs is to promote the use of climate information and services in meeting the SDGs and their relevant targets (ibid.). The notable example is Germany, which in accordance with the GFCS recommendations has innovated and developed climate services, including the following components: (1) Climate monitoring; (2) Climate modeling, forecasts, projections, climate impact assessment; (3) Climate information and data platform; (4) Communication with users; (5) Building climate capacities through international activities. Thus, the Deutscher Wetterdienst (DWD), besides providing data and information for portals, is also covering consulting with various customers and helping to "enhance users' capability to use climate data in various areas of application" (DWD 2019).

Because the planning process covers environmental, social and economic aspects of the subject area, in order to achieve resilient climate planning, information throughout the process is needed that covers various spatial and temporal scales. For that purpose, "Climate Services for urban planning need to be conceived as platforms where different kinds of data and information can be integrated and retrieved" (Giordano et al. 2018: 1). However, as noted, the use of climate services in daily activities is still far from being the standard in most EU cities (ibid.). One of the recognized barriers for the use of climate services is limited knowledge of the information already available. Therefore, climate services "need to be conceived not exclusively as a supply of information, but also as a shared platform though which the interactions among the different decision-makers are facilitated, enabling an effective information sharing process" (ibid.). The primary issue within climate services design should be "information users, the information needed and how this information will be integrated in the urban planning process." Recommendations for overcoming barriers are to co-design climate services together with end users, as results within Project EU-MACS demonstrated "that a collaborative design, acquisition and use of climate services, involving institutional actors, citizens and private actors, is feasible and can resolve broad scoped information need" (ibid.: 3). However, the other area of the work is to be done within adaptation policy making so that: "mitigation is prioritized over adaptation; short term policy cycles reduce the willingness to implement long-term adaptation measures; and the lack of tools for assessing the effectiveness of adaptation measures affects public awareness about the role of adaptation measures in reducing climate-related risks"(ibid.).

Planning and Protecting Natural and Cultural Heritage in the Context of Climate Change in Serbia

The Republic of Serbia, taking into account its aspiration towards European integration, is a signatory of all relevant documents that concern sustainable development and climate change (*the Paris Agreement, the UNFCCC, the Kyoto Protocol, the UNISDR, European Climate Change Programme, the European Emissions Trading Scheme (ETS), White paper on Adapting to Climate Change, and the EU Adaptation Strategy and others*). Regarding planning and climate change, it has been emphasized that the issue is represented within spatial and urban planning practice, primarily by advocacy measures that promote enlarging protected areas, the planning of ecological corridors and networking of habitats, water management, as well as measures for the protection of cultural heritage (Crnčević 2013; Crnčević et al. 2015). The results of this research emphasize the necessity to continue to innovate the current framework and planning practice towards integrating the climate change scenarios in the process of evaluating and risk management and mapping these areas together through the development of methods and techniques aiming to gain insight into the hazards and risks within the subject area and to direct the planning practice towards integrating climate change scenarios into the process of evaluating and managing risks and mapping these vulnerable areas (Lazarević 2011; Crnčević et al. 2015). Further, it is emphases the need for bottom up approach within further development of strategies and initiatives (i.e. green infrastructure, agriculture) in mitigating the impacts of climate change (Živanović Miljković et al. 2012). It should be stressed that adaptive measures for the field of agriculture, forestry and hydrology and water resources are given within the *Second National Communication of the Republic of Serbia to the UN Framework Convention on Climate Change* and that, after a review of the available data, Serbia's application has already begun for the sector of agriculture (RS 2017). However, given adaptation capacity, it should be stressed that the "development of a system for adaptation is still not recognized as a priority", as the "main limitations could be seen in the fields of impact research and implementation of the planning instruments" (ibid.: 167).

Under the *Law on Nature Protection* (2010), natural heritage includes protected areas, species and movable natural finds. In line with European frameworks, the adoption of the *Regulation on the ecological network* (2010) specifically promotes the protection of these areas within the planning process. In the context of the protection of cultural heritage, and in accordance with the *Law on Cultural Property* (1994), cultural heritage includes, inter alia, cultural monuments, spatial cultural and historical units, archaeological sites and notable places—immovable cultural property. However, as pointed out, the current situation is characteristic in that "*the current level of integration of climate change into sectoral and overall development strategy, the level of knowledge, institutional and individual capacities, available technology and financial resources at the national level, together with the involvement of local governments are not sufficient, despite numerous activities and efforts, for an effective and rapid response to climate change issues*" (RS 2017).

The legislative framework that has promoted the issue of climate change within last decade has been improved so that the adoption of the Climate Change Strategy with Action Plan is expected. The aim of this Strategy is to identify the possibilities for reducing the GSB emissions, as well as establishing adaptation measures for priority sectors on the basis of a broader list of measures provided under the *Second National Report under the UN Framework Convention on Climate Change.* In addition, the objectives of the Strategy is the identification of new opportunities for industry, directions of competitive and sustainable development, as well as consideration of energy security and the harmonization of national policies with EU frameworks (RS 2018). In the context of the climate services, the Strategy also identified the necessary data for the implementation of the Framework plan for the adaptation (FPA): (1) Climate change and extreme weather trends and dangers that could affect the scope of the FPA (floods, droughts, heat waves, temperature rise, precipitation and increase of precipitation intensity); (2) Historical data on relevant climate change and extreme weather hazards and trends and extremes related to temperature, trends and extreme conditions related to precipitation and details of significant climate events and extreme weather events that have occurred in the past (ibid.).

Taking into account what has been previously stated in terms of the necessity for establishing appropriate information support to promote adaptation and, in that sense, achieve resilient climate planning, it should be noted that the results of an analysis of the planning documentation (Crnčević et al. 2015) have shown that the following measures are present for (1) Natural heritage: promotion of increasing the resilience of natural areas, increasing the number of protected areas, increasing their size, maintaining or increasing the heterogeneity of habitats at the landscape level, maintaining the species resilience within communities, ensuring the functional connection between the protected species, the planning of ecological corridors and networking of the habitats, and (2) Cultural heritage: monitoring cultural heritage and preventing damage, taking planning measures that integrate cultural and natural heritage, conducting regular repairs and restoring cultural heritage facilities, and promoting research to avoid damage. Within the analyzed planning documents, there were no measures that promoted cultural heritage to be viewed as vulnerable to climate change.

Climate Services and Planning—Serbian Context

The meteorological service was founded on the 27th of September 1888—in the 19th century, over 120 years ago after the Regulation on the establishment of a unified network of meteorological stations in the Kingdom of Serbia. However, the systematic measuring of temperature, humidity, precipitation, wind and air pressure started within a privately owned parcel in Belgrade four years earlier, in 1848. Within less than a decade, a network of meteorological stations was created in 27 towns in Serbia that was the densest network in Europe at that time. The international exchange started in the beginning of the 20th century, at the same time when the daily publishing of weather reports and weather forecasts in the newspapers began. Under the Regulation of the Government of the Federative People's Republic of Yugoslavia, in 1947, the Federal Hydro meteorological Institute (FHMI) was founded so that FHMI was among the 45 world meteorological organizations that established the Convention on the establishment of the World Meteorological Organization (WMO), which was ratified in 1950. Following the disintegration of Yugoslavia in the 1990s, FHMI was abolished. In 2003, RHSS was entrusted as FHMI's legal successor, with all its responsibilities, including international cooperation (http://www.hidmet.gov.rs/eng/orhmz/istorija.php).

RHSS cooperates with WMO within the framework of the following commissions: Basic Systems, Instruments and Observation Methods, Climatology, Atmospheric Sciences, Aeronautical Meteorology, Maritime Meteorology, Agro Meteorology and Hydrology. In addition, the RHSS is an active participant of the following programs and projects: World Meteorological Waken, World Climate System, Atmospheric and Environmental Research Program, Program of Applied Meteorology, Technical Cooperation Program, Training and Education Program and Regional and Bilateral Programs. It has also established cooperation with international organizations such as: (1) European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) (http://www.eumetsat.de), where as an associate member has access to satellite images in real time, (2) The European Centre for Medium Term Weather Forecasts (http://www.ecmwf.int) where, as an associate member, among other things, has access to all analytical and prognostic products of the center as well as access to forecasts for up to ten days and seasonal forecasts (http://www.hidmet.gov.rs/).

In addition, RHSS hosts the South East European Virtual Climate Change Center and has participated in the OrientGate project, which has established a network of 30 partners, covering 13 countries across South East Europe. The aim of the OrientGate project is to "communicate up-to-date climate knowledge for the benefit of policy makers, including urban planners, nature protection authorities, regional and local development agencies, and territorial and public works authorities" (http://www.orientgateproject.org/). The lead partner and project coordinator is the Euro-Mediterranean Centre on Climate Change, while the RHSS is the leader of the Work Package 3—*Mapping and Harmonizing data and Downscaling*, which focuses on mapping various methodologies, tools and indicators used by meteorological services in South East Europe.

The OrientGate project foresees the creation of a database and indicators, i.e. the creation of a *Platform with data for climate scenarios and indicators in SEE*. This involves collecting and analyzing data on the availability, accessibility and handling of meteorological data throughout the SEE region. The set of indicators based on the new cross-harmonized set of climate-based parameters and indicators have been developed and proposed for consideration by various parties involved in the project (Kržič and Milić-Petrović 2014). The project has shown that there are enough meteorological and hydrological stations that have reliable measurements, and that most countries have experience in using climate indicators and in applying the results of climate models. As mentioned earlier, the results of the OrientGate project have shown some shortcomings in institutional and individual capacities and in limited financial and technical resources in relation to effective responses to climate change (SEE 2013). This may explain why the platform with the data provided by the OrientGate project has not yet been made publicly available.

Overview of the Selected Case Study

Within the main legal planning framework[3] there is not adequate support for achieving resilient climate planning as the issue of climate change is, as noted, indirectly presented within planning documents (Crnčević 2013; Crnčević et al. 2016; Crnčević

[3]Law on the Spatial Plan of the Republic of Serbia (Official Gazette RS no. 88/10), Law on Planning and Construction (Official gazette of RS No. 79/09, 81/09-correction, 64/10-US, 24/11, 121/12, 42/13-US, 50/13-US, 98/13-US, 132/14, 145/14 and 83/2018), Law on Strategic Environmental Assessment (Official gazette of RS no. 88/2010), Law on Environmental Impact Assessment (Official gazette of RS no. 135/2004. 36/2009), Law on Environmental Protection (Official gazette of RS no. 135/2004), Law on Emergency Situations (Official gazette RS no. 111/09, 92/11, 93/12), Law on Nature Protection (Official gazette. RS no. 36/2009, 88/2010) etc.

and Orlović-Lovren 2018). The selected case study, the Spatial Plan of the Area of Special Purposes (SPASP) of the National Park (NP) of Kopaonik (2016) was conducted after the establishment of the legal framework mentioned above. In accordance with the *Law on planning and construction*, the content of the SPASP NP Kopaonik includes: the starting points that provide an overview of the scope of the Plan together with borders; the obligations, requirements and guidelines, above all of the Spatial Plan of the RS, and other strategic development documents; the synthesis overview of the analysis and the assessment of the state and constraints and potentials by sectors; the principles and objectives of the spatial development of the area of special purpose; the planning solutions, land use rules, rules of arrangement and construction rules; the implementation, final provisions and graphic attachments in which, among others, there is an annex titled “Network of settlements, infrastructural systems and environmental protection, natural and cultural goods” in the scale of 1:25.000.

SPASP NP Kopaonik represents the planning basis for the protection, use and arrangement of the Kopaonik National Park, as well as other protected and planned-for protection of natural and immovable cultural goods, covered as part of the primary tourist area of Kopaonik and for the sustainable development of the encompassed local communities. The plan is conducted in an ESRI-based GIS environment (ArcGIS 10 h). The Plan, in addition to the area of the NP Kopaonik (with the zones of I, II and III degrees of protection), includes the area outside the National Park, on parts of the territory of the municipalities of Raška, Brus and Leposavić. The Kopaonik National Park extends across the northern part of the Kopaonik massif, which is the largest mountain of central Serbia and extends northwest—southeast in the shape of a reefed ridge about 82 km long and 40–60 km wide, across an area of about 2750 km^2.

The results of the analysis of the planning document based on the key words: climate, adaptation measures, adaptation, climate change, mitigation and impacts mitigation show that the climate problem is not, it can be said, directly represented in the Plan. Climate is primarily mentioned in the sense of being a natural factor of the subject area. On the other hand, taking into account measures that promote adaptation, i.e., the resilient climate planning of the natural and cultural heritage, are present. For the needs of the preparation of the Plan, in accordance with the legal obligation, the Conditions of the RHSS are included and form an integral part of the documentation base. In accordance with the given Conditions, the planning documentation should be in accordance with the *Law on Determining the Location of Meteorological and Hydrological Stations of State Networks and Protection Zones in the vicinity of these stations,* as well as types of limitations that can be introduced in the protection zones. As pointed out, for the production of the climatic base of the area and for the production of geotechnical and hydrolysis bases, the data used are from the Main Weather Station—Kopaonik along with the regional network of climatological and precipitation stations. For the submission of these data from measuring stations from the state network of stations specified in the conditions, in accordance with the given Conditions, it is necessary to contact the RHSS with a special request which includes the name and type of the measuring point, along with the type and volume of data required for the development of the planning and project documentation.

During the preparation of the planning documentation for such data there was no need to make this request as the available data from the existing planning basis and from the Internet was used. The average values of the basic climatic elements for the standard climatological thirty-year period for metering stations are available on the interent site of the RHSS (http://www.hidmet.gov.rs/). Further, for the preparation of the climatic substrate of the specified location, the appropriate request has to be submitted to the Department of Applied Climatology.

Conclusions

Climate services data and information products and services have a significant role in the decision-making and planning process, thus contributing to the formulation of adequate measures covering climate change mitigation and adaptation. Continuous data collection, their unification and public availability are an important instrument in the development of climate-adaptive plans. Some studies covering current experiences have identified certain shortcomings within existing climate services in planning. These shortcomings are, inter alia, related to information and data that do not sufficiently meet regional and local needs, are not spatially and temporally harmonized, are not sufficiently reliable and have limited accessibility for stakeholders. It is therefore important that the collection of relevant data is based on scientific research and experience, as well as in accordance with the needs of users.

In Serbia, progress has been made in the last few decades through the signing of a number of international documents on sustainable development and climate change. However, a system for climate change adaptation and the integration of climate knowledge into policy and territorial planning have not been established. On the other hand, there is a growing need for operational, consistent and continuous data collection and the creation of a platform with data that would be available to a wide range of stakeholders in the planning process, from decision makers and planners to the wider community. In this respect, it would be of particular importance to activate and regularly update the *Platform with climate data and indicators in the SEE* that was first initiated under the OrientGate project. The leading partner from Serbia in the project was RHSS. At the same time, after regulation, RHSS has been in charge of issuing appropriate climatic and related conditions in the planning process, so its role in activating the data platform would be crucial.

The case study presented, the Plan of the area of special purpose of the Kopaonik National Park, has shown that climate is mainly considered through the analysis of natural factors and that the adaptability problems of climate change are only indirectly processed. However, it should be noted that the lack or poor availability of climate-related data within the subject area leads to the inability to adequately formulate planning measures and guidelines for this area. On the other hand, setting up an operational data platform for climate scenarios and indicators will be of particular importance to the planning process of areas that include natural and cultural heritage due to their vulnerability to the impacts of climate change. The data platforms can also provide broader connections among relevant institutions and others concerned with the issue of climate change adaptation and natural and cultural heritage, at the same time contributing to the further strengthening of integration of climate knowledge into policy and spatial planning in Serbia.

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References

Bishop K, Phillips A, Warren L (1995) Protected forever? Factors shaping the future of protected area policy. Land Use Policy 12(4):291–305

Crnčević T (2013) Planiranje i zastita prirode, prirodnih vrednosti i predela u kontekstu klimatskih promena u Republici Srbiji – prilog razvoju metodoloskog okvira. Posebna izdanja no. 72. IAUS, Beograd

Crnčević T, Dželebdžić O, Marić I (2015) Klimatske pormene i zaštita – novija iskustva u planiranju područja kulturnog i prirodnog nasleđa. Arnitektura i urbanizam 40:37–46. https://doi.org/10.5937/a-u0-7759

Crnčević T, Dželebdžić O, Milijić S (2016) Planning and climate change: a case study on the spatial plan of the Danube corridor through Serbia. In: Leal Filho W, Adamson K, Dunk R, Azeiteiro U, Illingworth S, Alves F (eds) Implementing climate change adaptation in cities and communities. Climate change management. Springer, Heidelberg, pp 161–177

Crnčević T, Lovren-Orlović V (2018) Displacement and climate change: improving planning policy and increasing community resilience. Int J Clim Chang Strat Manag 10(1):105–120. https://doi.org/10.1108/IJCCSM-05-2017-0103

Climateurope. Linking Science and Society (2019) What do we mean by climate services? https://www.climateurope.eu/definitions-climate-services. Accessed 20 Nov 2019

Côté IM, Darling ES (2010) Rethinking ecosystem resilience in the face of climate change. PLoS Biol 8(7):e1000438. https://doi.org/10.1371/journal.pbio.1000438

Ćurčić N (2017) Prostorno-vremenska analiza antropogenih uticaja na prirodne ekosisteme u Nacionalnom parku Kopaonik [Spatio-temporal analysis of anthropogenic impact on natural ecosystems in National park Kopaonik]. Dissertation, University of Belgrade, Faculty of Geography

DWD (2019) DWD's climate services observing—modelling—consulting. https://www.dwd.de/EN/ourservices/climate_services_report/brochure.html. Accessed 20 Feb 2019

Decree on Ecological Network. Official Gazette of RS No. 102/2010

EU-MACS (2017) Climate services need to be integrated into existing urban planning tools. http://eu-macs.eu/new/climate-services-need-to-be-integrated-into-existing-urban-planning-tools/. Accessed 20 Jan 2019

GFCS (2019) What is the global framework for climate services and what will it accomplish? https://www.wmo.int/gfcs/what_is_GFCS. Accessed 25 Feb 2019

Giordano R, Vaittinen I, Pilli-Sihvola K, Portoghese I, Matarrese R (2018) Potential for climate services market enhancement and related innovation for urban planning. EU-MACS, deliverable 4.3—policy brief. http://eu-macs.eu/wp-content/uploads/2017/01/EUMACS_D4_3_Policy_Brief_final.pdf. Accessed 25 Feb 2019

http://www.eumetsat.de. Accessed 20 Mar 2019

http://www.ecmwf.int. Accessed 20 Mar 2019
http://www.hidmet.gov.rs/. Accessed 20 Mar 2019
http://www.hidmet.gov.rs/eng/orhmz/istorija.php. Accessed 20 Mar 2019
http://www.orientgateproject.org/. Accessed 20 Mar 2019

IPCC (2018) Summary for policymakers. In: Masson-Delmotte V, Zhai P, Pörtner HO, Roberts D, Skea J, Shukla PR, Pirani A, Moufouma-Okia W, Péan C, Pidcock R, Connors S, Matthews JBR, Chen Y, Zhou X, Gomis MI, Lonnoy E, Maycock T, Tignor M, Waterfield T (eds) Global warming of 1.5 °C. An IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. World Meteorological Organization, Geneva

Kržič A, Milić-Petrović B (2014) Proposed set of indicators. OrientGate. http://www.orientgateproject.org/uploads/Press%20releases/results%20docs/WP3_Proposed%20set%20of%20indicators.pdf. Accessed 25 Feb 2019

Lazarević Bajec N (2011) Integrating climate change adaptation policies in spatial development planning in Serbia: a challenging task ahead. Spatium 24:1–8. https://doi.org/10.2298/SPAT1124001L

Law on Determining the Location of Meteorological and Hydrological Stations of State Networks and Protection Zones in the vicinity of these stations, as well as types of limitations that can be introduced in the protection zones. Official Gazette of RS No. 34/13

Law on Nature Protection. Official Gazette of the Republic of Serbia No. 36/2009, 88/2010

Law on Cultural Property. Official Gazette of the Republic of Serbia No. 74/1994, 52/2011

Law on Planning and Construction. Official Gazette of RS No. 79/09, 81/09-correction, 64/10-US, 24/11, 121/12, 42/13-US, 50/13-US, 98/13-US, 132/14, 145/14 and 83/2018

Milinković M, Ćorović D, Vuksanović-Macura Z (2019) Historical enquiry as a critical method in Urban riverscape revisions: the case of Belgrade's confluence. Sustainability 11(4):1177. https://doi.org/10.3390/su11041177

Miljanović D (ed) (2015) Leksikon Nacionalnog parka Kopaonik [Lexicon of the Kopaonik National Park]. Beograd, JP Službeni glasnik, Geografski institute "Jovan Cvijić" SANU, JP Nacionalni park Kopaonik

Perry J, Falzon C (2014) Climate change adaptation for natural world heritage sites a practical guide. World Heritage Paper Series No. 37. UNESCO, Paris. http://whc.unesco.org/en/series/. Accessed 10 Jan 2019

Pérez A, Herrera Fernandez A, Gatti GR (eds) (2010) Building resilience to climate change: ecosystem-based adaptation and lessons from the field. IUCN, Gland

Rogers D, Tsirkunov VV (2013) Weather and climate resilience effective preparedness through national meteorological and hydrological services; directions in development environment and sustainable development. International bank for reconstruction and development, The World Bank. https://openknowledge.worldbank.org/bitstream/handle/10986/15932/81113.pdf?sequence=1&isAllowed=y. Accessed 10 Jan 2019

RS (2017) Drugi nacionalni izveštaj Republike Srbije prema Okvirnoj konvenciji Ujedinjenih nacija o promeni klime [Second National Communication of the Republic of Serbia to the United Nations Framework Convention on Climate Change]. Beograd, Ministarstvo životne sredine http://www.klimatskepromene.rs/wp-content/uploads/2017/12/Drugi-izvestaj-o-promeni-klime-SNC_Srbija.pdf. Accessed 7 May 2019

RS (2018) Strategija klimatskih promena sa Akcionim planom, Okvir za planiranje prilagođavanja. http://www.klimatskastrategija.eu/wp-content/uploads/2018/08/1_Result-5_Adaptation-Planning-Framework_final-srb-1.0.pdf. Accessed 28 Feb 2019

Spatial Plan of the Area of Special Purposes (SPASP) of the National Park (NP) of Kopaonik, Official Gazette of the Republic of Serbia, No. 89/16

SEE (2013) State of art on mitigation and adaptation plans and identification of cross sectoral links. OrientGate. http://www.orientgateproject.org/uploads/Press%20releases/results%20docs/WP7_7.1_Report_State%20of%20Art.pdf. Accessed 20 Mar 2019

UNESCO (2006) Convention concerning the protection of the world cultural and natural heritage. World Heritage Committee, 13th session, 8–16 July. https://whc.unesco.org/archive/2006/30com-en.htm. Accessed 7 Mar 2019

UNESCO (2007a) Climate change and world heritage. https://whc.unesco.org/document/8874. Accessed 7 May 2019

UNESCO (2007b) Case studies on climate change and world heritage. https://unesdoc.unesco.org/ark:/48223/pf0000150600. Accessed 7 May 2019

UNESCO (2013) Operational guidelines for the implementation of the world heritage convention. http://whc.unesco.org/archive/opguide13-en.pdf. Accessed 20 Mar 2019

UNESCO (2019) World heritage list. https://whc.unesco.org/en/list/. Accessed 10 Feb 2019

Vuksanović-Macura Z, Radulović S, Macura V (2018) Land cove changes of the Belgrade are over the past three centuries. Spatium 40:42–50. https://doi.org/10.2298/SPAT1840042V

Vincent K, Dougill AJ, Dixon JL, Stringer LC, Cull T (2017) Identifying climate services needs for national planning: insights from Malawi. Clim Policy 17(2):189–202. https://doi.org/10.1080/14693062.2015.1075374

WMO and GFCS (2016) Climate services for supporting climate change adaptation. World Meteorological Organization. https://library.wmo.int/pmb_ged/wmo_1170_en.pdf. Accessed 8 May 2019

WMO and GFCS (2017) White paper on the contribution of the global framework for climate services to transforming our world: the 2030 agenda for sustainable development (Agenda 2030). https://www.wmo.int/gfcs/white-paper-contribution-of-gfcs-to-sdgs. Accessed 20 Jan 2019

Živanović Miljković J, Crnčević T (2012) Land use planning for sustainable development of peri-urban zones. Spatium 28:15–22

Chapter 16
Impacts of Climatic Disasters in the Coastal Area of Bangladesh: 'Climate Service' a Way Forward

Sajal Roy and Ashraful Alam

Abstract This chapter considers 'climate service' as a tool to mitigate likely impacts of climatic disasters of the coastal regions in the southwest Bangladesh. Climate service enables to undertake the required development and capacity building for the coastal communities, who have the high potentiality of severe consequences of ecological disasters such as cyclones, flooding, sea levels rising and heat waves. The mitigation of adverse impacts of climatic disasters requires both comprehensive and appropriate plans and policies at national and regional level. In this chapter, we utilise life story interviews in the coastal area of Dacope sub-distrct under the division of Khulna, Bangladesh. The study analyses national and local development policies and plans to mitigate the impacts of climatic disasters in Bangladesh. Our study primarily explores the shortcomings of the national and local policies and plans to consider and apply climate service for mitigating the possible impacts of climate disasters. Our findings suggest that the current national and local development policies and plans insufficiently integrate climate service in undertaking the necessary developments and capacity building for risk reduction of climate disaster. Such inadequacies have significant impacts on the mitigation of the impacts of climate disaster. The outcome of the research will be instrumental for understanding and encouraging the stakeholders to integrate climate service in the national and local development policies and plans.

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Introduction

This chapter analyzes the current governmental and non-governmental arrangements for the Disaster Risk Reduction (DRR) to explore the advantages of the application of climate service to mitigate the impacts of the climatic disaster on the coastal community of Bangladesh. The coastal area of Bangladesh is very vulnerable and at high risk of the impact of climatic disaster including cyclone, storm, and flood (Roy 2019).[1] Climate disaster causes serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses, and impacts.[2] Every year, climate disaster causes a significant loss of life and erode gains in economic development. Nine in ten of the most commonly reported disasters are directly or indirectly related to weather or climate in Bangladesh.[3] Vulnerability to disasters is increasing as more people inhabit high-risk areas in coastal areas of Bangladesh. The global community has already evolved many guidelines to motivate necessary development and capacity building to mitigate the conspicuous consequences of climatic disaster including climate service.[4]

Climate service provides climate information in a way that assists decision making by the state to adopt the national strategy, policy, and plan for development and capacity building to mitigate the impacts of climatic disasters.[5] This provides scientifically-based information and products that enhance users' knowledge and understanding about the impacts of climate on their decisions and actions.[6] It provides high-quality data from national and international databases on temperature, rainfall, wind, and ocean conditions, as well as maps, risk and vulnerability analyses, assessments, and long-term projections and scenarios.[7] It plays a pivotal role in planning the necessary development of infrastructure and capacity building for DRR. The application of climate service in the current development and capacity building plan for DRR are at a very rudimentary stage in Bangladesh. This chapter examines the impacts of previous climatic disasters on the coastal community, and explores the extent to which climate service was considered and applied in the development and capacity building initiatives to mitigate the impacts of the climatic disasters in

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[1]Retrieved from http://bora.uib.no/handle/1956/7331. Accessed 4 May 2019.

[2]UNISDR (2009) UNISDR Terminology on Disaster Risk Reduction. Geneva: Switzerland.

[3]Asian Disaster Reduction Center, Annual Report 2017. Available at https://www.adrc.asia/publications/annual/17/2017_ADRC_Annual_Report.pdf. Accessed 10 Jan 2019.

[4]United Nations, Bali Action Plan 2012, FCCC/CP/2007/6/Add. Available at https://unfccc.int/resource/docs/2007/cop13/eng/06a01.pdf. Accessed 10 Jan 2019.

[5]GFCS, What are weather/climate services. Available at https://www.wmo.int/gfcs/what_are_climate_weather_services. Accessed 15 Jan 2019.

[6]American Metrological Society, Climate Service, A Policy Statement of the American Meteorological Society, (Adopted by the AMS Council 10 August 2012). Available at https://www.ametsoc.org/index.cfm/ams/about-ams/ams-statements/archive-statements-of-the-ams/climate-services/.

[7]Ibid.

Bangladesh. The objective of this research is to find out the necessity of the application of climate service to mitigate the impact of the climatic disaster on the coastal community of Bangladesh.

Climate Service and Disaster Risk Reduction: A Brief Overview from Literature

United Nations Office for Disaster Risk Reduction (UNISDR) defines climate disaster and its impacts.[8] The definition of climate disaster and its impact has been diversified by research to explore the impact of the disaster on economic, social and cultural interests. The concept of climate service was integrated into the climate disaster after the adoption of the United Nations Framework Convention on Climate Change 1992. The Global Forum for Climate Service (GFCS) defined climate service as the process to provide climate information in a way that assists decision making by the state to adopt the national strategy, policy and plan for development and capacity building to mitigate the impacts of climatic disasters.[9] Christel et al. (2018) explores the design for the development of effective climate service.[10] This crucial study shows the ways in which climate service is useable for decision making. The research also documents the challenges in generating and processing climate service data. Tall et al. (2018) analyzes the impact of the application of climate service in the context of agriculture.[11]

Many states have applied climate service in their national and local development planning for the mitigation of the adverse impacts of climate disaster. The United States applied climate service through the climate services enterprise comprising a wide variety of entities including the National Oceanic and Atmospheric Administration (NOAA).[12] In South Asia, the issue of climate change consideration in the disaster risk deduction was first raised in the book titled “Climate Change Adaptation and Disaster Risk Reduction: An Asian Perspective”.[13] This scholarly book does not precisely analyze the feasibility for the application of climate service for the mitigation of the impact of climate disaster. In Bangladesh, the disaster risk deduction has been gone through diversified research studies. Shaw et al. (2010) in his study overviewed the arrangements for climate change adaptation to reduce disaster in Bangladesh.

[8]UNISDR, Terminology on disaster risk reduction 2009. Available at https://www.unisdr.org/files/7817_UNISDRTerminologyEnglish.pdf.

[9]GFCS, What are weather/climate services. Available at https://www.wmo.int/gfcs/what_are_climate_weather_services.

[10]Christel et al. (2018).

[11]Tall et al. (2018).

[12]Ibid.

[13]Shaw et al. (2010).

Rashid and Bimal (2014) extended the analysis to find out the impacts of disasters including air temperature and sea level raise.[14] Their study also scrutinize the impacts of tropical cyclones, floods, and droughts. They analyze the relevant strategies to find out climate justice for climate change victims, particularly, climate refugees. Their research studies confronted climate change through disaster management initiatives, particularly, sea level rise in the coastal area of Bangladesh. Moreover, Ali and Islam (2014) examined the adverse impacts of climate vulnerabilities of livelihoods for disaster and poverty prone areas of Bangladesh.[15] The authors considered the impacts of natural disasters on the road infrastructure, drinking and irrigation water supplies and health services, and suggest for capacity building by the state. Subsequently, Takko and Shaw (2014) explored the role of private sector in the mitigating the impacts of disasters by improving community resilience; using expertise in engineering and construction, village design, and planning; developing a business continuity plan; and applying infrastructure resilience through the necessary risk mitigation strategy.[16] Bangladesh ranks the fifth most disaster-prone country in the world. The topographic and geo-physical location of the country has made it vulnerable to various natural hazards, particularly to climate-change, related natural disasters.[17] Flooding, cyclones, tidal waves, and river erosion are the most common climatic hazards which have been affecting around 44 million people living in the southwest coastal region of the country.[18] This coastal part of Bangladesh is one of the most vulnerable and ecologically threating spots in the world (Roy 2018).[19] This coastal region is likely to hit by a catastrophic cyclone almost every three years. The tropical cyclones that happened between 1991 and 2015 caused severe casualties and damaged local infrastructure including road, mud houses, tube wells, and damaged road and transportation system.[20] It has been argued that cyclone hazards are natural, but disasters are man-made. At present, the government of Bangladesh has developed capacities to track the speed and direction of cyclones and warn the coastal communities well in advance, but still, thousands of coastal families continue to be adversely affected by cyclones and flooding.[21]

Bimal and Rashid (2016) have presented the coastal hazards in Bangladesh and suggested structural and non-structural solutions.[22] The research mostly analyzes the institutional arrangements to solve the coastal hazardous in Bangladesh. Wedawatta et al. (2016) conducted important research as to the disaster risk reduction by the

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[14] Rashid (2014).

[15] Toufique and Islam (2014).

[16] Izumi and Shaw (2014).

[17] United Nations University—Institute for Environment and Human Security (UNU–EHS). World Risk Report 2016; UNU-EHS: Bonn, Germany, 2016.

[18] Mallick and Vogt (2011).

[19] Retrieved from https://link.springer.com/referenceworkentry/10.1007/978-3-319-71025-9_10-1. Accessed 5 May 2019.

[20] Auerbach et al. (2015).

[21] Hulme (2016).

[22] Paul and Rashid (2016).

infrastructure for the local communities of South-Western Bangladesh.[23] The authors investigated the existing and potential strategies for enhancing resilience to natural disasters, community perspectives on infrastructure and structural protection. Moreover, Haque et al. brought a new dimension of ecosystem service-based adaptation to climate change in the policy-making process of Bangladesh.[24] The paper analyzes the policy-making cycle by agenda setting; policy formulation; and policy implementation stage, where the contributions of ecosystem service-based adaptation can horizontally or vertically be mainstreamed and integrated. The study of Akbar et al. (2018) explores the damage caused by cyclone Sidr in 2007 in Bangladesh.[25] The researchers explored the impacts of the cyclone on the Sundarbans Forest and the adjacent communities. The research suggests for the application of the storm protection service of the Sundarbans mangrove forest in the disaster management policy of Bangladesh. Furthermore, Hassan (2018) shows the impact of the disaster on the Artisanal fishing and the fishing communities in Bangladesh.[26] The paper argues for appropriate climate responses at local levels to mitigate the impacts on fish and fisheries communities. The body of literature reviewed finds research on the impacts of disasters, structural development; capacity building; application of ecosystem service and storm protection service; and harmonization of national and local policies for the adaptation and mitigation of the impacts of the natural disasters in the coastal area. This inadequacy in research studies shows the application of the climate service in the national and local policies and plans to mitigate the impact of climate disaster in the coastal area of Bangladesh. This chapter substantially fills up this key gap in the literature addressing the necessity of the integration of climate service in the national and local development polices and plans to mitigate the impacts of climatic disasters in the coastal area of Bangladesh.

Research Method

We utilized autoethnography as an approach for describing and systematically analyzing personal experience in order to understand the experience of the local community. This approach was utilized along with twelve life story interviews. In addition, direct observation was conducted with the participants for documenting the developments provided by the government agencies and non-government NGOs to the climate survivors. A total of 12 participants (7 males and 5 females) aged around 25–45 were recruited through purposive sampling technique. This age group was selected to allow participants to share their past memories of climatic disaster along with its associated consequences on road and transport, drinking water and health.

[23] Wedawatta et al. (2016).

[24] Huq et al.(2017).

[25] Akber et al. (2018).

[26] Hasan and Nursey-Bray (2018)

The researcher conducted two months (1 December 2018 to January 2019) of fieldwork in Dacope Upazila, Khulna Division. Before starting interviews, the researcher clearly explained the study aims to participants and recorded their consents. Each interview lasted for 50 min. The researchers conducted life story interviews. An audio recorder was used to tape conversations in life story interviews. The participants shared the impacts of climatic disasters in their local area. The transcribed focus groups and interview data (Bengali texts, direct quotes) were coded. Thereafter, the thematic analysis was utilized to develop key-themes and associated sub-themes of the study.

Details Findings of the Study

The researchers focus on three aspects for examining the impacts of the climatic disaster on the coastal community of Bangladesh. The impacts on roads and transports, drinking water and health service are the motivating factors of this research. The impacts of the climatic disasters on these sectors are analyzed below.

Impact on the Road and Transportation System

Road and transport play a crucial role in reducing disaster risk and mitigate the impacts of climatic disasters. However, it is found that the road and transport system in the coastal area of Bangladesh is very vulnerable. The local participants narrate that the connecting road from the village to the union Parishad Office is made of mud and very narrow. As the roads are made of mud, these become very clay and slippery during monsoon, which makes impossible to ride a vehicle to transport themselves from their own village to another. The participants categorized two types of transports they usually use: motorcycle and engine boat, for travelling to the Union Parishad Office. Motorbike is used during the dry session, while diesel-run engine boat is utilized during the rainy session. The villagers have to go to the Union Parishad Office for obtaining any service, relief and facility provided by the government. Most importantly, the cyclone centre is located near the Union Parishad Office. The Union Parishad Office is about 4 km from the village. Although motorbike is the only transport during dry session, villagers cannot afford it because of highly expensive for them. Related to this, a participant noted:

> There is Motorcycle in the local bazar stand, that carries a passenger from the Bazar to the Union Parishad Office. But we go to the Office by walking as it is expensive to ride on Motorcycle. We are poor and can not afford the cost. So, we go by walking, that takes about one and half hour to go to the Union Parishad Office from this village.

According to participants, a motorbike as a vehicle is very risky for women and children. Although the local male can ride on it, women and children can not ride. The local women are not accustomed to riding these types of transports. The women and children travel from the village to the Union Parishad Office by walking, spending around about two hours even to go to the Union Parishad Office. Moreover, if there is rain, a driver fails to drive his motorbike as the roads become clay and slippery. Therefore, the villages have only one option of walking for traveling from the village to the Union Parishad Office. A youth activist reported,

> You (the interviewer) can not go with your motorcycle if there is a little rain in our village. You have to leave your motorcycle here and go by walking. Very often we fall down on the slippery road and get back pain.

Besides motorbike, engine boat is a popular mode of transportation for traveling from the village to other places. These boats are the only hope during rainy session and disaster. These small boats are very risky for traveling from the village while crossing a river. This is particularly risky for women, children and the elderly as they do not how to swim in a dense river. A participant described in the following way:

> The engine boat is the only mean for traveling from the village to Chalna (local city) during a disaster. There has no bus and three-wheeled van for transportation while commuting from the village to the Union Office. Most of the cyclone centres are located at a distance of at least 4 kilometers from the local village. The villagers face severe difficulties to move from the village to the cyclone centre.

As the roads are made of mud and very narrow, the hit of Cyclone and subsequent flooding compelled to wash away the muddy roads. Therefore, the villagers had no option to use any road driven transport. They have the only option of using engine-driven small trawler. Moreover, these trawlers are not available all times. During a disaster, there has a little possibility to get these trawlers as the owners of the trawlers are busy to save themselves. According to a local participant:

> During cyclone Aila (2009), I and my family members went to find out an engine boat to travel from the village to the Cyclone Centre. We waited for about 2 hours and got no boat. Finally, we crossed the river by swimming. We were thinking that we were about to drown in the river.

The villagers also used engine boat for traveling to the hospital. The hospital is located at least 6 km away from the village. It took at least 1–2 h to take the patient to the hospital. Moreover, the sound of the engine boat worsened the physical condition of the patient. The roads and transports were the common problems of the coastal community for long. There was no road for communication from the village to the Union Office before ‘Cyclone Aila’. There is no significant change in the road before and after the hit of Cyclone Aila. Immediately after Cyclone Aila, the condition of the road was very bad as it was washed away. The roads are now a little bit good compared to the previous condition. But, these muds made roads may be again washed away even if there is simple hit of cyclone or flood.

There are several arrangements for the reduction of the disaster risk provided by the Government of Bangladesh, international and local NGOs. There is a *Union Disaster Management Committee* which is headed by the Chairman of the Union Parishad. The committee coordinates climate service-related activities, which are executed by NGOs such as World Vision; *Nabjatra,* Sushilon, BRAC, Ullashi, and DSK. Although the committee hardly faces difficulty in coordination, the committee struggles to do necessary development because of the constraints of government's financial budget. The financial budget is very less compared to the annual budget necessary for infrastructural development. A local public representative stated:

> Suppose, we need to build a 1-kilometer concrete road, the budget is only Taka (TK.) 50,000 (USD 700) which is adequate only for half a kilometer of the total road. We have stopped working on half a kilometer as we do not have money.

There is an ongoing project for a water dam on progress to prevent entering water into the local village of the study area. The dam is to be used as a road for traveling from the village to the Union Parishad Office and the divisional city of Khulna. The Water Development Board of the Bangladesh Government is implementing the project. As the project is going on, it will take at least 1 year more to complete. By the meanwhile, the roads are in very fragile condition and at risk of broken down if there is even a simple strike of disaster. A participant noted that the main way for the prevention of the impact of the disaster is to build a water dam. Although the on-going project will be new hope for the road of this village, the outcome is dependent on the successful completion of the project. Moreover, there are some other projects for the development of road and communication in the village. The projects are Rural Infrastructure Reparation; Cash for Work; Maintenance of Rural Infrastructure (TRB). Furthermore, the government is implementing the Heise Bon Bon (HBB) project to develop the mud made road in the villages. Considering some budgetary constraints, a government officer reported:

> There are of course some barriers. Suppose, we need fund to repair a dam if there is a sudden breakdown. But we cannot do anything as we do not have any reserve fund for this. We have to wait for the approval of the District Commissioner.

The approved funding is very less compared to the actual necessity. The less budget is a challenge to take necessary developments for the mitigation of the impacts of the disaster. Furthermore, it takes more time to get the budget even the actual damage caused before 6 months. Thousands of kilometers of the road cannot be repaired because of budget constraint. The Government has developed the Risk Reduction Action Plan. The Union Disaster Management Committee takes the decision for the implementation of a plan according to the priority decided by the Risk Reduction Action Plan. The Committee makes a pilot project according to the allotted budget for the implementation of the plan. A project Implementation Officer stated:

> We take initiatives and actions based on the reports on the disasters happened at different times. We provide necessary help the victim (affected people) after the disasters. We analyze the loss and damages to the affected people and take activities. We prepare a report of the loss and damage after the disaster and send to the concerned ministry for the necessary financial budget and we implement the budget when we get. We also do the pre-disaster Management Meeting.

The Ministry has a Community Risk Assessment Programme which analyses the necessity of the community and adopts a Risk Reduction Action Plan according to the priority list. For example, repairing road, Calvert, and bridge repair etc. In addition to the government actions and plans, NGOs have been working to provide necessary developments and capacity building activities to mitigate the impacts of the climatic disaster on the coastal community of Bangladesh. World Vision is implementing a water dam project. A Project Implementation Officer reports that NGO can implement its project within the time frame. On the other hand, government projects take much time and cannot be completed within the time frame. However, the initiatives and plans taken by the NGOs are limited and insufficient for the development of necessary road and transports for traveling from the village to the UP Office, Hospitals and Cyclone Centres in the study site.

Impact on Drinking Water

The sever scarcity of drinking water is a primary concern for the coastal community of Bangladesh. A participant notes that the main problem of this area is the scarcity of drinking water. If we could manage drinking water for them, half of the problem could have been solved. The scarcity of pure drinking water is a daily and continuous problem for the coastal community. The rain water is the primary source of drinking water in the area. A local participant reported:

> Our main source of drinking water is rain water. We reserve rain water in polythene, mud pot, and water reserve tank. We do not get any drinking water from the government.

The rainy session lasts for 2–4 months. The coastal community reserve rain water during the rainy session and drink for the remaining months of the year. A local participant states that if the reserved drinking water is finished, we borrow water from others. However, it is very tough to get drinking water from others. Another local participant mentions that although we have some water tanks and reserve rain water there, the water can be at best be okay for 6 months. But we face severing scarcity for the remaining 6 months.

Some of the villagers have got water reservoir tank either from the government agencies or non-NGOs. However, the water tanks provided by the government agency and NGOs are not adequate to reserve drinking water for the whole year. A public representative of the local area states that we do not provide any facility for water. A local participant says,

> The scarcity of the drinking water is the main problem of this area. As we all do not have water tanks, we cannot reserve water adequately. If the government would provide a water tank for each family, that could be good for us.

Another local participant mentions that several families have got a water reserve tank, but we have not got. Even the government provided 2–3 water reserve tank in the whole union. The local Chairman and Member of the Union Parishad Office provide these tanks to their close relatives and we have never got any water tanks from the government. Apart from the nominal water tank provided by the government, the local NGOs have provided water reserve tanks to the local community. However, the water reserve tanks are not adequate for the reservation of the drinking water for them. A project implementation officer says,

> I think there are about 200 thousand people live in Dacope where there is no arrangement for pure drinking water. So, the main demand of the people of this area is a water reserve tank. The problem of drinking water could be solved if we could provide at least 2000-liter water tanks for each family.

The scarcity of the drinking water could be resolved by providing adequate deep tube-well in the area. Although there is less possibility for pure drinking water from the deep tube-wells, the government initiatives for providing deep tube-well is very nominal. A local participant reports,

> We have not got any tube well from the government. There are 2 tube-wells in our village. One supplies pure drinking water, and another gives salty water which is not suitable for drinking. The tube-well is located at least 1.5 kilometers from my house.

Another local participant stated:

> The most serious problem is the scarcity of drinking water in this area. Even we drink the salty water or water from a pond. The tube-well and pond are also far away from our house. It takes about 2-2.5 hours to collect water, therefore, we cannot do other necessary activities.

There was sever scarcity of drinking water after Cyclone Aila. A local participant reports that they did not get an adequate arrangement for drinking water provided by the government after the disaster Aila. He also mentions that all ponds and tube-wells were washed away by the Aila. They were temporarily supplied with drinking water from the cargo provided by the government. Moreover, they got some water reserve tank provided by the local NGOs. However, in maximum cases, the village leaders got the water tanks from NGOs. The water reservoir tank provided by NGOs were not adequate to solve the scarcity of drinking water of the coastal community. However, the coastal community got better support for drinking water compared to the government agency. A social worker states that we get maximum support from NGOs rather than the government to prevent the impacts of the disaster. Although the support by the NGOs is also limited and not adequate according to the necessity, it is better than the government support. The government project for solving the problem of drinking water is very limited.

Impact on Health Service

The climatic disaster has the most serious impact on the health service. Inadequate arrangement for health service maximizes the risk of severing impact of the disaster on the coastal community. The coastal people of Bangladesh do not have the minimum access to health service. A very limited number of doctors, non-availability of medicine and hospital make the coastal community vulnerable to the climatic disaster. Our data explore that there is a health clinic in the village. But the clinic provides no value for the health service of the villagers. A female participant informed:

> A clinic was established after Aila in this village. We go to the clinic for the health service. However, they do not get sufficient health service from the clinic. We do not get health service and medicine according to our necessity and demand. We get only some pain killer tablet for fever or pain. More interestingly, we have to tell them the name of the tablet. The doctor in the clinic does not know anything about health service. He is a compounder. There is no specialized doctor in the clinic.

According to participants, at the local clinic, the responsible doctor comes at 11.00 am and leaves at 1.00 pm. It means they stay only for 2 h. They mentioned that the clinic does not have any potential function to offer us a good medical service. They also report that we need to become a doctor by ourselves and tell them the name of the tablet. They do not get any treatment and medicine from this clinic. So, they do not go to this clinic. In most cases, patients usually go to the paramedical doctors of their village. There are some paramedical doctors in the village. The villagers go to the paramedical doctors for their treatment. They paramedical doctors only prescribe saline if they are caught of diarrhea and paracetamol for fever and pain. The villagers depend upon the paramedical doctor for their health service. As the clinic does not provide adequate medicine and doctor, the villagers go to *Sadar Hospital* which is located about 6 km far from the village. They cross a river by ferry which takes a long time to go to the hospital. A participant explained:

> We go to the other side of the river if we need any doctor. If there is any emergency, we go to the other side crossing the river by a trawler, which takes much time to manage and go. Moreover, the sound of the engine of those trawlers create problems of the patient.

The facilities for health service after Cyclone Aila were not adequate for the coastal community. The participants state that they got very less health service after Cyclone Aila. They got health service from the mobile clinic team after the disaster. They got two soaps and some saline from the mobile clinic team. A local female participant states that we got some medicine and health service after the disaster, for examples, saline, a tablet for diarrhea and dysentery. They got health service from Sun's smiled symbolled health clinic after the disaster. But these services are not available now. The villagers got some health service from NGOs, for examples, saline, and first aid. But the NGOs, now, provide no health service. A local public representative mentions that a *Nobo jatra*, a US-AID funded project provides a maternity payment for the pregnant women of the village. However, the service is very limited. As the health service provided by the government agency and non-governmental NGOs were not adequate, the villagers availed health service at their own costs. The villagers have to go to the divisional hospital for better health service. As there has no necessary road and transports, they go to the city hospital by a trawler, which takes at least 3 h to go. A local participant states that we have to go to Chalna or Khulna by crossing the river for any health care. We have to wait long for a trawler. Even we do not get trawler if it is at night, which makes it impossible to go for an emergency.

Climate Service for the Mitigation of the Impact of Climate Disaster on the Coastal Community of Bangladesh

Our analyses of the impacts of the climatic disasters explore that the governmental agency and NGOs do not adequately consider and apply climate service in the development and capacity building policies and plans to mitigate the impacts of the disaster in the coastal area of Bangladesh. It also shows that the local government agency knows that the roads made of mud are washed away and broken by the climatic disasters. The field data presents that the mud made roads become clay and slippery if there is rain even for a moment. The roads become unusable during the disaster. Although the government is implementing water dam projects to use for road, these are not adequate for the total coastal area. The villagers cannot move to the cyclone centre quickly because of the roads. Although the government agency has information, the government development plans and project do not adequately consider and apply this (climate service) information for taking and implementing appropriate plans and projects for the development of road of the coastal area of Bangladesh.

The study explores that the available transports in the coastal area are not suitable for moving from the village to the Cyclone Centre and the Union Parishad Office. A motorcycle cannot be used during the disaster as the roads become clay and slippery. Moreover, the women, children and old people cannot ride on Motorcycle. The small trawlers are very risky and not adequate for traveling from the village coastal area to Cyclone Centre, Union Parishad Office, and Hospital. The development and capacity plan and projects of the government agency and NGO do not take this (climate service) information while adopting and implementing projects for the development of the coastal area. There has no project for the affordable, suitable and safe transport system during climate disaster in the area.

Analysis of the generated data also explores that the scarcity of drinking water is a primary challenge for the coastal community. They are severely suffered for drinking water not only during the disaster but also at the current normal situation. Non-availability of ground water makes them to primarily rely on rain water. The government agency knows the information of the scarcity of drinking water, in particular, during and after disaster. However, the current policies, plans and projects do not take this information in consideration to develop plans and projects for establishing a large-scale water reservoir system under the government project.

The climatic disaster creates both short-term and long-term health impacts on the coastal community. Therefore, the mobile and temporarily clinical team is not a durable solution to provide health service for the coastal community. It is evident from the previous natural calamity on the coastal area of Bangladesh that usually the rainy session (from June to October) has more possibility of cyclone or flood. However, the governmental agency and non-governmental organization do not have appropriate plan and project to develop the medical facility for the coastal people.

The climatic disasters, in particular, Cyclone Aila caused sever impacts on the coastal community of Bangladesh. The impacts could be mitigated by taking and implementing appropriate national and local development policies, plans and projects with due consideration and application of climate service information. This study explores how the consideration and application of climate service information in the national and local development policies, plans and projects may mitigate the impacts of climate disasters on the coastal community of Bangladesh.

Climate service information urges the government and non-governmental initiatives for the development of road and transport that are safe and suitable for the coastal community during climatic disasters. The Government should adopt plan and project for concrete and pitch roads for sustainable communication in the coastal area. The on-going water dam project should be extended to cover the whole coastal area to mitigate the impacts of cyclone or flood. The dam and road must be much high that will not be usually flooded by climatic disasters.

Concerning the drinking water, both the Government Agency and NGO should adopt plan and policy for reserving drinking water for the coastal community. The government agency and NGO should take into consideration the information as to the level of water during flood or cyclone to establish water purifier plant in the coastal area. The government and NGO should arrange a water reserve in a safe place that is not down by flood or blown away by a cyclone. The government should take an immediate plan for adequate water reservoir tank for the coastal communities. The distribution of the water tanks must be a monitor for fair distribution and prevention of corruption.

In relation to the health and medical service, the Government and NGO should adopt plan and policies with the consideration of climate change information to resolve the problem of health service. The Government agency should arrange adequate doctors and medicine in the local health clinic during the period when there has more possibility of climatic disasters. The government agency should also consider the information as to the level of water to arrange necessary emergency transports to carry the patient for health service. Apart from the government project, NGOs should have more engaged in providing health service for the coastal community, in particular, for the women and children.

Concluding Notes

The climatic disasters have very measurable impacts on the coastal community of Bangladesh. In particular, disasters cause serious impacts on road and transport, drinking water and health service. The vulnerable and fragile roads block even the minimum chance of saving a life during the disaster. The scarcity of safe and available transport makes tougher to move out of the village to the cyclone centre. Moreover, the coastal community faces a severe scarcity of drinking water during the climatic disaster. Furthermore, the arrangements for the health service of the coastal community are very nominal, which is neither adequate nor desirable for such a highly disaster risk area. The current projects and plans were taken by the government and NGO do not take in consideration the climate service information to mitigate the impacts of the climatic disasters. The government agency and NGO should adopt development policy, plan and project with due consideration and application of climate service information for the coastal people. The application of climate service information will facilitate the government and NGO to design their plan and project for the necessary developments and capacity building to mitigate the impacts of climate disasters. Consideration of climate service information in the development and maintenance of road and transports project will accelerate to reduce the risk arising from the fragile road and communication. Application of climate service information for confirming enough drinking water will prevent scarcity of drinking water during the disaster. Moreover, consideration of climate service information in enhancing the health service for the coastal community will minimize the unexpected death and injuries of the coastal people. The application of climate service information in the development policies, plans in the coastal area will reduce the disaster risk and cause fewer sufferings of the coastal community of Bangladesh.

References

Akber MA et al (2018) Storm protection service of the Sundarbans mangrove forest, Bangladesh. Nat Hazards 94(1):405

American Metrological Society, Climate Service, A Policy Statement of the American Meteorological Society (Adopted by the AMS Council 10 August 2012). Available at https://www.ametsoc.org/index.cfm/ams/about-ams/ams-statements/archive-statements-of-the-ams/climate-services/. Accessed 15 Dec 2018

Asian Disaster Reduction Center, Annual Report (2017) Available at https://www.adrc.asia/publications/annual/17/2017_ADRC_Annual_Report.pdf. Accessed 10 Feb 2019

Auerbach LW, Goodbred SL Jr, Mondal DR, Wilson CA, Ahmed KR, Roy K, Steckler MS, Small C, Gilligan JM, Ackerly BA (2015) Flood risk of natural and embanked landscapes on the Ganges—Brahmaputra tidal delta plain. Nat Clim Chang 5:153–157

Christel I et al (2018) Introducing design in the development of effective climate services. Clim Serv 9:111

Bangladesh Metrological Department (2019) Archive Report, Govt. of Bangladesh. Accessed 27 November 2019

GFCS, What are weather/climate services. Available at https://www.wmo.int/gfcs/what_are_climate_weather_services. Accessed 5 Jan 2019

Hasan Z, Nursey-Bray M (2018) Artisan fishers' perception of climate change and disasters in coastal Bangladesh. J Environ Plan Manag 61(7):1204 (Pt Routledge)

Hulme M (2016) 1.5 °C and climate research after the Paris agreement. Nat Clim Chang 6:222–224

Huq N et al (2017) Mainstreaming ecosystem services based climate change adaptation (EBA) in Bangladesh: status, challenges and opportunities. Sustainability 9(6):926 (Pt MDPI AG)

Izumi T, Shaw R (2014) A new approach of disaster management in Bangladesh: private sector involvement. Risk Hazards Cris Public Policy 5(4):425

Mallick B, Vogt J (2011) Social supremacy and its role in local level disaster mitigation planning in Bangladesh. Disaster Prev Manag 20:543–556

Paul B, Rashid H (2016) Coastal hazards in Bangladesh: non-structural and structural solutions. Elsevier Science & Technology

Rashid H (2014) Climate change in Bangladesh: confronting impending disasters. Lexington Books. ISBN: 9780739183533

Roy S (2018) Livelihood resilience of the indigenous Munda community in the Bangladesh Sundarbans forest. In Filho WL, Ayal D (eds) Handbook of climate change resilience. Springer Nature, Germany, pp 1–22

Roy S (2019) Climate change impacts on gender relations in Bangladesh. Springer, Singapore

Shaw R et al (2010) Climate change adaptation and disaster risk reduction: an asian perspective. Emerald Publishing Limited

Tall A, Coulibaly JY, Diop M (2018) Do climate services make a difference? A review of evaluation methodologies and practices to assess the value of climate information services for farmers: implications for Africa. Clim Serv 11:1

Toufique KA, Islam A (2014) Assessing risks from climate variability and change for disaster-prone zones in Bangladesh. Int J Disaster Risk Reduct 10:236

UNISDR (2009) UNISDR terminology on disaster risk reduction. Geneva, Switzerland. Available at https://www.unisdr.org/we/inform/publications/7817. Accessed 15 Feb 2019

Wedawatta G et al (2016) Disaster risk reduction infrastructure requirements for South-Western Bangladesh: perspectives of local communities. Built Environ Proj Asset Manag 6(4):379 (Pt Emerald Group Publishing Limited, 60–62 Toller Lane Bradford West Yorkshire BD8 9BY United Kingdom)

United Nations Climate Change. Bali road map. Available at https://unfccc.int/process/conferences/the-big-picture/milestones/bali-road-map

Chapter 17
Towards More Resilient Food Systems for Smallholder Farmers in the Peruvian Altiplano: The Potential of Community-Based Climate Services

Andrea Rossa, Moritz Flubacher, Lizet Cristobal, Hugo Ramos and Filippo Lechthaler

Abstract Experiences from the disastrous 2016 El Niño revealed that its forecast, although available, was not known, accessed or understood by a large part of agricultural communities living in remote rural areas. This is all the more striking since these population groups are particularly vulnerable to adverse climate events as their livelihoods heavily depend on climate-sensitive agricultural production. In the framework of Climandes, a twinning project between the meteorological services of Peru and Switzerland, we implemented and evaluated the impact of community-based climate services that were co-developed with the target smallholder communities of the semi-arid highlands of the southern Peruvian Andes, where small-scale farmers are especially exposed to adverse climate events due to high inter-annual climate variability and weak socio-economic capacities. In this chapter we analyse the project implementation through a socio-economic lens. Research results generated alongside the project indicate that the well-directed user engagement resulted in a strong increase of trust in the weather service SENAMHI Peru and led to improved consideration of the information provided in the respective decision-making processes. We highlight the key steps that proved to be indispensable for the implementation of meaningful and sustainable climate services. The project outcomes point to the great and widely untapped potential of community-based climate services to reduce vulnerability and strengthen resilience of smallholder farmers in the face of changing climate conditions.

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Introduction

Implementing the Global Agenda at the Local Level

Climate change constitutes a substantial challenge for developing countries and countries with emerging economies due to their often limited adaptation capacities. People and regions that are socially or economically marginalized are particularly at risk as climate-related hazards will further exacerbate their already constrained livelihoods (IPCC 2012). In the coming decades climate change is expected to amplify existing climate risks and create new ones for society.

In 2015, the international community set new global targets for the period 2015–2030 for disaster risk reduction (Sendai Framework), climate change mitigation and adaptation (Paris Agreement) and sustainable development (Agenda 2030). Climate services support the achievement of these three global agendas. For the Sendai Framework, weather and climate predictions on a broad range of spatial and temporal scales are a fundamental element of multi-hazard early-warning systems, which in turn are the basis for enabling proper disaster preparedness to safeguard lives and livelihoods. Under the Paris Agreement, improved communication of scientific information on climate variability, trends and extremes contributes to climate risk assessments and supports the promoted National Adaption Plans (NAPs). Finally, the majority of the 17 sustainable development goals (SDGs) are climate-sensitive, which renders climate services critical for achieving these goals.

Well aware of this cross-cutting importance of climate, the third World Climate Conference in 2009 decided to launch the Global Framework for Climate Services (GFCS) with the aim to improve availability, quality and access to climate services to better deal with climate-related risks. The GFCS recognized that developing countries and countries with emerging economies are often lacking even basic weather and climate information and, therefore, are given a high priority in the implementation of the Framework.

An innovative core element of the GFCS implementation strategy is the establishment of a User Interface Platform (UIP), designed to ensure effective dialogue and interaction between users and providers of climate services, helping providers to understand user needs and, correspondingly, allowing users to understand technical and scientific opportunities and thereby correctly interpret weather and climate information and services. Moreover, the GFCS proposes to set up this platform in a way that provides a structured process to foster the indispensable user-supplier dialogue and a managed method to define and reconcile user needs and provider capabilities, all with a view towards promoting effective climate-smart decisions.

In 2012, the Swiss Development Cooperation launched Climandes (*Servicios climáticos para el desarrollo*) as one of the first GFCS priority pilot projects under the Global Program Climate Change and Environment. This cooperation project between the Peruvian National Meteorological and Hydrological Service SENAMHI and the Swiss Federal Office of Meteorology and Climatology MeteoSwiss aimed at developing and providing climate services tailored to the agricultural sector of the Andean highlands with emphasis on food security and subsistence farming. As such, Climandes can be considered an innovative example of how to transform the GFCS into practical solutions at the local level and hence improve the resilience of agricultural communities in the Peruvian highlands. Climandes was performed in two phases periods 2012–2015 (Rosas et al. 2016) and 2016–2019 (Gubler et al. 2020), respectively.

The Importance of Small-Scale Agriculture and Enhanced Access to Weather and Climate Information

In Latin America, Sub-Saharan Africa or East and South Asia, small-scale farmers provide almost three quarters of food calories, hence playing an essential role in sustaining food security, jobs and income in rural areas of developing countries and countries with emerging economies (Samberg et al. 2016). However, smallholder farming is frequently exposed to socio-economic, cultural and environmental risk factors that affect the production system. In 2016, El Niño-driven weather patterns and political instability caused an intensification of global food insecurity in 2016 (FAO et al. 2017). An analysis of the 2016 El Niño event, which affected more than 60 million people worldwide, revealed that a major part of the exposed population was uninformed and unprepared for the pronounced climate anomalies (Frei et al. 2016). Tailored communication of weather and climate information is critical to reducing the impact of agro-climate hazards by enabling proactive action to reduce crop yield losses. While information on adverse events often exists, too often it is not known, accessible or understood by large user groups, particularly smallholder farmers in remote rural areas (Carr and Onzere 2017).

Indeed weather and climate information often fail to complete "the last mile" to reach large user groups, as for instance in the case of smallholder farmers in remote rural areas. For many national meteorological services climate information are not co-developed with and tailored for specific users or user groups, nor are they well anchored at the institutional level, especially in developing countries and countries with emerging economies. To address these shortcomings and following the GFCS guidelines, the Climandes project developed a prototype of a UIP designed to enable a strong engagement with key stakeholders. The implementation of such a UIP was probably the single most decisive factor in successfully bridging the supplier-user gap. The stakeholders involved encompass the information providers, intermediary users such as sectoral experts, and representatives as well as local communities and small-scale farmers.

Conceptual Framework

To plan an intervention that aims at strengthening climate resilience, it is paramount to understand the target populations' climate-related vulnerabilities. Socio-economic vulnerability to climate-related hazards on the one hand is given by a combination of the magnitude of typical weather and/or climate events, the exposure and sensitivities of people and assets to such events. On the other hand, the peoples' adaptive and coping capacities is determinant to how large an impact will result (Fig. 17.1). In the case of small-scale farming, extreme weather and climate events result in immediate short-term impacts such as crop losses, which depend on exposure, sensitivity of the agricultural production, but in a substantial way on the adaptive capacity to such events. As a matter of fact, significant weather and climate services can help the decision-making process for putting in place impact-mitigating measures to reduce the crop losses. A use case example for the mitigating effects of user-tailored climate services on the impact of a hypothetical frost event on the Andean highland quinoa harvest is given in Box 1.

Box 1 Frost example—Why do Juan and Pablo experience different quinoa losses from the same frost event? Juan's farmland lies in a shallow basin where a pool of cold air forms during the night (higher exposure to frost). Due to better yields, he uses a more productive but less frost-resistant crop variety (higher sensitivity). Furthermore, he lives in a remote area that has no radio signal. Therefore, he does not receive the frost warning from a local radio station and cannot trigger corresponding protective measures (low adaptive capacity). During a strong heavy frost night in February, Juan loses almost half of his quinoa production. Pablo lives in the same community as Juan, but his farmland lies on the slope (lower exposure to frost). Julissa, a friend of Pablo is working at an agricultural research institute and is developing new frost-robust resistance quinoa varieties that are less productive but more robust to frost and drought (lower sensitivity to frost). Julissa regularly sends text messages with specific agricultural advice based on information from the meteorological service and Pablo protects his cultures with foil in case of frost (high adaptive capacity). During the frosty night in February, Pablo does not suffer any quinoa loss. Luckily, Pablo is sharing a part of his quinoa harvest with other community members like Juan who would otherwise lack food (coping capacity).

For subsistence farmers, significant crop failures imply long-term consequences, typically including strained livelihoods and increased food insecurity. These consequences arise from a combination of the farmers' large dependence on home-grown food and insufficient capacity to recover from external shocks for a lack of savings and other social or financial protection. As a result, a single event can set in motion a negative feedback process (see Fig. 17.1) which pushes vulnerable people into poverty, and potentially propagates this status to keep them locked in a poverty trap

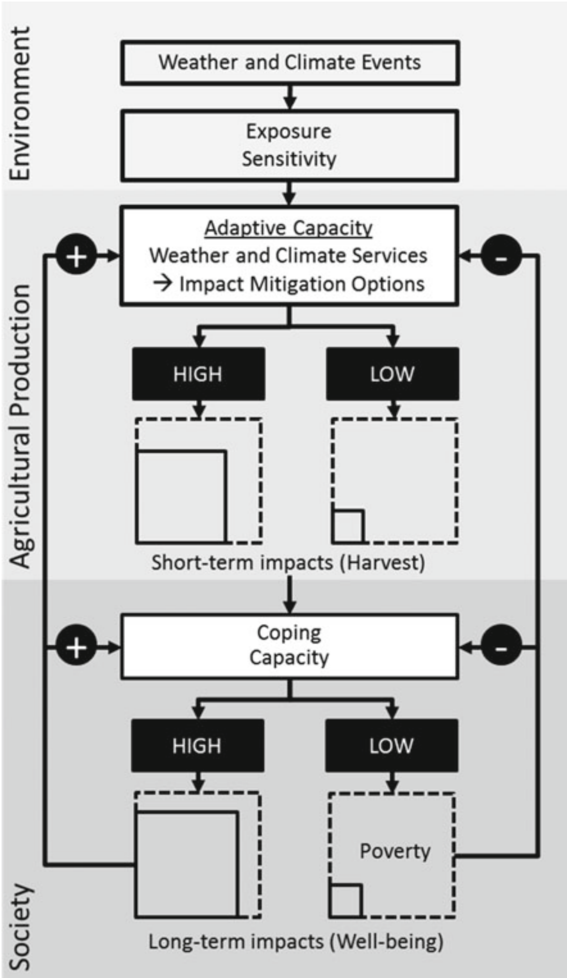


Fig. 17.1 Shows the underlying concept of socio-economic vulnerability to weather and climate events. Socio-economic vulnerability towards climate-related hazards is composed of an environmental and societal dimension. The environmental dimension comprises the magnitude of the weather and climate event, how often someone is hit (exposure) and how sensitive they are towards it (sensitivity). The societal dimension encompasses the ability of a specific population to prepare for an up-coming event (ex-ante adaptive capacity) and to overcome the associated impacts (ex-post coping capacities). For small-scale subsistence farming, severe weather and climate events may, depending on the adaptive capacity, translate into short-term impacts in form of partial or total harvest losses. Frequently ensuing long-term impacts on the population's well-being may, depending on their coping capacity, endanger their livelihoods and leading to poverty. Dashed/solid squares represent typical/reduced harvest and well-being. The larger the missing portion of well-being, the larger the risk for poverty. Note, that the feedback processes determined by good or poor adaptive and coping capacities can lead, respectively, to a sustainable livelihood or quickly into poverty

and thwart years of improved welfare. In the context of disaster risk management and adaptation planning, the nexus of poverty and vulnerability has recently gained much attention (Hallegatte et al. 2017). The Climandes project paid particular attention to this nexus by evaluating the smallholders' ability to manage climate-induced crop failures depending on their individual wellbeing. This information helps to better anticipate the social effects of the implementation of climate services in order to make these more inclusive.

In summary, both exposure and sensitivity to adverse weather and climate events can be reduced, for example by properly choosing the location of land to be farmed and using robust crop varieties, for instance. Climate services, for example in form of early warnings allow farmers to trigger preventive disaster-reducing measures. Additionally, an improved ability to recover from disasters can reduce the negative long-term impacts of events on the farmer's livelihood and welfare. Such recovery mechanisms include the enhancement of access to social and financial protection mechanisms like crop insurance, safety nets, savings and governmental aid, aspects which are beyond the reach of the present study.

Objectives

This chapter assembles the practical, user dialogue-related experiences of project Climandes. It outlines the project's approach and reports key findings and lessons learnt, with a particular focus on user participation and the presentation of pilot GFCS User Interface Platform (UIP). The chapter is meant to provide examples of "best practices," and give guidance for similar initiatives in developing countries or countries with emerging economies. It is not intended to be a comprehensive manual, but rather a description of essential steps, that emerged to be indispensable for the design and implementation of effective and sustainable climate services tailored to user needs.

The chapter is organized as follows: first, we describe the context for the implementation of Climandes and the project's approach; the following two sections present the project's key findings and insights from the project and illustrate applied research activities; we conclude with a discussion of our main findings and recommendations for practical applications.

A Two-Stage Approach for Evidence-Based Action

Climate Service Implementation as a Multidisciplinary Effort

In 2014, the GFCS stated that user dialogue and feedback is only just beginning and that gaps therein were impeding the process of moving from data to decisions. The

GFCS introduced an innovative concept—the User Interface Platform (UIP)—and encourages the development of UIP models that are not overly sector-specific, but instead identify and clearly articulate the common aspects of a UIP that make it sufficiently flexible to meet the needs of a wide range of climate-sensitive sectors. On the other hand, the GFCS recognized that, even though the geographical scope of the UIP is targeted to the global, regional, and national levels, possibly with multi-sectorial reach, actual implementation actions take place at the local level and often focus on a specific sector. There is an evident need to reconcile the scale gap between 'changing the world at once' and 'helping individuals'. This scale gap is exemplified in many regions where weather and climate information exist, but do not cover the 'last mile' to reach remote rural communities who are most in need of such information. All these issues make the design and implementation of climate services a very complex, inherently multidisciplinary challenge that involves a variety of stakeholders ranging from an individual smallholder farmer to national governmental institutions. It combines expertise from natural and social sciences as well as traditional knowledge in order to understand the decision-making processes of the users.

While the GFCS proposed guidelines to setup a UIP to address these challenges (WMO 2014), the specific activities of such a platform are not well defined or specified in any implementation-ready manner. In fact, a review of the GFCS recently concluded that 'the purpose and functioning of a UIP is not well understood by many climate service producers and users' (Gerlak et al. 2017). We responded to this inherent difficulty by setting up a pilot GFCS UIP in a way that reflected the needs of targeted groups, allowed regular interaction and training, built trust in the climate service provider and motivated users to engage in a monitoring and evaluation activity. In a nutshell, we found that a significant user engagement is a key element for implementing climate services and reaping their benefits.

The Climandes Two-Stage Approach of a User Interface Platform

In our quest to ensure that all relevant voices are heard and climate services respond to their needs, we implemented the pilot UIP in a structured two-stage approach (Table 17.1). The approach was set up to promote a close user engagement from the very beginning of the project that helped to design climate services that are in line with the users' demands. We conceived the first stage to provide the robust evidence necessary to plan subsequent interventions. In the second stage, we implemented climate field workshops to facilitate interaction with climate service end-users in two rural communities, along with the corresponding monitoring measures to evaluate the intervention's performance and impact. The first stage involved a mapping of stakeholders, aimed at identifying all relevant actors, integrating sectoral expertise and building strategic alliances. We further carried out a comprehensive assessment

Table 17.1 The two stage set-up of the prototype UIP implementation in Puno

Pilot GFCS User Interface Platform (UIP)	
Stage I: Evidence for action	Stage II: Translating evidence into practice
Stage I: Building blocks • Stakeholder mapping • Vulnerability assessment through a7 household survey • Socio-economic benefits estimation • Constraints to utilization of weather and climate information	Stage II: Building blocks • Building a continuous dialogue between provider and user • Establishing a feedback mechanism • Improving climate literacy • Monitoring and evaluation measures
To gain evidence for the intervention, we conducted a representative survey with 726 small-scale farmers in 15 districts in the Puno region. The investigation aimed at assessing the smallholders' climate vulnerability in terms of exposure, adaptive and coping capacities, as well as the current use of and prevailing barriers to weather and climate information	The intervention consisted of a series of monthly climate field workshops in the two agrarian communities Churo López (Aymara community) and Ccamara (Quechua community) during the growing season 2017/18. The workshops aimed at establishing a continuous feedback mechanism, sensitizing farmers about the use of weather and climate information, overcoming key factors limiting their use and evaluating the impact of the project

of vulnerability to climate-induced hazards through a household survey including a representative sample of more than 700 small-scale farmers (<10 ha) covering a total of 60 peasant communities in the northern (Quechua) and southern (Aymara) part of the Puno region (Fig. 17.2). The survey aimed at assessing the end-users' characteristics, knowing their major climate-related problems for agricultural production, evaluating their decision-processes and eliciting their needs for weather and climate information. Based on these data, we then estimated the potential economic value of improved access to information. Communicating potential socio-economic benefits in monetary terms to policy makers is expected to raise their awareness and foster sufficient and sustainable public investment in climate services. Finally, we identified major barriers to the utilization of weather and climate information among end-users.

The second stage of the intervention translated the previously generated evidence into practice in the form of climate field workshops. We paid particular attention to the development of a user-tailored service focusing on targeted communication and user involvement through the setup of a community outreach strategy (climate field workshops). These workshops were geared to facilitate effective uptake of the information provided, as well as to build trust among users on the weather and climate information offered. Workshops were designed as a pilot intervention to evaluate the potential for scaling-up effective user-driven climate services in the future. The number of farmers participating in the workshops did not change significantly, but the proportion of participants interviewed after the workshops to carry out an impact analysis was highest during the first session.

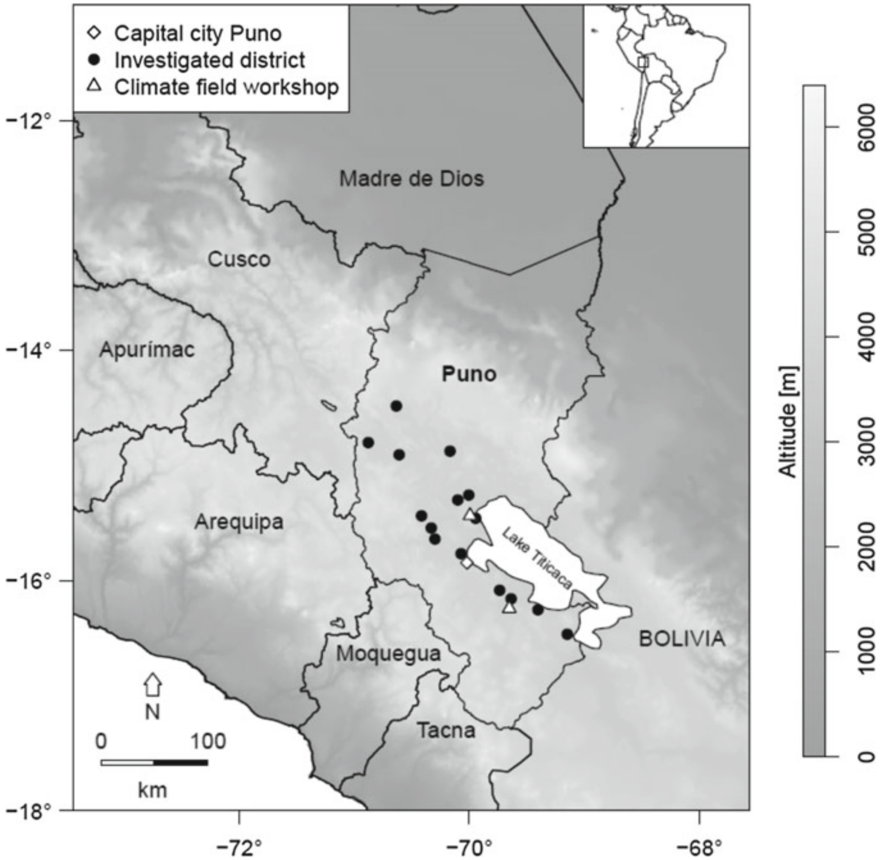


Fig. 17.2 The Climandes two-stage approach in the pilot region Puno. We implemented a GFCS pilot User Interface Platform (UIP) using a two-stage approach that is built around evidence-guided action with early involvement of the user community. The applied approach is generic and transferable to other regions and climate-sensitive sectors. The intervention took place in Puno, a semi-arid highland area in the southern Andes of Peru (grey shades denote topography) where smallholder farmers are especially exposed to the impacts of adverse weather and climate events due to high inter-annual climate variability and weak adaptive and coping capacity. The filled black circles indicate districts investigated, while the triangles denote the two pilot communities for which monthly climate field workshops were conducted. The regional office of SENAMHI Peru is located in Puno (diamond)

The workshops were built on the UIP guidelines proposed by the GFCS (WMO 2014). These guidelines include (i) the setting up of a mechanism to receive feedback from the user community, (ii) building a continuous dialogue between users and providers of climate service, (iii) improving the climate literacy of the user community and (iv) developing evaluation and monitoring tools to measure whether the implementation delivers the expected results.

Characteristics of the Implementation Context and Target Population

The pilot implementation took place in Puno, one of the two pilot regions of the project. Puno is located in the southern highlands of the Peruvian Andes with an average altitude around 4000 m a.s.l.

Its climate is characterized by dry conditions in the austral winter from May to September and wet summers from October to April, with occasionally occurring frost. ENSO influences both seasonal temperature and precipitation variability. El Niño (La Niña) is related to warmer (cooler) than usual temperatures. El Niño (La Niña) summers are also drier (wetter) than usual, although this relation is less robust (Lavado et al. 2013; Garreaud 2009). Future climate scenarios predict a decrease in precipitation and a growing risk of drought by the end of the 21st century (Neukom et al. 2015).

Puno has a population of 1.4 Million inhabitants, who account for 5% of the Peru's population. Puno is among the four Peruvian regions identified as having a very high level of food insecurity (INEI 2012). Although contributing only 15% to the region's GDP, 43% of the economically-active population works in the agricultural sector, with a majority of small-scale subsistence farms (INEI and MINAM 2013). Due to the short duration of the growing season (from October to April), the extensive nature and the low technological development of agricultural production systems and climate and soil constraints, agricultural productivity is below the national average. More than 96% of the population relies on rain-fed agriculture for their livelihoods, which makes the region especially susceptible to weather and climate events.

The main food crops are potatoes, quinoa and broad beans. Livestock farming provides an additional source of income. For quinoa, the demand on international markets has recently risen due to recognition of its nutritional value. For the majority of small-scale farmers in Puno, however, home-grown quinoa is still an essential food source. This crop has been grown for more than 7000 years, mainly using traditional cultivation methods without pesticides or mineral fertilizers. The cultivation of quinoa, in contrast to many other crops, is well adapted to the harsh climate conditions of the Altiplano. Due to the high importance of quinoa for the local population, it was chosen as a pilot crop for the project implementation.

Evidence for Action

Vulnerability to Hazards Depends on Farmers' Socio-economic Status

The household survey with 726 smallholder farmers in the Puno region allowed us to compare their actual harvest with their historical baseline and, therefore have a meaningful measure for production and yield losses among individual producers. First of all our analysis revealed that frost and drought events are the most frequent (*Exposure*) and damaging (*Sensitivity*) natural hazards which was also reflected by the farmers' perception (Fig. 17.3a).

Farmers were clustered into three income groups based on their possessions. Poor farmers seem to be more sensitive to crop losses due to natural hazards compared to their better-off counterparts. Unequal distribution of income within a community and exposure to frost negatively impacted relative harvest levels. The use of weather and climate information for production and the number of viable protection measures were positively associated with the actual harvest.

Considering that frost and drought are the two hazard types having the greatest impact, the majority of the study participants stated that they could make good use of early warnings to reduce crop losses by taking preventive measures (*adaptive capacity*).

Throughout all income classes, the ability of an individual farmer to recover from crop failure (*coping capacity*) is limited (Fig. 17.3). The largest share of farmers (53%) is forced to reduce their food intake due to lack of savings or stored crops (Fig. 17.3b). In the case of financial shortages, farmers switch to strategies that further increase pressure on their already constrained livelihoods: selling of livestock, stored food or other assets (86%) and engagement in casual external work (33%). Formal social and financial protection mechanisms are very limited: 2% of the farmers have crop insurance and 5% have access to bank credits (Fig. 17.3c).

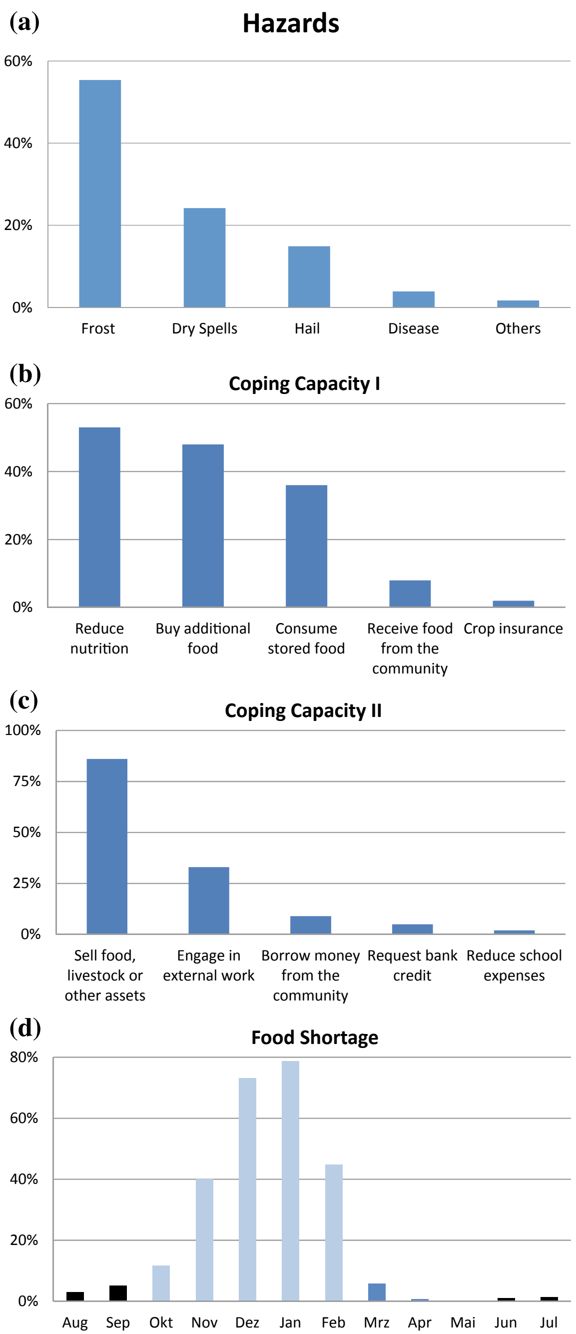
Considering that a large number of the targeted actors practice subsistence farming, using up to two thirds of their production for self-consumption and due to the low coping capacities observed, crop failures directly translate into food shortages. In particular, poor households whose dependence on homegrown food is higher, exhibit significant problems of food insecurity which peaks in January, shortly before the next harvest starts (Fig. 17.3d).

The Evaluation of Crop Protection Measures for Effectiveness and Applicability

The survey also revealed that while farmers in the region apply preventive options to protect crops from extreme climate events, the effectiveness of such options remains largely unclear. In order to evaluate the viability of these measures, the method of analysis of real options was applied to evaluate the effectiveness and applicability of two viable management options that could potentially reduce crop losses due to extreme climatic events: (i) changing the variety of quinoa to one more resistant to frost and (ii) cultivation in elevated fields, called *Waru Waru* (in Quechua) or *Sukakollo* (in Aymara). The latter is an ancestral cultivation practice that increases yields and offers resistance to harsh climate conditions such as frost and dry spells.

Results indicate that switching to a more robust crop variety, offering higher yields, can significantly improve the farmers' revenues. However, adopting new quinoa

Fig. 17.3 The main results of the vulnerability assessment. These reveal the most severe climate hazards for production (panel **a**, in % of smallholders), the population's low ability to cope with shocks and their precarious livelihoods (**b** strategies for crop failures, **c** strategies for financial shortages) reflected in the form of food insecure periods. The percentage of households reducing meals for each month of the year is displayed in panel (**d**, light shading denotes growing period, medium shading the harvest period)



varieties is also associated with additional costs for new seeds and learning how to handle the new variety. In the case of the elevated fields, production is not worth undertaking for individual farmers, or the community, unless there is further evidence related to the increase in productivity of quinoa or subsidies from governmental or non-governmental institutions. This finding concurs with the fact that the occurrence of the technique remains low. Furthermore, it appears that even after implementation, raised fields have been abandoned in 3 out of 4 cases. Regarding these and other preventive measures to protect crops from weather extremes such as frost fires, water harvesting or specific irrigation systems, more investigation of their potential effects and benefits is required and results need to be mainstreamed to farmers and farmers' organizations.

A Frost Warning for Subsistence Quinoa Farming Potentially Values 2.7 Million USD for the Puno Region

The estimation of the socio-economic benefits (SEBs) of enhanced access to weather and climate information is essential to better understand the likely returns of public investment in climate services, as well as for the purposes of formulating public policies. However, such evaluations are particularly scarce for interventions in developing countries and countries with emerging economies. During the first phase of Climandes a pilot SEB study for the coffee growing sector yielded a very substantial benefit of an early warning system for conditions conducive to coffee rust (Lechthaler and Vinogradova 2017). In the second phase of Climandes the SEB study was done with a different approach. The estimate this time is based on a stochastic life-cycle model that builds on the relevant context information from the household survey and simulates a quinoa farmer's production and consumption decisions over a representative farming year. Based on the model, a specific frost warning is estimated to generate an increase of approximately 10% of their actual quinoa harvest. Translated into a monetary value and extrapolated to the total cultivated area of quinoa, this leads to a potential increase of 2.7 million USD per year for the Puno region (Brausmann et al. 2019).

Why Do Farmers not Incorporate Weather and Climate Information into Their Decision-Making?

The model we applied in the previous section assumes that a farmer correctly interprets and trusts the forecasted warning and knows how to apply the corresponding preventive measures. This is a strong assumption since the actual use of climate services by smallholder farmers in developing countries and countries with emerging economies remains a major challenge, as has already been shown in the context of

Sub-Saharan Africa (Carr and Onzere 2017). Even if climate services are available, they often fail to provide the information in a way that is meaningful to end-users. In order to properly design the climate services, the current barriers that limit the use of weather and climate information by the end-users were analyzed. Four aspects were especially evident and are described in Table 17.2. Firstly, the acceptance of science-based information is not complete. Secondly, access to information was not ensured for all farmers. Thirdly, farmers perceive the information currently disseminated as confusing and hard to understand. And finally, the information currently provided is insufficiently detailed for the specific location of their community.

Translating Evidence into Practice

Community Outreach: A Promising Strategy for Designing User-Driven Climate Services

The evidence generated in the first stage of Climandes unveiled the discrepancy between the weather and climate information currently provided and user requirements and expectations. This was manifested through low confidence in the information provided by the national meteorological service SENAMHI. It became clear that incorporating scientific weather and climate information into agricultural decision-making in remote rural regions like the Altiplano requires the active involvement of those targeted communities. In order to make available information meaningful for the end-users, we needed to overcome the four identified key constraints to utilization presented in the previous section, i.e. the lack of acceptance, lack of access, lack of comprehension, and lack of accuracy. To address this challenge, we undertook a community-based approach by conducting a series of monthly climate field workshops in two agricultural communities in Puno during the growing season 2017–2018. These workshops were organized and carried out by a multidisciplinary team, among them meteorologists and agronomists from the regional office in Puno and the headquarters of SENAMHI in Lima, as well as local non-governmental and governmental stakeholders interested in climate resilience and agriculture. The objectives of these workshops were to sensitize farmers to the use of weather and climate information, overcome key factors limiting their use, monitor and evaluate the impact of the intervention, as well as establish a continuous feedback cycle between the user and provider community.

Monitoring and evaluating the outcome of the intervention constituted a central part of our approach. To this end we developed a monitoring and evaluation approach that helped to continuously adapt the climate service to the user's needs and measure the impact of the intervention. The approach consisted of two elements:

(i) After each workshop, the facilitator responsible provided feedback on the workshop using a standardized form aimed at documenting the content and development of a given session;

Table 17.2 A community outreach through climate field workshops

Stage I: Evidence	Stage II: Evidence-based action
1. Lack of acceptance	Combining weather and climate information with traditional knowledge to enhance acceptance
Preference for environmental predictors One out of two farmers in the region favor traditional indicators over science-based information and considers these methods as sufficient for decision-making	Local traditional knowledge was widely used for predicting weather and climate by farmers in the study region. This knowledge served as a crucial entry point for discussing the information provided by the meteorological services. Each workshop started with a comparison between the previsions of a local community representative based on environmental predictors and a forecast presented by a meteorologist from SENAMHI. This activity served to illustrate the potential complementarity between scientific information and the traditional indicators in order to gain a robust foundation for decision-making. In order to value and preserve this ancestral traditional knowledge, Climandes made great efforts in documenting the natural indicators currently used in practice and published a book titled "Willay", using the Quechua expression for *reading natural signs* (Willay—Midiendo el Tiempo sin Instrumentos)
2. Lack of access	Improving the distribution channels to provide access to climate data and information
Lack of and unequal access to forecasts and warnings Almost 20% of the farmers are uninformed of upcoming weather and climate events. Low access is particularly prevalent in poor, less educated and female farmers	In the initial workshop, farmers were asked to present their preferred communication medium for receiving weather and climate information. In response to farmers' requests, we established two distribution channels to better reach the target population Local radio stations enable isolated communities to receive weather and climate information and agricultural advice. Thus, the first service consisted in transmitting the daily forecasts through two local radio stations in the pilot areas (*La Decana* in Juliaca and *Onda Azul* in Puno) in local languages Quechua and Aymara as well as in Spanish As the coverage for mobile phone networks is high and sharply increasing in rural regions (every other farmer in the target group owned a mobile phone), Climandes established, as second service, a text message service (SMS). The messages included weekly weather forecasts and early warnings of frost and drought events. According to feedback from farmers receiving these messages, they passed the information on to another four people on average in their community. In order to strengthen credibility of information and communication with farmers, it was essential that the SMS were disseminated by specialists from the SENAMHI regional office

(continued)

Table 17.2 (continued)

Stage I: Evidence	Stage II: Evidence-based action
3. Lack of comprehension	Improving climate literacy for a better comprehension of weather and climate information
Forecast is poorly understood 42% of producers perceive the information currently disseminated as hard to understand. These comprehensive issues are particularly prevalent in less educated and female respondents	A core element of the climate field workshop was the capacity-building of the user community. Local SENAMHI meteorologists covered weather and climate aspects such as the general principles and limitations of scientific forecasts, characteristics of the local climate, the El Niño phenomenon, cloud types, as well as causes of high-impact events like frost, drought and hail. Local agronomists complemented this input with corresponding measures to protect crops from agro-climate hazards. Farmers were shown how to interpret the weather and climate information they receive via radio and text messages. Users gave feedback on the information provided which led to modifications of the content and distribution of the information
4. Lack of accuracy	Discussing local implications of weather and climate information to address the accuracy issue
Forecast not accurate at local scale Information currently provided information is not accurate enough for the specific community to take decisions	All weather and climate information is by nature uncertain with the level of uncertainty typically increasing with forecast lead time. The highly complex terrain of the Puno region makes localized forecasts very difficult, even on short-time scales. This difficulty is also associated with the low density of available weather stations. To avoid unrealistic expectations by the farmers, the limitations of weather and climate information were regularly discussed with participants during the UIP workshops. With this in mind, the implications of the most recent forecast for their specific area was analyzed and discussed. Also, the choice of the kind of weather and climate information communicated to the users has to be adapted in a smart and careful way to the specific user groups. For instance, long-term information such as seasonal forecasts or even climate scenarios is not appropriate for individual smallholder farmers, as they are usually characterized by a high degree of uncertainty. Delivery of such information, typically communicated in a deterministic way, is potentially counterproductive, as it will inevitably lead to many false or missed alarms and counteract the increased trust in the national meteorological service

The identified main constraints of weather and climate information utilization for small-scale farmers were directly and specifically addressed in the monthly climate field workshops organized in two agrarian communities in Puno

(ii) Over the workshop series, we repeatedly tracked specific indicators reflecting farmers' acceptance, comprehension, accuracy and trust through a structured questionnaire. The resulting indicator values were used to quantify the impact of the climate field workshops. This analysis was carried out with 68 farmers after the initial, 32 farmers after the midterm and 37 farmers after the final workshop. Only 4 farmers were interviewed after all of the three workshops.

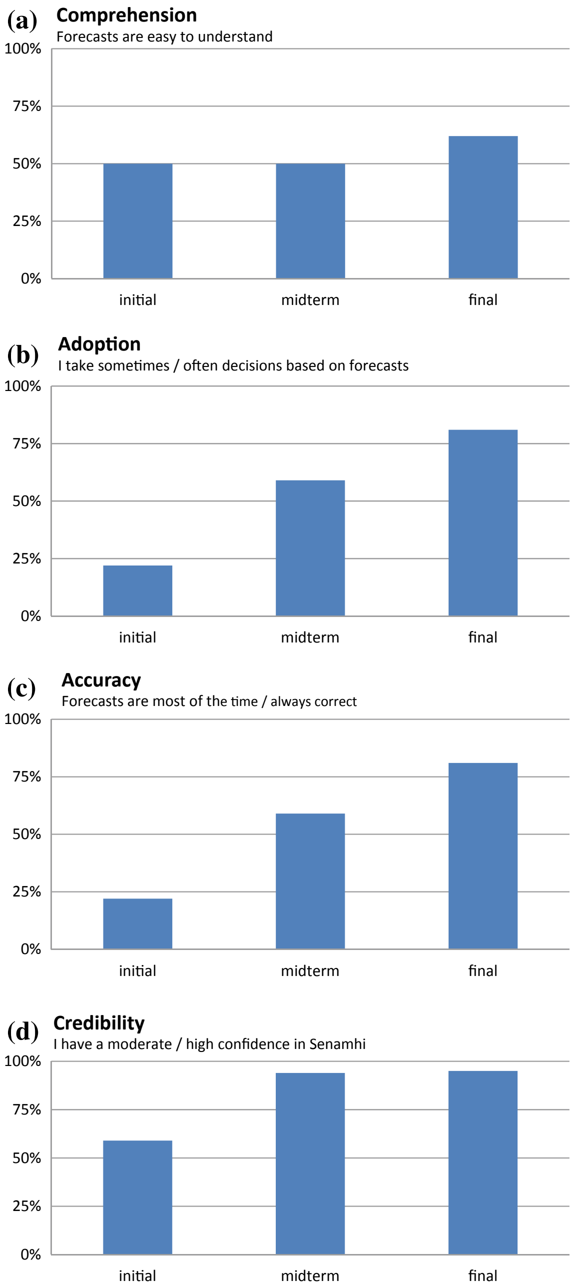
The results of this procedure are summarized in Fig. 17.4. They indicate that the workshops fostered a strong increase of trust in the meteorological service (SENAMHI) and in the weather and climate information they provide (Fig. 17.4). This was not only reflected by a growing credibility for the institution (panel d, *credibility*, an important attribute of information) but also by the perception that the information provided coincided with reality (panel c, *accuracy*). Farmers reported that they considered this information in their decision-making (panel b, *adoption*) and that, in doing so, it actually improved their prospects for production. The understanding of weather and climate information was still a critical point in the user community we worked with and did not improve significantly over the period of intervention (panel a, *comprehension*).

The fact that the adoption of climate increased from below 50% to around 80% but the comprehension stayed basically the same is not very intuitive and deserves some discussion. Why would the users progressively base their decisions on forecasts they did not have a better understanding of? On the other hand, the uptake of the services can occur while understanding still remains poor. For example if the awareness of the existence of services is low, utilization can simply be increased through better information on existing offers, independently of how well they are understood. Alternatively, many farmers may have understood the information, but did not know where it came from. Also, the credibility of the services improved after the first workshop almost to the maximum value possible. This could have been the case because the explanation given by the technicians was very convincing, or because the users were impressed by the novelty of the kind of services. It is fair to say, especially given the users' noticeable reservations about modern climate and weather information and their prior lack of experience in interpreting this information, it will probably require longer interventions to enhance the overall acceptance of new information. That credibility it is built by using the products consistently over an extended period of time. So that the benefit becomes tangible, but the results of the monitoring point in the right direction.

Beyond Climate Service Implementation

Through the results of our study and the experience gained during the project implementation, we have learnt that—besides the fundamental necessity of weather and climate information—there are critical factors which are beyond the scope of the

Fig. 17.4 After the initial, midterm and final workshop held in the two communities, we asked farmers to fill out a survey. The results demonstrate some of the benefits of our pilot UIP. While comprehension only slightly increased (**a**), farmers report that they more often integrate forecasts in their decision-making (**b**), perceive forecasts to be more accurate (**c**) and have more confidence in SENAMHI (**d**). Bars on the left of the plots denote results from initial workshop (sample size n = 68), bars in the middle from midterm workshop (n = 32), and bars on the right from final workshop (n = 37)



project mandate to enhance the resilience of the most vulnerable populations. Nevertheless, we would like to discuss complementary issues to climate services that became evident. A key finding of this project is the target population's low capacity to overcome shocks such as high-impact weather and climate events. The evidence brought forth by the project made clear that access to formal financial services, crop markets, social protection and governmental aid have to be strengthened in order to mitigate the negative long-term consequences arising from these events. As a matter of fact, these results highlight the very low access to formal insurance against crop losses with only 2% of the households being insured. Risk transfer would prevent farmers from selling their livestock and other assets, abandoning their farmland to find alternative work elsewhere and borrowing money or reducing nutrition. Therefore, micro-insurance services based on weather indices have gained increasing attention in recent years in the framework of development cooperation.

An additional prominent vulnerability factor was found to be the low incomes compared to other sectors and hence the lack of savings necessary to recover from the effects of a high-impact event. Smallholders could benefit from better access to market systems to receive better market prices. Although the majority of production in the project region Puno is extensive, only a very small share of the smallholder farmers certify their production as organic, even though prices are significantly higher for certified crops (+33%). The main reason for not certifying the products is lack of knowledge (84%) and—to a lesser degree—the high administrative burden (13%). Farmer cooperatives like Agrobosque in the Peruvian region Madre de Dios, for example, help their members sell their quality products for better market prices, by providing direct market access and organic certification.

Summary and Conclusion

Climandes was performed from 2012 to 2019 in two phases as a twinning project between SENAMHI Peru and MeteoSwiss to implement user-tailored pilot climate services for the agricultural sector, more specifically for the smallholder farmers of the Peruvian Andean highlands. The main findings can be summarized as follows:

- Climandes provides a proof-of-concept for the relevance of the UIP concept as a basis for user tailored climate service implementation. We implemented a GFCS pilot UIP using a two-stage approach that is built around evidence-guided action. This approach turned out to be a key factor for the success of the Climandes project, which is mainly due to the involvement of the user community at a very early stage. This community not only includes small-scale farmers as end-users, but also involves intermediary users such as private and public partner institutions that transformed the climate data and information into agro-climatic advice. As exemplified by this user-supplier interaction, the project confirmed the importance of incorporating sectoral, and hence transdisciplinary expertise in order to provide meaningful end-to-end climate services.

- Although Climandes focused specifically on smallholder farming in the Andean highlands, the proposed two-stage approach to set-up a UIP involves a number of generic elements that can be transposed and applied to other sectors with quite different user profiles, while continuing to ensure a user-driven process. We therefore provide a summary of these key elements of the process in form of a checklist for the proposed two-stage approach for designing user-driven climate services (Table 17.3). These comprise the participation of the user communities, the tailoring of the climate information and communication, on the supply side the provider capacities, and finally, for the sustainability of the results most importantly, a dialogue at the policy making level. Overall, the checklist highlights the importance as well as the necessity of a substantial user-supplier engagement, in whatever form effective.
- Community outreach requires decentralized resources, i.e. the regional office of Peru's meteorological service proved to be the mainstay for effective provision of climate services. Not only were the personnel responsible for the production and distribution of the weather and climate information but, more importantly, it had the hands-on knowledge of the hazards to which local communities are exposed, as well as the ability to reach out and engage with the local population. Thus, our experience made it clear that the implementation of a UIP based on community outreach is resource-intensive and requires enhanced capacities of technical staff in meteorological offices in peripheral regions. Particular attention must therefore be paid to the decentralization of meteorological services in the implementation countries.
- We deem that the twinning approach chosen for the Climandes project implementation was a recipe for success. The main focus and effort of the intervention has been in the development of capacities in the climate and user communities. All activities were developed in a partnering collaboration between the regional and national offices of SENAMHI Peru and MeteoSwiss, and can be seen as an effective peer-to-peer, on-the-job training and also as a means of building personal professional networks. Capacity development was complemented with a series of both online and classroom courses covering all themes of the project and providing training on specific climate-service related topics. The courses were attended by international participants, also fostering the exchange between professionals of the weather services of the region, for example through monthly online briefings on seasonal forecasts. The course material remained available upon registration on the platform for online courses from the Peruvian meteorological service.

Although this chapter mainly focused on the user's perspective of climate services specifically the UIP, Climandes made great efforts and progress in the other technical and provider-oriented components of the GFCS framework. We put particular emphasis on the quality of observational data because spatially and temporally complete, high resolution climate data are required for climate services to be reliable (Gubler et al. 2017; Hunziker et al. 2017). We also developed daily gridded datasets of precipitation and temperature, as these are necessary for analyzing the past climate in more spatial detail and for increasing the spatial resolution of the statistical forecasts, which are carried out operationally at SENAMHI. We investigated the skill of SENAMHI's seasonal forecasts using statistical and dynamical forecast models. Besides temperature and precipitation, parameters tailored to the phenological cycle were analyzed (e.g. frost days or dry days during the growing season), yielding significant skills for some temperature-based parameters and only marginal skills for

Table 17.3 Checklist for the design of user-driven climate services based on expertise gained in the Climandes project

Stage I: Setting the scene by providing evidence	Stage II: Establishing a user-driven climate service prototype
User community participation	
• Identify and evaluate key stakeholders and users relevant for climate services (stakeholder mapping) • Assess socio-economic vulnerability of the target population including the characterization of key hazards (exposure and sensitivity) as well as socio-economic characteristics (adaptive and coping capacities) • Identify vulnerability factors such as gender, socio-economic status, income inequalities, etc.	• Establish a continuous interaction mechanism e.g. through workshops targeted to directly address the identified constraints to the use of weather and climate information • Improve the climate literacy of the target users
Tailored information and communication	
• Identify key constraints to utilization of weather and climate information • Assess cultural aspects regarding climate service utilization (e.g. indigenous knowledge, traditional farming practice) • Understand how target population can be reached (e.g. radio stations, mobile phone distribution)	• Develop a distribution strategy • Establish information tailored to the users and delivered through identified distribution systems • Establish a feedback mechanism to verify that forecasts and warnings are received and understood with the aim to continuously improve the service
Provider capacities	
• Identify scientific, technical and operational gaps regarding climate service provision (e.g. low station density, lack of technical capacities, insufficient data and product quality, missing human resources at peripheral level)	• Rectify the scientific, technical and operational gaps on the provider side to improve data and product quality • Increase awareness in the climate community to guarantee an appropriate user commitment to the consideration of user needs for climate data and products
Policy dialogue	
• Evaluate potential socio-economic benefits of planned climate service to facilitate policy engagement • Implement a monitoring and evaluation process to measure the impact of the intervention	• Hold a policy dialogue with local, regional and national policy-makers to help them understand the return on their current and future investments in climate services

(continued)

Table 17.3 (continued)

Stage I: Setting the scene by providing evidence	Stage II: Establishing a user-driven climate service prototype
Striving for sustainability	
• Bring all developed services to operation • Upscale the prototype service to a wider user community	• Share lessons learnt and key experiences with other organizations and practitioners

We provide this checklist for the proposed two-stage approach for designing user-driven climate services. These stages encompass an accurate assessment of the implementation context (setting the scene by providing evidence); base the implementation processes on this assessment (establishing a user-driven climate service prototype) and ultimately, an operationalizing and scaling-up of the implementation to a wider region (striving for sustainability)

precipitation and parameters based on the latter. Given the substantial uncertainty at the seasonal range level, these forecasts do not seem to be of direct use for individual farmers. Rather, we see a potential value at a more institutional level, where seasonal forecasts can raise the awareness for releasing humanitarian funding, trigger risk-reducing actions, enhance preparedness and response and thus make disaster risk management overall more effective.

In summary, the Climandes project demonstrated that improved access to weather and climate information for the most vulnerable people significantly enhances their disaster preparedness and therefore contributes to protecting their livelihoods. The estimated potential socio-economic benefits of enhanced use of climate and weather information are likely to exceed the costs of developing and maintaining the provision of that information. However, the project testified to the great challenges in climate service implementation in developing countries and countries with emerging economies.

Through the user-participatory approach, we managed to overcome identified key constraints in the utilization of weather and climate information. In fact, our experience suggests that the co-developed climate service implemented enhanced the user communities' trust in scientific information and improved their adoption in agricultural decision-making in order to tap the potential socio-economic benefits that climate services provide.

In the face of the global climate change challenge, Climandes caters to the great need for climate service interventions in developing countries and countries with emerging economies. As such, it is well in line with, and can be seen as a significant contribution to the GFCS. Climate services are public assets, for which unrestricted and unlimited access should be guaranteed for the entire population. In other words, we should strive to make climate services more inclusive, by paying particular attention to the needs and constraints of the most vulnerable and marginalized population groups, which encompass the poor, the low-educated and women, as underlined by the evidence gained in this project.

Our study had some limitations. Most importantly, only a subset of the workshops participants were included in the data collection. Producing a more in-depth impact evaluation of improved access to weather and climate services would require an experimental design including a larger sample and a control group. Furthermore, field experiments could potentially quantify the impact of weather and climate services and corresponding management decisions on the yields and socio-economic status. However, such a study design could not be carried out within budget and time horizon of this project.

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Glossary

Climate services A climate service is a decision aide for governments, organizations and individuals and seamlessly derived from information about the past, current and future climate. Design and implementation of a specific climate service requires in-depth and iterative engagement with the users in order to tailor it to their key characteristics and needs. Effective climate services support climate-smart decisions and in this way lead to increased social and economic resilience to climate variability and change (WMO 2013).

User Interface Platform The User Interface Platform is one of the five main pillars of GFCS necessary for a functioning climate service system. It is the mean of interaction for users, researchers and climate service providers to bridge the gap between the science and user community and to guarantee the climate services meet users' needs. The design of a UIP can vary sector-specifically, but importantly, its design is based on evidence of the users' needs.

Resilience Resilience describes the capability of a system or part of a system to absorb or recover from the effects of a hazardous event and return to its former functionality. This can happen through preservation.

Hazard A hazard describes the potential occurrence of a natural or human-induced physical event that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, and environmental resources. Climate-induced hazards are hazards from atmospheric phenomena, that have the potential to affect humans, their structures or activities adversely. This includes all kind of events that deviate strongly from the mean climate, such as cold waves, dry periods or heavy precipitation events. More specifically, agro-climatic hazards are climate hazards with adverse effects for the agricultural system.

Exposure Exposure describes the exposition of people, livelihoods, resources and infrastructure to environmental hazards. The exposure matters, as an environmental hazard only becomes a risk if people or infrastructures are exposed and vulnerable to this hazard.

Sensitivity Sensitivity describes the degree to which a system (a community or an ecosystem) reacts and responds to a climate change or event. This includes both beneficial and problematic responses, resulting for example in food insecurity due to unfavorable climate conditions and yield loss.

Adaptive capacity Adaptive capacity describes the ability of an individual, community or society to prepare for a coming hazard and take actions to alleviate its adverse impacts. The adaptive capacity to mitigate damage depends upon the available resources (e.g. financial), decision options as well as available information.

Coping capacity The coping capacity is the ability of people, organizations, and systems, using available skills, resources, and opportunities, to address, manage and overcome adverse conditions; in the case of climate an extreme event such as a drought, a frost or an extreme precipitation.

Vulnerability This refers to the predisposition of a community, system or asset to be susceptible to the damaging effects of a hazard through a set of characteristics and circumstances. This can include for example a low adaptive capacity relative to a hazard or a high sensitivity towards it.

Risk transfer Risk transfer describes the process of shifting the financial consequences of a risk from the asset at risk to another, in many cases, less vulnerable party. A risk transfer can occur formally through insurance or through governmental aid.

References

Brausmann A, Flubacher M, Lechthaler F (2019) Valuing meteorological services in resource-constrained settings: application of an integrated economic assessment to smallholder farmers in the Peruvian highlands (in preparation for publication)

Carr ER, Onzere SN (2017) Really effective (for 15% of the men): lessons in understanding and addressing user needs in climate service from Mali. Clim Risk Manag 22:82–95

FAO, IFAD, UNICEF, WFP & WHO (2017) The state of food security and nutrition in the world 2017: building resilience for peace and food security. Food and Agriculture Organization of the United Nations, Rome, 120 pp

Frei H, Huggel C, Steinemann M (2016) The El Niño phenomenon and related impacts. Climate Change Environment, Nexus Brief, Nr. 2. Swiss Agency for Development and Cooperation, Berne

Garreaud RD (2009) The Andes climate and weather. Adv Geosci 22:3

Gerlak AK, Zack G, Knudson C (2017) Mid-term review of the global framework for climate services. World Meteorological Organization, Geneva, 31 pp

Gubler S, Hunziker S, Begert M, Croci-Maspoli M, Konzelmann T, Brönnimann S, Schwierz C, Oria C, Rosas G (2017) The influence of station density on climate data homogenization. Int J Climatol 37(13):4670–4683. https://doi.org/10.1002/joc.5114

Gubler S, Rossa A, Avalos G, Brönnimann S, Cristobal K, Croci-Maspoli M, Dapozzo M, van der Elst A, Escajadillo Y, Flubacher M, Garcia T, Imfeld N, Konzelmann T, Lechthaler F, Liniger M, Quevedo K, Rohrer M, Schwierz C, Sedlmeier K, Spirig C, De Ventura S, Wüthrich B (2020) Twinning SENAMHI and MeteoSwiss to improve climate services in the agricultural sector in Peru (in preparation for publication in Climate Services)

Hallegatte S, Vogt-Schilb A, Bangalore M, Rozenberg J (2017) Unbreakable: building the resilience of the poor in the face of natural disasters. Climate Change and Development. World Bank, Washington, DC, 189 pp

Hunziker S, Gubler S, Calle J, Moreno I, Andrade M, Velarde F, Ticona L, Carrasco G, Castellón Y, Oria C, Croci-Maspoli M, Konzelmann T, Rohrer M, Brönnimann S (2017) Identifying, attributing, and overcoming common data quality issues of manned station observations. Int J Climatol https://doi.org/10.1002/joc.5037

INEI (2012) IV Censo Nacional Agropecuario 2012. Instituto Nacional de Estadística e Informática, Lima

INEI & MINAM (2013) Resultados Definitivos: IV Censo Nacional Agropecuario – 2012. Instituto Nacional de Estadística e Informática & Ministerio del Ambiente, Lima

IPCC (2012) Managing the risks of extreme events and disasters to advance climate change adaptation. In: Field CB, Barros V, Stocker TF, Qin D, Dokken DJ, Ebi KL, Mastrandrea MD, Mach KJ, Plattner G-K, Allen SK, Tignor M, Midgley PM (eds) A special report of working groups I and II of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, UK, and New York, NY, USA, 582 pp

Lavado WS, Labat D, Ronchail J, Espinoza JC, Guyot JL (2013) Trends in rainfall and temperature in the Peruvian Amazon-Andes basin over the last 40 years (1965–2007). Hydrol Process 27(20):2944–2957

Lechthaler F, Vinogradova A (2017) The climate challenge for agriculture and the value of climate services: application to coffee-farming in Peru. Eur Econ Rev 94:45–70

Neukom R, Rohrer M, Calanca P, Salzmann N, Huggel C, Acuña D, Christie D, Morales MS (2015) Facing unprecedented drying of the Central Andes? Precipitation variability over the period AD 1000–2100. Environ Res Lett 10(8):084017

Rosas G, Gubler S, Oria C, Acuña D, Avalos G, Begert M, Castillo E, Croci-Maspoli M, Cubas F, Dapozzo M, Díaz A, van Geijtenbeek D, Jacques M, Konzelmann T, Lavado WS, Matos A, Mauchle F, Rohrer M, Rossa A, Scherrer SC, Valdez M, Valverde M, Villar G, Villegas E (2016) Towards implementing climate services in Peru—the project Climandes. Clim Serv 4:30–41. https://doi.org/10.1016/j.cliser.2016.10.001

Samberg LH, Gerber JS, Ramankutty N, Herrero M, West PC (2016) Subnational distribution of average farm size and smallholder contributions to global food production. Environ Res Lett 11(12):124010

WMO (2013) What do we mean by climate services? WMO Bulletin, 62. Geneva, WMO

WMO (2014) Annex to the implementation plan of the global framework for climate services—user interface platform component. World Meteorological Organization, Geneva, 44 pp

Chapter 18
Meteorological Services for Forecast Based Early Actions in Indonesia

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Abstract The increasing frequency of climate related hazards leading to disasters stipulates the government of Indonesia to pay serious attention to mitigate the adverse impacts of the disasters. An initiative is the utilization of climate and/or weather forecasts to support the installment of impact-based forecasts and risk-based warnings. This study investigated the feasibility of supporting Forecast Based Early Actions (FbA) implementation in Indonesia based on document reviews, identification of supporting tools, and stakeholders' consultations with the key informants. Understanding the available resources for supporting early actions, the study recommends focusing on two major climate related hazards, i.e., floods and drought, as the two most impacted hazards on human lives and assets with refer to the available datasets from 1972 to 2018. The implementation of FbA for the two hazards also sounds promising with regards to available and accessible forecasted rainfall occurrences and amount (e.g., one day, 3-day and 10-day prediction, and seasonal forecasts) across the country provided by Meteorological, Climatological, and Geophysical Agency named in bahasa Badan Meteorologi, Klimatologi, dan Geofisika (BMKG). Nevertheless, the forecast accuracies should still be improved and automatically connected with hazard-based models (e.g., flood or drought) nationally. This demand urges that further efforts are needed to endorse the implementation of FbA in Indonesia.

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Introduction

The Government of Indonesia (GoI) paid a serious concern on addressing climate related hazards considering such climate extremes can pose severe challenges on a wide range of economic sectors. Global climate change, which has been acknowledged impacting regional climate and weather extremes in the country such as erratic rainfall and/or pro-long dry season as recapitulated in the recent country report (Perdinan et al. 2017), may potentially cause the changing occurrences of climate related hazards such as floods and drought. The linkage of the potential impacts of climate change on increasing the frequency of climate related hazards adds more concerns as the hazards have been seen as a serious threat that can inhibit the achievements of development plan of the country. For example, it was reported that the frequency of floods and drought was increasing in Indonesia. The recapitulation of hazard occurrences nationally for the period of 1815–2015 shows that about 73% of the hazard events, equal to about 1884 events, are hydro-meteorological or climate-related hazards, which urges a serious attention concerning the impacted damages as reported by National Disaster Management Authority in bahasa Badan Nasional Penanggulangan Bencana (BNPB) (Source: dibi.bnpb.go.id). Floods and drought at a particular region/location in Indonesia are regularly associated the ENSO (El Nino and La Nina) events. During El Nino many regions in Indonesia experience low rainfall, whereas, the opposite condition will occur during La Nina. As global warming is expected to increase the frequency of ENSO events (Timmermann et al. 1999), rainfall variability in Indonesia is also expected to change. Shorter rainy season and longer dry season may happen in many Indonesian regions, which may increase the frequency of floods and drought.

Understanding, the potential impacts of climate variability and change particularly on climate related hazards, the GoI already suggested the needs to address such challenges through actions on climate change adaptation, National Action Plan on Climate Change Adaptation—Rencana Aksi Nasional Adaptasi Perubahan Iklim (RAN API) (BAPPENAS 2014). The GoI also already submitted the Initial National Communication (INC) document to UNFCCC in 1999, the Second National Communication (SNC) in 2010, and recently the Third National Communication in 2016. Recently, the GoI has submitted the first National Determined Contribution (NDC) as a commitment to address climate change issue in the late of 2016. Specifically for the climate related hazards, under the coordination of Ministry of Environment and Forestry-Kementerian Lingkungan Hidup dan Kehutanan (KLHK) and BNPB, the government already initiates the convergence of climate change adaptation (CCA) and disaster risk reduction (DRR). This initiative is purposed to support designing potential strategies for enhancing adaptive capacity/community resilience and environmental management in order to minimize the climate change risks. The other purpose of the initiative is to provide national and sub-national institutions and/or the related stakeholders to devise the CCA-DRR strategies using proper data and information so that the implementation and the results can be monitored and evaluated effectively and efficiently.

As part of the CCA-DRR initiative, the proposed idea on Forecast Based Actions (FbA) is strongly relevant to promote early actions on reducing the potential adverse impacts of climate related hazards such as drought and floods on many economic sectors. The FbA will provide protocols for the government and communities to allocate resources to an anticipated climate related hazards with regards to the weather forecasts. The forecasts hint a lead-time opportunity to allow for doing early actions so that the adverse impacts can be minimized. Concerning the potential losses and damages due to disasters are huge as reported by BNPB (2017), the implementation of FbA can be seen as an innovative approach in humanitarian activities. The FbA is designed for using scientific data/techniques to indicate elevated risks and then release humanitarian funding for actions before the occurrence of potential disasters. In Indonesia, Palang Merah Indonesia (PMI) has identified FbA as a priority for Disaster Risk Reduction programs, focusing on enhancing resilience to floods and drought. The FbA is not focused on hazards but more on the impacts of the hazards, which will cause disasters, to devise proper actions. With refer to Law No. 24/2007, natural disasters include earthquakes, volcanic eruptions, hurricanes, landslides, droughts, forest or land fires due to natural factors, pest and disease infestations, epidemics, extraordinary events, and space/celestial bodies. Of these groups, the FbA focuses on climate related hazards such as floods, droughts, landslides, and cyclones, which are strongly affected by weather extremes that can be forecasted using scientific approaches. Whereas, currently the FbA does not include the geological related disasters such earthquake and volcanic eruptions as the forecast capacity is much lower than that for the weather events. Additionally, The FbA focuses on high impact disaster events, not those recurring climate related hazards on short-time period.

Understanding the requirement on forecast capability for the FbA protocols, this scoping study on meteorological services was conducted to evaluate the potential implementation of FbA in Indonesia with refer to the capabilities of the weather and/or climate services. This study provides with a greater conceptual clarity about **early warning** and **early action** in Indonesia by identifying existing forecast competencies and capacities, and its utilization. This study report includes five sections, namely: (1) Overview of Indonesia Climate Related Hazards; (2) Requirement of Forecast Based Early Actions (FbA); (3) The Support of Meteorological Services for FbA Implementation; (4) Institutional Support; (5) Conclusions and Recommendations.

Overview of Indonesia Climate Related Hazards

Historically, climate-related hazards, i.e., drought, floods, strong winds and landslides, are the most frequent disasters in Indonesia compared to other natural disasters. Of the climate-related hazards, floods and strong winds shows the highest recurring-frequency over the past 10 years (Fig. 18.1). The two climate related hazards have a tendency to increase every year, reaching up to 421 flood events and

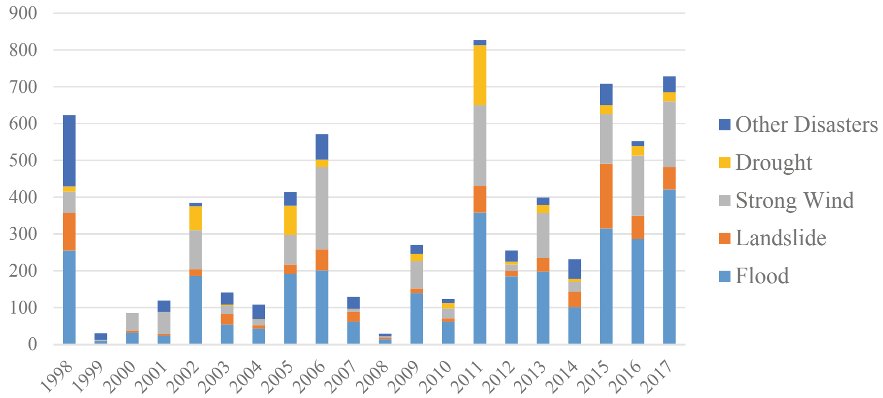

Fig. 18.1 Number of disaster events in Indonesia 1998–2017. *Source* BNPB (2017)

179 strong wind events throughout the country in 2017. The numbers of flood events in 2017 exhibits the highest flood events in the last 10 years; whereas, the highest incidences of strong winds at about 223 occurrences are reported in 2006 (Fig. 18.1).

The total numbers of the hazards can not describe the impacts as a hazard event may not automatically lead to cause a disaster. To further elaborate on the impacts, we analyzed the reported numbers of victims caused by hazard events over the country. Figure 18.2 illustrates the list of provinces in Indonesia that experience the highest impacts of multi-hazard events for the period of 1998–2017 reported in the 90% percentile of total victims. The calculated impacts are the fatalities caused by the disasters, which is in line with the purpose of FbA for humanitarian. The analysis shows that the impacts of drought are the least as compared to the other three climate related hazards, i.e., floods, landslides, and strong winds (Fig. 18.2).

Requirement of Forecast Based Early Actions (FbA)

Forecast-based Financing (FbF) or hereafter called Forecast based Actions (FbA) is a mechanism for releasing humanitarian funding triggered by a pre-established forecast threshold of climate related hazards (Climate Centre 2017). In Indonesia, the disaster risk management (DRM) is divided into broadly three activities, i.e. pre-disaster (preparedness), at disaster (emergency response), and post-disaster (rehabilitation and recovery) as directed by BNPB. With refer to the DRM framework, the FbA (GRC 2018) are activities within the scope of preparedness completed with information on lead-time of weather forecasts leading to climate related hazards that may cause disasters. The forecasts are directed to trigger the implementation of early actions prepared for anticipating the potential impacts of the predicted disaster events (Fig. 18.3).

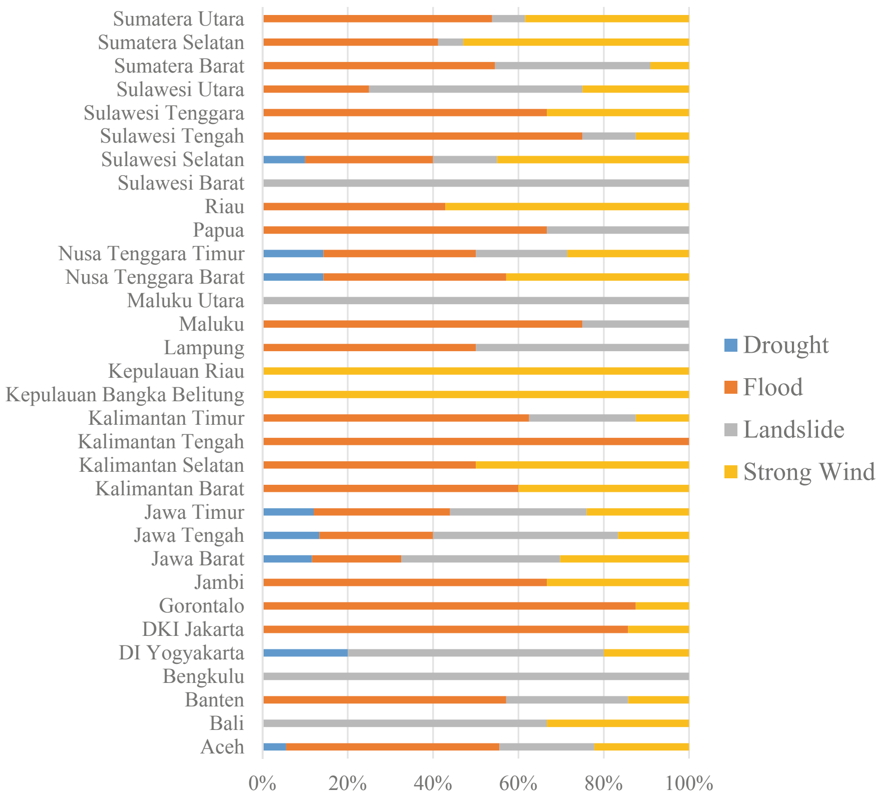

Fig. 18.2 The most impacted area caused by climate related hazards calculated by the frequencies of 90% percentiles of the total victims for the period of 1998–2017 (BNPB 2017)

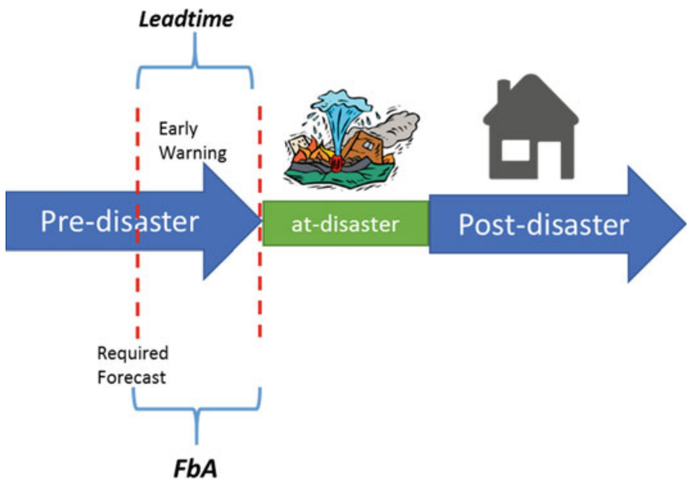

Fig. 18.3 Visualization of the framework of forecast based actions (FbA)

We adopted the FbF into FbA as the FbF builds on Early Warning Early Action (EWEA) efforts on standardizing and systematizing Early Action protocols and securing funding well in advance of a disaster event (Coughlan de Perez et al. 2015). However, recent dialogue has begun to acknowledge that the term 'financing' places undue emphasis on the funding aspects of the mechanism without being inclusive of other standardization and early action elements that are vital to FbF. Key actors within the movement have instead begun to re-define FbF as Forecast-based Early Action (FbA), a term which moves beyond the focus on financing to encompass the full spectrum of early actions and interventions that are possible. FbA mechanisms build on earlier EWEA efforts "by placing considerable emphasis on decision-making protocols, so actors know what to do on the basis of a forecast; on ex-ante financing of early action; and by using cost–benefit analysis more rigorously to help promote ex-ante investment in disaster risk reduction (DRR)" (Wilkinson et al. 2018). As such, FbA reflects a commitment to resourcing and planning early action based on weather forecasts and historical data in various forms: finance, resources, Non-Food Items (NFIs), evacuation, expertise and/or personnel.

In choosing to use the term FbA, we build off of the shifts in language that emerged in the January 2018 report entitled "Forecasting hazards, averting disasters: Implementing forecast-based early actions at scale" (Wilkinson et al. 2018). This decision also reflects language adopted by IFRC Disaster Relief Emergency Fund (DREF), which in May of 2018 established an FbA mechanism that for the first time opens a funding stream that is accessed using forecasts of a disaster (Matthew and Freebairn 2018). In our study, FbA shall refer to the overall mechanism, with FbF being used to designate the financing component of FbA. FbF will also be used to refer to FbA projects which have already been implemented using the language of FbF.

The FbA is innovative in the context of placing the protocols, funding, and commitment to early actions that permits practitioners and communities to take action based on the forecasts of a disaster, rather than responding in the aftermath of the disaster. This preemptive approach is part of a larger shift towards anticipatory approaches within humanitarian assistance (ECOSOC 2018; FAO 2017) These approaches protect lives and assets, enable communities to take actions needed to mitigate risk, involve lighter resource use, and reduce suffering.

A successful Forecast-based Early Action implementation will depend on several aspects, ranging from availability of risk information to engagement of potential stakeholders. Learning from ongoing pilot experiences, this guide sets out a set of new considerations that can be used to select intervention areas that are most "ripe" for the introduction of Forecast-based Early Action, encouraging the establishment of interventions that further consolidate knowledge and practice in this area. Based on the results of discussing each of the associated questions on FbA, practitioners can focus their priorities in the design of a specific Forecast-based Early Action intervention, focusing on the areas that need greatest support.

The criteria presented here will facilitate the feasibility analysis of Forecast-based Early Action possible interventions. For each of the presented criteria, stakeholders should arrive to a consensus that will be described in three levels "High FbA feasibility", "Medium FbA feasibility", "Low FbA feasibility". High FbA feasibility: there is sufficient progress in this area. If a project is implemented, there is a high chance of effective results and it will be possible to build robust evidence about Forecast-based Early Action impacts. Medium FbA feasibility: some work exists in this area. Although not all the conditions are ideal for the implementation of Forecast-based Early Action, it would be possible to implement as long as key weak points are managed strategically. For example, the lack of contingency plans at organization/government level could pose some challenges for the implementation. This could be overcome if information or progress in this area is improved alongside the intervention. Low FbA feasibility: No work exists in this area. The total lack of information and/or capacities is major challenge for a Forecast-based Early Action intervention. The low feasibility indicates that it could be more difficult to implement any intervention in the respective context that is being studied but also indicates that the implementing organization should design a strategy that manage the risks posed by the lack or weak performance of the specific criteria that has been analyzed.

The vision for FbA in Indonesia is to shift the current disaster risk management (DRM) mindset of response to a disaster, to one that is 'response to a forecast'—a shift that leverages current capacities and strengths and applies them to anticipatory approaches. For this purpose, we evaluated the support of meteorological services as a fundamental element required for the FbA implementation (Fig. 18.4). The capacities of meteorological and/or climate services will dictate the successful of implementing the FbA as guided in document of "Criteria for identification and design of Forecast-based Financing interventions" (Climate Centre 2017). The document explains that the feasibility assessment of FbA required assessments on three subjects, namely: Forecast Capabilities, Government Level, and Organizational Level. We envisaged an approach on evaluating the Forecast Capabilities based on literature review and secondary data analysis using available data and information released by BMKG. In addition, key informant interviews, specifically to the BMKG officers who were managed weather and/or climate services, were placed to explore further information on the capabilities of weather and/or climate forecasts.

The Support of Meteorological Services for FbA Implementation

Analysis for this scoping study was comprised of both primary and secondary research methods. As explain in the last section, we sought out opportunities to gather first-hand information through interviews and focus group discussions. These included a wide range of actors: from technical to institutional to organizational; from public, private, and research spheres; and from community-level up to national level. The research team also engaged with practitioners who have already implemented FbA in other countries, actors from across Indonesia who would be potential FbA

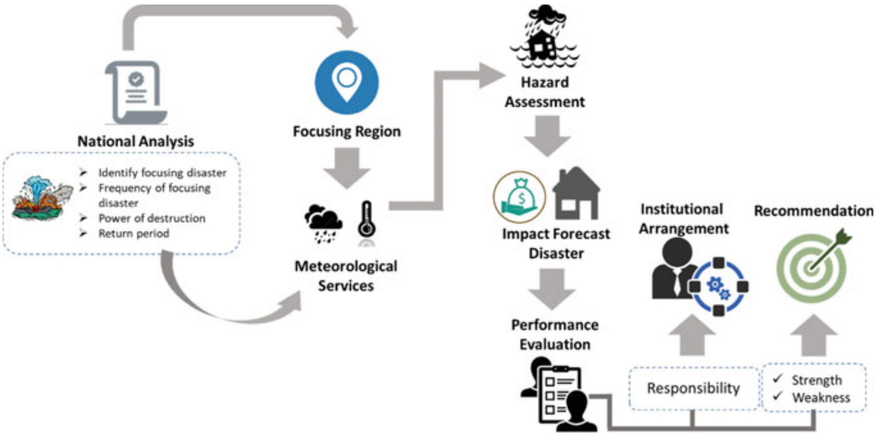

Fig. 18.4 Review methods on evaluating meteorological services in Indonesia

implementers, and community members who are involved in disaster management or who have themselves been impacted by disaster. In total, the team interviewed more than 65 actors to help inform this feasibility analysis.

The review starts from analyzing available data on impacts of disasters nationally to devise strategy to propose priority areas based on Indonesian Disaster Data and information released by National Agency on Disaster Management (Badan Nasional Penanggulangan Bencana—BNPB). The capacity of meteorological services in Indonesia was evaluated by exploring available weather and climate data through the accessible platform (i.e., web-based tools) of the authoritive agency on meteorological services (Badan Meteorology, Klimatologi, and Geofisika—BMKG). In addition, we also conducted in-person interview with BMKG stakeholders to clarify the weather and/or climate services against four aspects: availability, accessibility, quality, and data-update. The next step is evaluation of capacity on the hazard assessment by reviewing available tools for hazard assessments which have been released by the Government, private sector or university, and community. The next step is to review the inclusion of weather/climate forecasts into hazard assessments which can cause disasters (i.e., Impact Forecast Disaster). The objectives of the entire analysis are to review the capability of the country (i.e., Performance Evaluation) specifically on available meteorological/climate services and supporting tools to support the implementation of FbA in Indonesia.

The review processes found general and specific findings with regards to the characteristics of the occurred climate related hazards and the capabilities of meteorological services in Indonesia. The general and specific findings are listed below.

General Findings

1. Java Island is the island which have the highest disaster event (flood, drought, landslide, and strong wind) intensity, however the island have the lower impacts (considering the analysis of disaster events, disaster years, and impacts of DIBI database), as these areas have high capacity and resilience.
2. The reliability/skill of the rainfall forecast occurrences that provided by BMKG in Indonesia are about 75–77% (Table 18.1).
3. Meteorological services in Indonesia provide the lead time of weather forecasts, however the government institution does not provide the exact lead time for different disasters (i.e. flood, drought, landslide, strong wind, and cyclone).
4. BMKG releases the weather/climate information (website or mobile application) so that users can access the information directly. With regards to disaster mitigation, BNPB/BPBD applies the forecasts of BMKG to devise the mitigation action. However, users may be charged to some fees or requires an MoU when requesting for specific data which are not available on the websites, e.g., BNPB collaborates with BMKG to initiate the link of the forecasts with INARISK (a web-based tool of disaster risk information system).

Specific Findings

Floods

1. There are 1335 flood events with 51 events/years for period 1972–2018.
2. The return period of **flood** events is about 1–3 years, and the return period for flood disasters with big impacts of around 4–8 years, which is coherence with **ENSO** events.
3. **Floods** impacted majority provinces in Indonesia.
4. The province with highest **flood** frequency is **Central Java**, but the biggest impact is **South Kalimantan** (529,478 people die and evacuate).
5. BMKG provides weather forecasts and/or climate prediction on the website and mobile application (BMKG Info that can be downloaded through app store). BMKG has 1-day and 3-day weather forecasts and 10-day rainfall prediction that can be applied to predict **flood events**.
6. Government of Indonesia through BBWS of MoPW initiates program/tools for disaster risk reduction for **flood** by developing floods monitoring system (i.e. BBWS Citarum and Bengawan Solo); however, the coverage area is only for Citarum and Bengawan Solo)

Drought

1. There are 403 drought events with 32 events/year for the period of 1972–2018.
2. The area with the highest frequency of drought and the biggest impacted area is **West Java** (172,925 people die and evacuate).

Table 18.1 Summary of meteorological services

No.	Scientific criteria	Variable	Temporal/lead time weathers	Coverage	Location	Skill of Forecast		Source
						Event	Magnitude	
1	1–3 day probabilistic rainfall and temperature forecast available	**Daily Forecast**: Temperature, Cloud cover, humidity, flood potency, wind speed	1 days	National	Indonesia/province	75–77%	–	Depth interview and website
		3-day weather forecast: Information/potential rainfall, air pressure, and wind speed	2 days	National	Indonesia/province	75–77%	–	Depth interview and website
2	10-day probabilistic rainfall and temperature forecast available by National Meteorological Service	**Weekly Weather Prospect**: information/potential rainfall news, wind speed, and air pressure	10 days	National	Indonesia/province	75–77%	–	Depth interview and website

(continued)

Table 18.1 (continued)

No.	Scientific criteria	Variable	Temporal/lead time weathers	Coverage	Location	Skill of Forecast		Source
						Event	Magnitude	
3	Probabilistic 3-month seasonal rainfall and temperature forecasts available by national institutions	**Precipitation and rainfall type**	1–3 month	National	Indonesia/province	75–77%	–	Depth interview and website
4	20-day probabilistic hydrologic forecasts available by national institutions	**Monthly rain forecast** (to predict flood event potency)	20 days	National	Indonesia/province/district	75–77%	–	Depth interview and website

(continued)

Table 18.1 (continued)

No.	Scientific criteria	Variable	Temporal/lead time weathers	Coverage	Location	Skill of Forecast		Source
						Event	Magnitude	
5	Historical forecast data or hind casts available for more than 10 years, and forecast verification analysis published	–	–	–	–	–	–	Depth interview and website
6	Historical forecast data or hind casts available for more than 20 years, and forecast verification analysis published	–	–	–	–	–	–	Depth interview

(continued)

Table 18.1 (continued)

No.	Scientific criteria	Variable	Temporal/lead time weathers	Coverage	Location	Skill of Forecast		Source
						Event	Magnitude	
7	Historical forecast data for ENSO	**See surface temperature (SST) and El Nino Index 3.4**	10 days and monthly			–	–	Depth interview
8	Climate change models	Change of seasonal **rainfall**, seasonal heavy rain, days without rain, seasonal consecutive **dry days** index, seasonal consecutive **wet days** index, and the mean value of **temperature** (average, maximum and minimum)	**Future**: 2032–2040	National (medium resolution/island): high resolution (province)	High resolution: (Java Island/province) and Sulawesi Island/province)	–	–	Depth interview and website

3. BMKG releases the probabilistic 3-month seasonal rainfall and temperature forecasts that can be applied to predict the **drought event**.

Landslides, Strong Wind (typhoons), and Cyclone

1. There are 1890 landslide events with 86 events/year; 1688 strong wind events with 84 events/year; and 33 cyclone events with 7 events/year for the period of 1972–2018.
2. Landslide forecast, which require soil and topographic information not only weather information, is still limited as of now.
3. Landslide, strong wind, and cyclone are the other disasters in Indonesia which have the big impacts for people and infrastructure. The highest frequent area for **landslide** disaster is in **Central Java**, with the biggest impacted area is in **West Java** province (4353 people die and evacuate). In addition, the highest strong wind frequent is in **Central Java**, however the most impacted area is in **East Nusa Tenggara** (10,085 people die and evacuate). For cyclone, the most frequent area is in **Maluku Island**, and the most impacted area is in **Coastal Java Island** (41 people die and loss).
4. **Cyclone** is one of the most disastrous hazards with low probability, but high impact. However, historical cyclone event In Indonesia has not been recorded yet.

Exploring more the findings, we evaluated the capacities of meteorological capacities to support the implementation of FbA in Indonesia using the guided scientific criteria (Table 18.1). The evaluation reveals that many advances have been made in the country, as many services are already available with regards to the scientific criteria for measuring the capacities of meteorological services. The government through BMKG already provided rainfall forecasts and prediction for different future periods covering the countrywide regions with the skills of forecasting the occurrences of about 75–77%. Unfortunately, no evaluation to the forecasting skills has been made for forecasting the amount of rainfall and the magnitude of temperature.

Furthermore, the performance evaluation was made to determine the potential use of the meteorological and/or climate services in Indonesia (Table 18.1) for predicting the occurrences and/or magnitude of a specific climate related hazard. We carefully mapped the existing services that can be used for a specific hazard (i.e., flood, drought, landslide, and cyclone/strong wind) as the **advances**, and the required further developments or needs as the **challenges** for supporting the implementation of the FbA in Indonesia (Table 18.2).

The capacity of meteorological services in Indonesia was also evaluated with regards to lead time, available forecasting services and publicly accessed of hazard models or tools. We firstly conducted literature review on lead time of forecasts for relevant climate variables with respect to specific climate related hazards (i.e., flood, drought, landslide, and cyclone/strong wind) in other countries. We used them as a reference for exploring available services in Indonesia, and found that majority services are readily available in Indonesia (Table 18.3). Additionally, hazard assessment tools are also available for estimating the potential occurence or prone areas to a

Table 18.2 Performance evaluation of each hazard

No.	Hazards	Advances	Challenges
1	Flood, Drought, Landslide	The reliability data of 1–3 days rainfall forecast is more than 75% (**for flood**)	To access the data from BMKG need the MoU or no free access data
		The reliability data of 3-month seasonal rainfall forecast is more than 75% (**for drought**)	Information in the form of images, not interactive, users cannot get raw data, predictions of rainfall events not rainfall intensity. Validated based on range of rainfall magnitude
		1–3 days forecast (wind and air pressure); 10-days/weekly forecast (wind and air pressure) have reliability data more than 75% (**for landslide**)	DIBI data is more recording periods since the 1990s, there is no information on the magnitude level of disasters
		The prediction services is increased time by time	There is no data specific watershed from BMKG
		BNPB utilizes the weather/climate prediction data from BMKG as an input that overlay with **flood disaster map**	There are many hazard assessment tools, but need integration with BMKG data to develop the disaster forecast (event and magnitude). Until now, just InaRisk tools is integrated with BMKG data
		The Flood Potential Forecast data (map) in BMKG website covering to district level (flood)	FEWEAS model for **flood and drought** event is still low accuracy, poor validation methods, still not employed by government
		Data stored since 1972 until now, covers all districts and cities in Indonesia, noting the impacts and losses caused by each disaster. All types of disasters that occur in Indonesia are stored in DIBI	Most the hazard assessment tools in Indonesia not provide the forecast disaster event/magnitude, therefore need to develop the tool to increase the tools reliability
		Update and monitoring real time, High temporal and spatial resolution (BBWS Citarum Monitoring System) **(Flood and Drought)**	Until now, BMKG release the forecast base on weather/climate threshold, therefore society difficult to understand the BMKG information/data, so need to develop the forecast based on hazard impact (BMKG in preparing this services)
		InaRisk, InaSafe, InaWare, and InaRIsk Personal involving the socio-economic data	There is big bias for reliability data (accuracy data) in drought season (up to 100%), because no rain, and the different assessment with flood assessment accuracy

(continued)

Table 18.2 (continued)

No.	Hazards	Advances	Challenges
		BMKG application is Easy to used, Predictions for the next two days, Early warnings can be obtained by activating hazard notifications	For ENSO event, BMKG provides the information about ENSO, but not updated properly (**flood and drought**)
		BMKG web have a lot of information has been provided and processed, including the use of high resolution ECMWF data	Until now, BMKG only uses one model for future climate change (MIROC 5), but in practice must use other model to know the best climate projection model (to prevent the extreme event (ENSO), related with **flood and drought**
2	Cyclone	BMKG has TCWC Jakarta to monitoring the cyclone in Indonesia. This monitoring is continuously performed everyday for 24 h by using various kind of technology, from satellite, radar, and manned or unmanned observation stations. It purposes to monitor the development of cyclone, its movement and intensity	A little hazard assessment tools for cyclone event (just BMKG and accuweather)
		Tropical Cyclone Warning Centre is also responsible to provide tropical cyclone related warning and information and disseminate them to the threatened area	TCWC Jakarta just provides information about cyclone event probability, not inform the magnitude of cyclone

specific hazard as listed in the column of Hazard Model/Tools. Despite the advances, the linkage of the weather or climate forecasts with the hazard model/tools for predicting the occurrences and/or magnitude of a specific hazard covering the entire country has not been employed well. The existing tools are more towards explaining or monitoring historical hazard events in the country, such as INARISK a web-based tools of hazard information published by BNPB. The other tools listed in Table 18.3 are also initiated to monitor or inform the hazard events.

Understanding the existing meteorological services in Indonesia as presented in Tables 18.1, 18.2 and 18.3, we determine the feasibility of the services to support the implementation of FbA against the guided scientific criteria. The capacity assessment justifies that the feasibility of weather and/or climate services are high with regards to meteorological services for shorter time periods; whereas, the long-term records required for supporting the FbA implementation in Indonesia are still posed challenges (Table 18.4). Further details of the advances and challenges in Capacity of Meteorological/Climate Services are provided below.

Table 18.3 Evaluation on available weather or climate data and hazard models or tools for forecast assessments in Indonesia

Hazards	Literature			Indonesia	Availability of data services			Conclusion	
	Lead time	Location	Source		Climate/weather data	Hazard model/tools	Disaster classification	Event	Impact/magnitude
Flood	7–18 h	India	Government of India (2012)	6–8 h (base on water table): *Source*: *Interview with BBWS*	1–3 day rainfall forecast (BMKG data)	InaRISK	None	1. There are the climate/weather data to predict the disaster potency (such as flood, land slide, drought, and cyclone), but need more validation to increase the data reliability 2. Need the tools to classified the disaster (low, moderate, or high) to impact assessment 3. Need more evaluation to assess the reliability of disaster data	1. There are the impact data of disaster (dead people, house destruction, and others) in DIBI database, but need to increase the data inventory record and more evaluation 2. The hazard tools in Indonesia, mostly no data about the disaster magnitude, so we need the tools to predict the disaster magnitude to classified the disasters
	7–8 h	Nepal	Dugar et al. (2017)			InaSAFE	None		
	3–12 h	Germany	Philipp et al. (2016)			InaWARE	None		
	4–15 h	Spain, Austria	Schroter et al. (2008)			InaRISK Personal	None		
	3 h	Mahanadi River	ISRO (2012)			DIBI	None		
	5–12 h	Italy	Bocchiola and Rosso (2006)			BMKG Apps	None		
						BMKG Web	None		
	1–8 h		Golding (2009)			SADEWA	None		
	2 and 48 h	USA	WMO (2011)			BBWS Citarum Monitoring System	None		

(continued)

Table 18.3 (continued)

Hazards	Literature			Indonesia	Availability of data services			Conclusion	
	Lead time	Location	Source		Climate/weather data	Hazard model/tools	Disaster classification	Event	Impact/magnitude
	6–12 h	France	WMO (2011)			EWS by BBWS Bengawan Solo	None		
	3–48 h	Austria	Komma et al. (2008)			VAMPIRE	None		
						Windy.com	None		
						FEWEAS	None		
						Accuweather	None		
Drought	3, 6, 12 Month	Texas	Mehr et al. (2014)	6 month (based on onset by BMKG): *Source*: *Interview with BPBD Central Java*	3-month seasonal rainfall forecast (BMKG data)	InaRISK	None		
	6 Month	Iran	Morid et al. (2007)			InaSAFE	None		
	1–2 Month	India	Mishra and Desai (2005)			InaWARE	None		
	12 Month	Australia	Baros and Bowden (2008)			InaRISK Personal	None		
	3–6 Month	San Juan and Colorado Basin	Kalra and Ahmad (2012)			DIBI	None		

(continued)

Table 18.3 (continued)

Hazards	Literature			Indonesia	Availability of data services			Conclusion	
	Lead time	Location	Source		Climate/weather data	Hazard model/tools	Disaster classification	Event	Impact/magnitude
	2 Month	Buyuk Menderes River Turkey	Durdu (2010)			BMKG Apps	None		
	Up to 5 Month	Four basins in Africa	Dutra et al. (2013)			BMKG Web	None		
	2 Month	Turkey	Ozger (2011)			SADEWA	None		
	3, 4, 5 Month	Limpopo River Basin (Southern Africa)	Trambauer et al. (2015)			BBWS Citarum monitoring system	None		
	1–3 Month	Ethiopia	Belayneh et al. (2015)			EWS by BBWS Bengawan Solo	None		
	3 Month	North America	Lyon et al. (2012)			VAMPIRE	None		
	3–6 Month	South-Central America	Carrão et al. (2018)			Windy.com	None		
	1–6 Month	Korea	Rhee et al. (2016)			FEWEAS	None		

(continued)

Table 18.3 (continued)

Hazards	Literature			Indonesia	Availability of data services			Conclusion	
	Lead time	Location	Source		Climate/weather data	Hazard model/tools	Disaster classification	Event	Impact/magnitude
	1–3 Month	United States	McEvoy et al. (2016)			Accuweather	None		
	4 Month	Europe Center	Turco et al. (2017)				None		
Land-slide	48 h	Japan	Sassa et al. (2010)	No information/data	1–3 days rainfall forecast (BMKG data)	InaRISK	None		
	24 h	Europe	Calvello (2017)			InaSAFE	None		
	12 h	Italy	Calvello and Piciullo (2015)			InaWARE	None		
	48 h	Italy	Segoni et al. (2015)			InaRISK Personal	None		
						DIBI	None		
						BMKG Apps	None		

(continued)

Table 18.3 (continued)

Hazards	Literature			Indonesia	Availability of data services			Conclusion	
	Lead time	Location	Source		Climate/weather data	Hazard model/tools	Disaster classification	Event	Impact/magnitude
						BMKG Web	None		
Cyclone	10–15 days	Bangladesh	Worldbank (2018)	1–3 days. *Source*: *TCWC Jakarta* (http://meteo.bmkg.go.id/siklon/outlook)	1–3 days forecast (wind and air pressure); 10-days/weekly forecast (wind and air pressure) (BMKG data)	BMKG Apps	None		

Table 18.4 Results of forecast capacity assessment

Scientific criteria	Description	Feasibility
1–3 day probabilistic rainfall and temperature forecast available	Validated data every day by weather observers at each weather station in Indonesia	High
10-day probabilistic rainfall and temperature forecast available by National Meteorological Service	Data is built from station observation data, and high-quality weather prediction data such as ECMWF, NOAA, GSF, GSM, and Toulouse	High
Probabilistic 3-month seasonal rainfall and temperature forecasts available by national institutions	Data is updated every month, and claimed has skill of forecast more than 75%	High
20-day probabilistic hydrologic forecasts available by national institutions	Forecast for disaster only available for floods and only cover Jabodetabek regions. The disaster forecast services will be developed for all regions in Indonesia	Moderate
Historical forecast data or hind casts available for more than 10 years, and forecast verification analysis published	Available but not published yet	Low
Historical forecast data or hind casts available for more than 20 years, and forecast verification analysis published	Available but not published yet	Low
Historical forecast data for ENSO	The ENSO index forecast data is released every month and compared to the ENSO index released by other world meteorological agencies	High
Climate change models	Climate change projections only use one model with low resolution. High resolution is only available for several islands in Indonesia	Low

Advances in Capacity of Meteorological/Climate Services

The review found that the analysis on existing meteorological/climate services accessed via online platform and stakeholders' consultation suggests some advances in delivering and utilizing weather or climate forecasts for impact (hazard) assessment. The advances are:

1. BMKG is the solely authoritative agency on weather/climate services.
2. The reliability/skill of the rainfall forecasts for occurrences of BMKG across the country is more than 75%, i.e., 1-day and 3-day weather forecasts, 10-day probabilistic rainfall and temperature forecasts, 3-month seasonal rainfall and temperature prediction. The BMKG weather forecasts and climate prediction are available nationally.

3. BMKG improves its weather services continuously. BMKG initiates National Digital Forecast nationally in 2015. BMKG has used the high-resolution model (ECMWF) to increase the quality of weather forecast in Indonesia.
4. BMKG releases monthly flood potential (prone areas up to district level) based on historical events in the format of static image in coordination with MoPW and BIG (now is on hold).
5. BNPB already established historical disaster data and impact in a database system named DIBI available starting from 1972 up to now.
6. BMKG releases an android application of BMKG Info for 3-day weather predictions and early warnings by activating hazard notifications.
7. The high resolution model outputs (ECMWF) has been subscribed and installed in BMKG to support spatial-based weather forecasts.
8. BNPB already initiates and releases hazard assessment tools (InaRisk, InaSafe, InaWare) that can be overlaid with socio-economic data from other institutions. These tools provide the data/information of several disaster, i.e. floods, flash floods, extreme weather, extreme waves and abrasion, earthquakes, forest and land fires, drought, volcano, landslides, tsunami, multi hazards.
9. There is an initiative to integrate BMKG forecasts and hazard assessment tools of BNPB (InaRisk).
10. BBWS Citarum (also Bengawan Solo) are now working on a project for monitoring water table and discharge. The tools is developed by government and Korea collaboration, and have high temporal and spatial resolution, and also it have real time updating and monitoring system.
11. BMKG has TCWC Jakarta to monitoring the **cyclone events** in Indonesia. This monitoring is continuously performed everyday for 24 h using various kind of technologies, i.e., satellite, radar, and manned or unmanned observation stations. The purposes are to monitor the development of cyclone, its movement and intensity.

Future Needs or Challenges in Capacity of Meteorological/Climate Services

The meteorological services and hazard assessment required for supporting the implementation of FbA in Indonesia still face many challenges, specifically with regards to the accuration of the weather or climate forecasts, the integration of weather forecasts and hazard assessments covering country-wide, and the limitation of available impact estimation as a based for early action. The challenges are justified below.

1. The model accuracy is diminishing when predicting weather in dry season.
2. The skill of BMKG weather forecast is measured solely based on the predicted events such as rainfall occurence, whereas, the accuracy for the magnitude has not been validated.

3. Accessibility of BMKG data is limited to users, i.e., may be charged to some fees, or requires an MoU. User obtain the special access (can access the require data/information, that not release in BMKG website), after sign an MoU.
4. Lay persons or common users are difficult to understand the BMKG information or data. To increase the people understanding about the weather data, it is needed to develop the forecasts based on hazard impacts and BMKG in preparing this services.
5. BMKG provides ENSO information, but not updated regularly. BMKG provides the sea surface temperature data (10 days and monthly data) and El Nino Index 3.4 (1985–2015).
6. There is a need for integrating BMKG data and forecasts for hazard assessment.
7. There is no data specific for watersheds monitored by BMKG.
8. There is limitation on hazard assessment for cyclone events, only potential occurrences.
9. The relatively high quality monitoring system for hydrological events lead to predicting flood events initiated by government (i.e., BBWS Citarum and BBWS Bengawan Solo) covered only the targeted areas.
10. Utilization of weather forecasts for predicting specific disasters (i.e., flood, drought, landslide, cyclone, and strong wind) is still limited.
11. TCWC Jakarta only provides information about **cyclone** potential occurrence, and does not inform the magnitude of cyclone.

The Institutional Supports for FbA Implementation

The implementation of FbA in Indonesia requires a strong coordination among different institutions. This coordination is required in order to reach the same interpretation on defining actions with refer to the forecasts. The end users may not have adequate capacity to directly use information from BMKG as the producers of weather and/or climate forecasts. Other institutions should work cooperatively with BMKG to translate the forecasts into hazard predictions specifically for estimating the occurrences, impacted areas, and magnitudes of the impacts. An interpretation should be made to the impacts so that recommendation can be issued to the end users to define required actions for mitigating the potential adverse impacts. The relevant institutions that should be part of the FbA installed architecture which we proposed on the basis of our assessment of the authority of the institutions (Table 18.5) are drawn in Fig. 18.5.

Conclusion and Future Prospects

The study highlights the FbA in Indonesia should be focused on floods and drought, as the two most impacted hazards on human lives and assets, occurring relatively in

Table 18.5 Institutional roles and authorities based on law/regulation

Institutions	Authorities	Role
Meteorological, Climatological, and Geophysical Agency—Badan Meteorologi, Klimatologi, dan Geofisika (**BMKG**)	Implementation, guidance and control of observation, and data and information processing in the fields of meteorology, climatology and geophysics Data and information services in the fields of meteorology, climatology and geophysics Submitting information and early warnings to relevant agencies and parties as well as the community regarding disasters due to meteorological, climatological and geophysical factors	Weather Forecast
National Disaster Management Authority—Badan Nasional Penanggulangan Bencana (**BNPB**)	Providing guidance and direction to disaster management efforts that cover disaster prevention, handling emergency response, rehabilitation and reconstruction fairly and equally at National level; Delivering information on disaster management activities to the community at National level;	Determination of hazard impacts
Regional Disaster Management Authority—Badan Nasional Penanggulangan Bencana Daerah (**BPBD**)	Providing guidance and direction to disaster management efforts that cover disaster prevention, handling emergency response, rehabilitation and reconstruction fairly and equally at Provincial/district level; Delivering information on disaster management activities to the community at Provincial/district level	Determination of hazard impacts
Ministry of Public Works and Public Housing of the Republic of Indonesia (**PUPR**)	Formulation of technical policies in the field of clan development and decommissioning Organizing government affairs and public services	Hazard Prediction
River Basin Development Agency—Balai Besar Wilayah Sungai (**BBWS**)	Management of water resources in the river area which includes planning, construction, operation and maintenance in the context of conservation and utilization of water resources and controlling the destructive power of water in rivers, beaches, dams, lakes, situ, ponds, and other water reservoirs, irrigation, swamps, ponds, ground water, and raw water as well as urban main drainage management	Hazard Prediction
Indonesian Red Cross Society—Palang Merah Indonesia (**PMI**)	Assisting the Indonesian government in the field of social humanity, especially Kepalangmerahan tasks which include: Disaster Relief and Disaster Preparedness, First Aid Training for Volunteers, Health and Community Welfare Services, Blood Transfusion Services.	Action

(continued)

Table 18.5 (continued)

Institutions	Authorities	Role
National Institute of Aeronautics and Space—Lembaga Penerbangan dan Antariksa Nasional **(LAPAN)**	Formulating national policies in the field of research and development of space and atmospheric science, aerospace and space technology, and remote sensing and their utilization Implementation of research and development of space and atmospheric science, aerospace and space technology, and remote sensing and its utilization;	Hazard Prediction
Geospatial Information Agency—Badan Informasi Geospasial (**BIG**)	Formulation and control of technical policies in the field of geospatial information Preparation of plans and programs in the field of geospatial information Implementation of basic geospatial information which includes data collection, processing, storing data and information, and the use of basic geospatial information	Hazard Prediction
Ministry of Finance Indonesia—Kementerian Keuangan (**KEMENKEU**)	Formulation, determination and implementation of policies in the fields of budgeting, tax, customs and excise, treasury, state wealth, financial balance, and financing and risk management	Action
Ministry of Health—Kementerian Kesehatan (**KEMENKES**)	Formulation, determination and implementation of policies in the field of public health, prevention and control of diseases, health services, and pharmaceuticals and medical devices	Action
Ministry of Social Affairs—Kementerian Sosial (**KEMENSOS**)	Formulation, determination and implementation of policies in the areas of social rehabilitation, social security, social empowerment, social protection, and the handling of the poor	Action
National Search and Rescue Agency—Badan Nasional Pencarian dan Pertolongan (**BASARNAS**)	Formulation and determination of norms, standards, procedures, criteria, and licensing requirements and procedures and/or recommendations for conducting search and rescue operations	Action

many provinces in the country (particularly the West and Central Java), with refer to the available DIBI datasets from 1972 to 2018. The implementation of FbA for the two hazards is also promising with regards to available and accessible forecasted rainfall occurrences and amount (e.g., one day, 3-day and 10-day prediction, and seasonal forecasts) provided by BMKG nation-wide. The BMKG claimed that the forecast skill on rainfall occurrence is about 75–77% for the rainfall prediction; however, the forecasts for rainfall amount do not have the same skills, and the accuracy will diminish as forecast time goes further in the future.

Unfortunately, the forecasts have not been connected with flood or drought models nationally so that there is not much information on the forecast-lead-time for floods

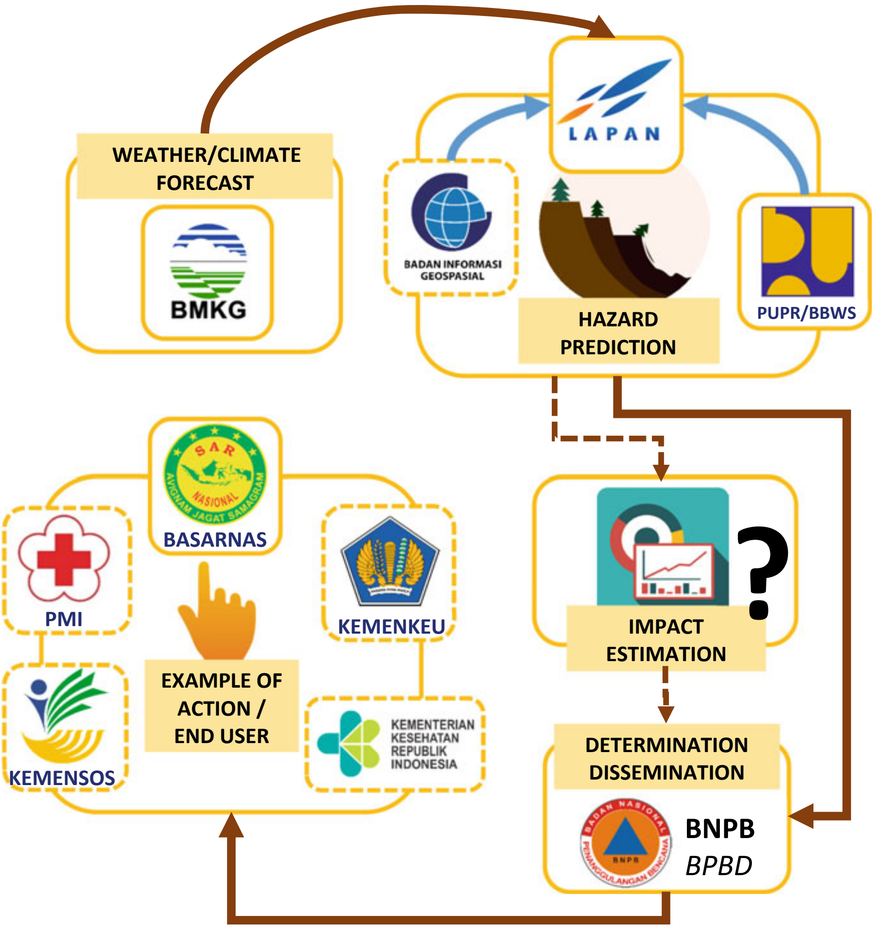

Fig. 18.5 Institutional arrangement of utilizing weather forecasts for FbA in Indonesia

and drought. Nevertheless, understanding the temporal period for rainfall forecasts and prediction, the lead-time for forecasting floods and drought can be about 3 days and 10 days to 3 months, respectively. This study also reveals that one of major challenges is on communicating and utilization of the weather and/or climate forecasts. The accuracy of the forecasts such as rainfall is more on the occurrences, whereas forecasting the rainfall amount completed with estimated probability is still lacking or only available for a specific region. The impact-based forecasts still require much effort to connect existing tools on weather forecasts and historical hazard analysis or monitoring such as those initiated by BNPB (INARISK) and BBWS of MoPW (i.e., BBWS Citarum and BBWS Bengawan Solo).

Understanding the review results, we recommend the following activities that can be approached to support the implementation of FbA in Indonesia. The activities are outlines as follows:

- Improve capacity in interpreting weather and climate data and information through training, workshop, and other programs as the released weather and climate information has not been used optimally by emergency alert actors
- Develop hazard based-models to optimally use the forecasts through collaboration among national institutions with refer to existing modalities, e.g., BMKG, PUPR/BBWS, LAPAN and BNPB
- Equalize the weather and climate forecast capacity across the country which include the forecast probability for occurrence and magnitude
- Establish robust validation system for weather forecasts and climate prediction to measure the accuracy of the forecasts across the country.

Finally, this study already attempted as much as we could to collect available data and information and to interview the key informants; although, we acknowledge further works can enhance the study on the FbA context in Indonesia. This study focussed more on the feasibility of the FbA in Indonesia so that several limitations and constrains should still be considered for more comprehending studies on the FbA actions, particularly with refer to data availability and further analysis and evaluation for the weather and/or climate services, as described below:

1. This study does not conduct homogeneity tests to evaluate the quality of BMKG data
2. The evaluation on forecast lead-time is only based on the interviews and literature review
3. The long-term series of weather data combined with the information on characteristics of disaster occurrences (i.e., location, period, magnitude, damages) are required to better evaluate the lead time based on more through analyses
4. The local capacity of the stakeholders (provincial and/or district level), such as the public understandings on information released through the weather and/or climate services, have not been assessed to allow for the implementation of FbA at the local level as the focus is more at the national level capacities.

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References

BAPPENAS (2014) Rencana aksi nasional adaptasi perubahan iklim (RAN-API). BAPPENAS, Indonesia

Baros AN, Bowden GJ (2008) Toward long-lead operational forecasts of drought: an experimental study in the Murray-Darling River Basin. J Hydrol 357:349–367

Belayneh AM, Khalil B, Adamowski J (2015) Short-term SPI drought forecasting in the Awash River Basin in Ethiopia using wavelet transforms and machine learning methods. Sustain Water Resourse Manag. https://doi.org/10.1007/s40899-015-0040-5

BNPB (2017) Data Informasi Bencana Indonesia (DIBI). Retrieved 1 Aug 2018, from http://dibi.bnpb.go.id/

Bocchiola D, Rosso R (2006) Real time flood forecasting at dams: a case study in Italy. Int J Hydropower Dams 13(1):92–99

Calvello M (2017) Early warning strategies to cope with landslide risk. Rivista Italiana di Geotecnica 51(2):63–91

Calvello M, Piciullo L (2015) Assessing the performance of regional landslide early warning models: the EduMap method. Nat Hazards Earth System Science 16:103–122. https://doi.org/10.5194/nhess-16-103-2016

Carrão H, Naumann G, Dutra E, Lavaysse C, Barbosa P (2018) Seasonal drought forecasting for Latin America using the ECMWF S4 forecast system. Climate 6(48):1–26

Climate Centre (2017) Criteria for identification and design of Forecast-based Financing interventions. IFRC

Coughlan de Perez E, van den Hurk MK, van Aalst B, Jongman T Klose, Suarez P (2015) Forecast-based financing: an approach for catalyzing humanitarian action based on extreme weather and climate forecasts. Nat Hazards Earth Syst Sci 15:10. https://doi.org/10.5194/nhess-15-895-2015

Dugar S, Smith P, Parajuli B, Khanal S, Brown S, Gautam D, Bhandari D, Gurung G, Shakya P, Kharbuja R, Uprety M (2017) Enhancing community based early warning systems in Nepal with flood forecasting using local and global models, EGU General Assembly. Geophysical Research Abstracts, vol 19, EGU2017-8995-1

Durdu OF (2010) Application of linear stochastic models for drought forecasting in the Büyük Menderes river basin, western Turkey. Stoch Environ Res Risk Assess 24:1145–1162

Dutra E, Di Giuseppe F, Wetterhall F, Pappenberger F (2013) Seasonal forecasts of droughts in African basins using the standardized precipitation index. Hydrol Earth Syst Sci 17:2359–2373. https://doi.org/10.5194/hess-17-2359-2013

ECOSOC (2018) Innovation—financing, technology, knowledge and action. ECOSOC Humanitarian Affairs Segment, Palais des Nations, Geneva

FAO (2017) From early warning to early action in Mongolia—bracing for the cold to protect livestock and livelihoods (Press release)

Golding BW (2009) Review long lead time flood warnings: reality or fantasy? Meteorological Appl 16:3–12. https://doi.org/10.1002/met.123

Government of India (2012) Flood early warning system—a warning mechanism for mitigating disaster during flood. Department of administrative reform and public grievances, Ministry of Personnel, Public Grievances & Pensions, p 44

GRC (2018) REPORT Dialogue Platform on FbF Issue No. 02/2018 (Press release)

ISRO (2012) Flood early warning system and damage mitigation. Indian Space Research Organization, India

Kalra A, Ahmad S (2012) Estimating annual precipitation for the Colorado River Basin using ocean ice atmospheric oscillations. Water Resour Res 48. https://doi.org/10.1029/2011wr010667

Komma J, Blöschl G, Reszler C (2008) Soil moisture updating by Ensemble Kalman Filtering in real-time flood forecasting. J Hydrol 357(3–4):228–242

Lyon B, Bell MA, Tippett MK (2012) Baseline probabilities for the seasonal prediction of meteorological drought. J Appl Meteorol Climatol 51(7):1222–1237

Matthew C, Freebairn C (2018) New fund could be a "game-changer" for humanitarian action. Retrieved 1 Aug 2018, from https://media.ifrc.org/ifrc/press-release/new-fund-game-changer-humanitarian-action/

McEvoy DJ, Huntington JL, Mejia JF, Hobbins MT (2016) Improved seasonal drought forecasts using reference evapotranspiration anomalies. Geophys Res Lett 43(1):377–385

Mehr AD, Kahya E, Ozger M (2014) A gene–wavelet model for long lead time drought forecasting. J Hydrol 517:691–699. https://doi.org/10.1016/j.jhydrol.2014.06.012

Mishra AK, Desai V (2005) Drought forecasting using stochastic models. Environ Res Risk Assess 19:326–339. https://doi.org/10.1007/s00477-005-0238-4

Morid S, Smakhtin V, Bagherzadeh K (2007) Drought forecasting using artificial neural network and time series of drought indices. Int J Climatol 27:2103–2111. https://doi.org/10.1002/joc.1498

Ozger M (2011) Long lead time drought forecasting using a wavelet and fuzzy logic combination model: a case study in texas. J Hydrometeorol 13:284–297. https://doi.org/10.1175/JHM-D-10-05007.1

Perdinan, Adi RF, Sutoro T (2017) Perkembangan Studi Kerentanan, Resiko, Dampak dan Adaptasi Perubahan Iklim: Tantangan dan Peluang. Direktorat Jenderal Perubahan Iklim – Kementerian Lingkungan Hidup dan Kehutanan, Jakarta. ISBN: 978-60-2740-119-8

Philipp A, Kerl F, Büttner U, Metzkes C, Singer T, Wagner M, Schütze N (2016) Small-scale (flash) flood early warning in the light of operational requirements: opportunities and limits with regard to user demands, driving data, and hydrologic modeling techniques. IAHS-AISH Proc Rep 373(1):201–208

Rhee J, Im J, Park S (2016) Drought forecasting based on machine learning of remote sensing and long-range forecast data. International Archives of the Photogrammetry. Remote Sens Spat Inf Sci-ISPRS Arch 41(July):157–158

Sassa K, Nagai O, Solidum R, Yamazaki Y, Ohta H (2010) An integrated model simulating the initiation and motion of earthquake and rain induced rapid landslide and its application to the 2006 Leyte landslide. https://doi.org/10.1007/s10346-010-0230-z

Schroter K, Gocht M, Ostrowski M, Nachtnebel HP (2008) EWASE—early warning systems efficiency: evaluation of flood forecast reliability. Paper presented at the Flood Risk Management: Research and Practice, London

Segoni S, Battistini A, Rossi G, Rosi A, Lagomarsino D, Catani F, Moretti S, Casagli N (2015) Technical note: an operational landslide early warning system at regional scale based on space-time-variable rainfall thresholds. Nat Hazards Earth Syst Sci 15(4):853–861

Timmermann A, Oberhuber J, Bacher A, Esch M, Latif M, Roeckner E (1999) Increased El Nino frequency in a climate model forced by future greenhouse warming. Nature 398(6729):694–697

Trambauer P, Werner M, Winsemius HC, Maskey S, Dutra E, Uhlenbrook S (2015) Hydrological drought forecasting and skill assessment for the Limpopo River basin, southern Africa. Hydrol Earth Syst Sci 19(4):1695–1711

Turco M, Ceglar A, Prodhomme C, Soret A, Toreti A, Francisco JD-R (2017) Summer drought predictability over Europe: empirical versus dynamical forecasts. Environ Res Lett 12. https://doi.org/10.1088/1748-9326/aa7859

Wilkinson E, Weingartner L, Choularton R, Bailey M, Todd M, Kniveton D, Venton CC (2018) Forecasting hazards, averting disasters: implementing forecast-based early action at scale. Overseas Development Institute, London

WMO (2011) Manual on flood forecasting and warning, vol 1. WMO, Switzerland

Worldbank (2018) Improving lead time for tropical cyclone forecasting: review of operational practices and implications for Bangladesh. Worldbank, Bangladesh

Chapter 19
Appraising Climate Services in Uganda: Impact on Adaptation and Mitigation of Climate Change

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Abstract Climate change is a serious challenge globally more so in developing countries. This has led to increased need for climate services to facilitate decision making by the indigenous communities at the grassroots. The indigenous communities including the farmers, pastoralists, fisher folks are engaged in various activities which basically rely on climate. The indigenous communities are illiterate, are concealed in poverty and have little access to climate information. Data was collected through Focus Group Discussions and Key Informant Interviews. The paper finds that statutory agencies are offering climate services that are fairly contextualized however they are presented in a scientific language hardly understood by the indigenous communities. As a result, the indigenous communities' awareness on the changing climate is low and they are not making informed adaptation and mitigation decisions. There is need for robust generation and dissemination of climate information that is localized and presented in acceptable language through mediums accessible to the indigenous communities.

Introduction

Climate change is one of the most pressing challenges globally. Climate change affects various regions differently (World Bank 2010). The 2008 report of the African Progress Panel observes that climate change will affect Africa more severely than other regions of the world, and will have devastating impact on food production and the livelihoods of the rural poor. The devastating impacts of climate change are most felt in Africa a continent with least resilience capabilities and where majority of the population depend on natural resources for survival in terms of income, employment and food. Adverse effects of climate change threaten to undo decades of development efforts and negatively impact agriculture, settlement, infrastructure and health in developing countries (IPCC 2007; Padgham 2009; Thornton et al. 2011; Okonya and Kroschel 2013). The 2008 report of the African Progress panel noted that many

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of the poorest particularly in urban areas are already facing the consequences of climate change for example the high food prices situation that will be worsened by the loss of agricultural productivity.

It is projected that most countries especially in sub-Saharan Africa will indeed experience losses rather than gains in agricultural productivity resulting from climate change. Uganda is one of those countries that are likely to experience significant losses in agricultural productivity of 15–25%. Agriculture in Uganda like in most of sub-Saharan Africa is mainly rain fed. Agriculture is essential to Uganda's economy contributing about 25% to the country's Gross Domestic Product (GDP) and offering direct employment to over 70% of Uganda's population (Uganda Bureau of Statistics (UBOS) 2016). Agriculture account for nearly 50% of Uganda's total export earnings (UBOS 2016).

Climate change possess great risk to livelihoods based on agriculture in Uganda. Smallholders farmers grow crops against a background of limited, erratic and poorly distributed rainfall in time and space resulting into frequent crop failures and food insecurity especially in this era when varying and changing climate have made drought more common (Soropa et al. 2015). In Uganda like in other sub Saharan countries drought means household food insecurity as a result of complete crop failure (Food and Agricultural Organization 2009; Okonya and Kroschel 2013). Some of the direct impacts of climate change on agricultural systems are alteration in evapotranspiration, photosynthesis and biomass production; seasonal changes in rainfall and temperature which would impacts agro-chemical conditions, altering the planting, harvesting calendars, pests, disease and weed populations and water availability; and alteration in land suitability for agricultural production (Jiri et al. 2016; Mark et al 2008).

To address these impacts, farmers require climate information to particularly devise coping, adaptation to negative consequences of climate variability and change as well as devise appropriate mitigation strategies (Goddard et al. 2010; Jiri et al. 2016). Gukurume (2014) observes that the way small holder farmers respond to climate variability and change depends on the information attained and use to decipher appropriate adaptation and coping strategies. Adaptation methods are those strategies that enable the individual or community to cope with or adjust to the impacts of climate in the local areas (Nyong et al. 2007). Such strategies range from activities that are predominantly developmental to those that focus on reducing climate change impacts (Jiri et al. 2016). Adaptation strategies may include one or a combination of adaptation of efficient environmental resources management practices as well as adaptation of efficient technological products. On the other hand, mitigation is a continuum of practices that help to prevent or minimize the process of climate change. Mitigation strategies involves changes in societal organization, economic structure or individual behavior and; technological solutions (Swart et al. 2003). Traditionally, mitigation practices reduce the emission of Green House Gases from anthropogenic sources and enhance carbon "sink" (Nyong et al. 2007). In the era of climate change, climate information encompassing research, observation, predictions and projection is significant in devising adaptation and mitigation strategies

(Zillman 2009). Besides, climate information is important in improving agricultural production and improving food security (Moeletsi et al. 2013; Roncoli et al. 2009).

In order for adaptation and mitigation strategies to climate change to be effective, all segments of society need reliable and accurate information to make critical decisions on adaptation and mitigation of climate change. Uganda's National Adaptation Programmes of Action (NAPA) (GoU 2007) mentions indigenous knowledge documentation and awareness creation as well as weather and climate information among the eight (8) prioritized intervention areas for effective climate change adaptation and mitigation. A number of studies (Manyanhaire and Chitura 2015; Jiri et al. 2016; Nyong et al. 2007; Okonya and Kroschel 2013; Soropa et al. 2015; Chengula and Nyambo 2016) have been carried out on climate information services in various parts of Africa have largely focused on Indigenous knowledge and weather forecasting. Nevertheless, there is a dearth of studies that synthesize the climate information services available i.e. scientific forecasting and indigenous knowledge and how they influence climate change adaptation and mitigation.

Climate Change in Uganda

Climate change is a serious challenge in Uganda. *Uganda Vision 2040* observes that one of the challenges to the country's development is the "weak management of environment and climate change" because the government has paid less attention on preserving the environment, which has resulted into global warming and other environmental conditions associated with climate change (GoU 2013).

Uganda ranks 159 out of 178 countries in the ND-GAIN Index[1] (2013) which is worse that 2010 (rank 156) (NCEA 2015). By implication, Uganda is getting more vulnerable to climate change effects although its contribution to climate change causes is negligible. Uganda ranks 15th on vulnerability and 147th on readiness implying that it is very vulnerable to, yet very unready to combat climate change effects. Vulnerability measures the exposure, sensitivity and ability to cope with climate related hazards as well as accounting for the overall status of food, water, environment, health and infrastructure within the country. On the other hand, readiness targets those portions of the economy, governance and society that affect speed and efficiency of adaptation.

Records from 16 climatic zones over two epochs (30-year periods), that is; 1951–1980 and 1981–2010 identified a statistically significant increase in temperature between the two epochs ranging from 0.5 to 1.2 °C across the country (NCEA 2015). Although this increase seems to be a small one, it has dire consequences on climatic patterns. At the same time, the magnitude of observed warming especially since the early 1980s is large and unprecedented within the past 110 years representing a large

[1]ND-GAIN index, summarizes a country's vulnerability to climate change and other global challenges in combination with readiness to improve resilience. http://index.gain.org/country/uganda.

deviation from the climate norm (NCEA 2015). Daily temperature observations show significantly increasing trends in the frequency of hot days and much large increasing trends in the frequency of hot nights (McSweeney et al. 2010). Between 1960 and 2003, the average number of hot days per year increased by 74 and the average number of hot nights increased by 134 during the same period. Similarly, observation of rainfall over Uganda shows statistically significant decreasing trends in annual rainfall at an average rate of 3.4 mm per month (3.5%) per decade (McSweeney et al. 2010).

Global projections downscaled to Uganda for 2015–2045 period indicate that there may be an increase in precipitation during December, January and February which has historically been dry seasons across the country. The increase in rain during the dry seasons is expected to have a significant impact on livestock and agriculture especially perennial crops and post-harvest activities such as drying and storage. The expected increase in percentage of precipitation events is anticipated to escalate the risks of disasters such as floods and landslides. On the other hand, the warming trend is projected to continue with some models projecting an increase of more than 2 °C by 2030. Additionally, projections indicate a potential for an increase in frequency of extreme events namely heavy rainstorms, flooding, drought, etc. (NCEA 2015).

According to *Uganda Vision, 2040*, that there is still poor understanding of climate change and climate variability and hence inadequate adaptation and mitigation measures currently in place (GoU 2013). The National Development Plan NDP II (2015/2016–2019/2020) (GoU 2015) observe that climate change is not only a challenge to the population but also one of the greatest challenges impeding growth and the country's transition from a low income country to a mid-income country.

Scientists have observed that changes in precipitation and atmospheric temperatures have had serious disastrous effects. The 1997 and 2007 long rains resulted into severe flooding in Eastern and Northern Uganda resulting into loss of life, destruction of infrastructure like roads, communication and houses, destruction of food crops resulting into famine, hunger and malnutrition. In fact in 2007, flooding in Uganda resulting from the changing climate led to cholera and dysentery and 525 people died of cholera and 1000 people hospitalized for cholera incidents (Population Secretariat 2009). The temperature rise resulted into an increase in infectious diseases. Malaria cases increased by 43% in Ntungamo, 51% in Kabale and 135% in Mbarara (Population Secretariat 2009).

In semi-arid areas, tick borne diseases have become rampant because of higher temperatures. The tsetse fly belt has expanded, while meningitis and eye infections have increased (GoU 2007). It has been observed that droughts are increasing in Uganda especially western regions and Mbarara district in particular with seven droughts logged by scientists' between 1991 and 2000 and droughts affecting western, Northern and North Eastern are becoming more severe (Hepworth and Goulden 2008). The severe droughts have resulted into frequent dust storms and associated respiratory and eye infections in low lying areas. In addition, the frequent droughts have resulted into lowering of the water table leading to drying of boreholes with the poor and the cattle corridor most affected. At the same time the increased temperatures have affected the agriculture crops like coffee, cassava and soya and they have led to emergency of new pests (GoU 2007). These changes observed and experienced by the farmers has illuminated the farmers need for climate information to guide their adaptive and mitigation strategies.

Overview of the Concept Climate Services

Whatever human activities carried out, being able to predict the weather has been an advantage (Manyanhaire and Chitura 2015). Early warning systems have proven to be indispensable in preparedness for climate events like floods, landslides, onset of rain, tsunami, droughts and related food insecurity; and earthquakes (Tadesse et al. 2008). The ability of farmers to accurately forecast and use climate information is imperative in ensuring the sustainability of livelihoods under a changing climate and increasingly variable weather (Chengula and Nyambo 2016). Climate variability has a considerable influence on the success of agriculture production and other aspects like health in Uganda. Climate elements like rainfall, temperature and humidity which influence availability of moisture to crops through their influence on the rates of evaporation determine agriculture production. The IPCC (2014) conceptualized the possible impacts of climate change with a climate risk framework consisting of vulnerability, hazards and exposure. To effectively deal with the climate risks, it is important to understand and assess the risks and their elements for appropriate management (Ribot 2014; McDowell et al. 2016; Jones and Preston 2011). Jones and Preston (2011) adds that risk management could guide adaptation to climate change. Therefore, there is need for climate services to facilitate climate risk assessment and management (Räsänen et al. 2017).

Climate services are decision relevant, actionable, science-based information that stakeholders can act upon (Räsänen et al. 2017). However, climate services have been criticized for being supply driven, disregarding the demands of information users when generating climate services (Lourenço et al. 2016). In the end some of the convectional climate services are irrelevant, not addressing the needs of the users. Given the complexities of climate change and variability, the availability of scientific evidence to support decision making is not solely enough, but relevance is equally important as it determines the uptake of climate information services. There is a lot of research done in Africa on indigenous knowledge systems and weather forecasting (Okonya and Kroschel 2013; Kagunyu et al. 2016; Manyanhaire and Chitura 2015; Soropa et al. 2015; Jiri et al. 2016) however an investigation of available climate services and a linkage to climate change adaptation and mitigation in Uganda is lacking.

Methodology

The study was carried out in Kalangala and Kayuga districts in (Buganda/Central region) and Hoima district (Bunyoro region) in Uganda. A total of 108 households (36 households per district) were interviewed. Three sub counties were randomly selected per district and in each sub county two parishes were chosen. Six villages were chosen per parish. Six households were randomly selected per village. Respondents were people who had resided in the area for at least the last 20 years and were older than 40 years. Respondents were interviewed from their homes using an interview guide. Focus Group discussions were also held with a group of 8–10 people at one village per parish. The methods used gave the respondents the opportunity to describe the climate services they receive. Focus Group Discussions and qualitative interviewing have a specific relevance to the study because it emphasizes to understand and explain complex phenomena more comprehensively. However, this research being a case study, its findings may not be generalized.

Climate Services Available in Uganda

According to responses from the field investigations climate services available in Uganda are two folded; scientific climate information services and climate information from the indigenous knowledge forecasts. Uganda National Meteorological Authority (UNMA) is the statutory government organ responsible for predicting weather and climate in Uganda. UNMA provides seasonal rainfall forecasting with three forecasts produced per year. The first seasonal forecast covers the months of January, February, March and April (JFMA), the second forecast covers the months of May June, July, August (MJJA) and the third forecast covers the period of September, October, November, December (SOND). UNMA like other convectional climate and weather forecasters use statistical and dynamic methods (Gissila et al. 2004; Jiri et al. 2016; Johnston et al. 2004). The forecasts are disseminated to the public through various media such as newspaper supplements, on the Authorities website and select radio and Television stations. The meteorological information is generated after monitoring and observation by the climate change outlook forum for the Greater Horn of Africa involving international, regional and national climate scientists and downscaled by UNMA. A general forecast for the country is generated and further down spatial seasonal rainfall forecasts that provide a detailed forecast for each region as per Table 19.1.

As per Table 19.1, UNMA down scales weather/climate forecasts to sub regional level. Dissemination of the information in the newspapers targets the national level while dissemination of the information on regionally based radio stations targets the regional and sub-regional forecasts.

UNMA rainfall forecasts details the projected climatic conditions expected in each of the months under forecast for example thunderstorms, showers, start of

Table 19.1 Spatial seasonal rainfall forecast regions of Uganda

Region	Sub region	Districts
Lake Victoria Basin and Central region	Western parts of Central	Nakasongola, Luwero, Kyankwanzi, Nakaseke, Kiboga, Mubende, Kasanda, Ssembabule, Lwengo, lyantonde, Kyotera, Rakai
	Eastern parts of Central	Mukono, Buikwe, Kayunga, Buvuma
	Central and Western Lake Victoria Basin	Kalangala, Kampala, Wakiso, Masaka, Mpigi, Butambala, Kalungu, Bukomansiimbi, Gomba, Mityana
	Eastern Lake Victoria Basin	Jinja, Bugiri, Busia, Mayuge, Namayingo, Tororo
Western region	South Western	Kabale, Kisoro, Rukungiri, Kanungu, Ntungamo, Mbarara, Kiruhura, Isingiro, Ibanda, Bushenyi, Buhweju, Mitooma, Sheema, Rubirizi, Rukiiga, Kasese
	Central Western	Bundibugyo, Ntorooko, Kabarole, Kyenjojo, Kyegegwa, Kamwenge, Masindi, Buliisa, Hoima, Kikuube, Kakumiro, Bunyangabu, Kibaale
Eastern region	South Eastern	Kamuli, Iganga, Bugweri, Luuka, Namutumba, Buyende, Kaliro, Butaleja
	Eastern Central	Pallisa, Butebo, Budaka, Kibuku, Mbale,, Sironko, Manafwa, Bududa, Bulambuli, Kapchorwa, Kween, Bukwo, Bukedea, Kumi, Kaberamaido, Soroti
	North Eastern	Amuria, Kapelebyong, Katakwi, Moroto, Kotido, Nakapiripit, Nabilatuk, Abim, Napak, Amudat, Kaabong
Northern region	North Western	Moyo, Yumbe, Adjumani, Arua, Terego, Zombo, Nebbi, Pakwach, Koboko
	Eastern Northern	Lira, Kitigum, agago, Otuke, Pader, Kole, Dokolo, Kaberamaido
	Central Northern	Gulu, Apac, Kwania, Pader, Lamwo, Nwoya, Amuru, Oyam, Kiryandongo

Source Adapted from UNMA September–December, 2018 seasonal rains, peak of seasonal rains, cessation of seasonal rains and in the end carry descriptive terminologies reflective of the overall rainfall prediction as "Above normal (above average), normal (average), near normal (near average), near normal (near average) to above normal (above average), near normal (near average) with a tendency to above normal (above average) below normal (near average). These descriptions though explained but farmers had difficulties of interpreting them and having the slightest imagination of what to expect.

Scientific predictions carry advisories and early warning per various sectors such as Agriculture and Food Security sector (see Table 19.2), Water Resource Management and Energy sector, Health sector, Disaster Preparedness sector; which facilitates decision making which is critical in adaptation and mitigation of climate change.

Farmers demand for seasonal and medium to long term forecasts to support their farm decisions. They use a combination of indigenous knowledge and meteorological information in their seasonal forecasting. The farmers primarily depend on Indigenous knowledge but are eager to receive scientific forecasts (Jiri et al. 2016; Mapfumo et al. 2015; Orlove et al. 2010; Roudier et al. 2014). The farmers blend IK and scientific information and they adjust their practices. For some farmers it is hard to tell what information they are relying on because of the blending but the combination of IK and scientific information influences farm decisions.

Climate services are important because farmers approach a season with prior experience as well as input from scientific real time forecasts. A key aspect of interest to farmers in making decision is the potential evidence of rainfall pattern which influence crop management activities namely bush clearing, garden preparation, planting time, weeding, application of fertilizers and pesticides. The farmers modify decisions based on continuous advisories from UNMA as well as emerging predictive symbols from environmental observations about the expected weather conditions and soil moisture.

The scientific information is not only useful to farmers in modifying their decisions but also reinforce what they have already decided on in the circumstances that it is in agreement. Farmers in Uganda use a mix of IK and scientific climate information to maximize benefits from the anticipated conditions enhancing their capacity to adapt and mitigate climate change. The advisories provided by UNMA highlight climate extremes and provide recommendations for actions to be taken is crucial in curtailing risks which would affect agricultural productivity and the resultant food insecurity. The informed use of climate information is important in reducing agriculture risks, responsible allocation of agriculture resources which is important in increasing agricultural productivity.

While scientific information is crucial in decision making for farmers, its uptake remains low. Climate information generated through indigenous knowledge is the most predominantly used by farmers in making farm decisions in Uganda. Farmers use a combination of methods to predict weather such as calendar months, atmospheric indicators (wind circulation), plant phenology indicators, cloud cover, appearance of the moon, insect movement, bird migration and other social-cultural indicators.

Table 19.2 Advisory for the Agricultural and Food Security sector for SOND 2018

Sub-sector	Areas expected to receive above normal rainfall	Areas expected to receive normal rainfall
Crop sector-advisories	*Crop sector-advisories*	
	• Early stocking and delivery of inputs for the season • Timely planting at the onset of rainfall (start planting by early August/mid–September) • Plant improved high yielding varieties e.g. Longe series, NABE series • Stagger/relay planting of short cycle crops • Plant long maturing crops at the start of the season • Plant agro-forestry species/crops e.g. fruit trees, Ficusspp, Albizzia, Meosopsis, etc. • Apply good agronomical practices (GAPs) like timely weeding, spacing of crops, thinning, timely harvesting • Soil and water conservation practices e.g. contour bands, grass bands, trenches, water harvesting for drier period and irrigation use in times of drought	• Plant short maturing crops like the leafy vegetables, • Plant drought tolerant/early maturing varieties e.g. Longe 5, 7H, 10-11H. • Plant cover crops to conserve moisture and nutrients like mucuna, lablab • Soil and water conservation practices e.g. permanent planting basins, contour bands, grass bands, trenches, water harvesting for drier period and irrigation use in times of drought, mulch the garden to conserve the soil moisture • Enhanced water harvesting • Plan for irrigation towards the cessation of the season (SOND) 2018
	Negative impacts	
	• Increased incidences of pests/vectors and diseases of crops and livestock Destruction of crops, death of livestock in flooded areas as well as loss of fishing equipment due to heavy waves and ghost fishing • High postharvest losses in crops and fish • Increased soil erosion and siltation of the ponds • Waterlogging/Flooding/Leaching likely to be high • High water accidents especially at night • Food insecurity likely to occur (due to tuber crops rotting)	• Some incidences of pests/vectors and diseases occur for crops and livestock • Slightly lower catches of fish • Low/limited water for honey production

(continued)

Table 19.2 (continued)

Sub-sector	Areas expected to receive above normal rainfall	Areas expected to receive normal rainfall
	Positive impact	
	• High crop yield • Increased water flow into the ponds • Increased natural fish food in the lakes • Increased production of fish in lakes and rivers and milk production • Ambient temperatures for fish breeding • Adequate water • Adequate pasture • Abundance of flowering plants required by bees	• Increased crop yields • Reduced water accidents • Reduced postharvest losses of fish and crops • Adequate water and animal feed • Conducive weather conditions for pasture and forage growth • Conducive environment for fish breeding and their increased production • Increased honey production and other bee products • Increased bees population
Fisheries sector advisories	• Enhance on Monitoring Control Surveillance (MCS) activities on water bodies • Protect wetlands for seasonal migratory fish as their breeding places e.g. African catfish, lung fish • Raise pond banks by adding more soils • Clear water ways around the fish farms to avoid silting • Stock fish in ponds due to availability of water • Prepare drying racks/raised platforms for fish drying • Have safety gadgets like life jackets for Fishermen or water travelers • Conserve wetlands • Observe the capacity of the fishing boats • Plan fishing trips rightly • Leave early during the day and avoid night travels on the lake to reduce the risks of accidents • Repair or rebuild the boats/fishing vessels to ensure sea worthiness	• Monitor the water quality in ponds • Harvest water into reservoirs for future use • Manage/clear water ways leading to the ponds • Protect fish breeding areas • Provide right fish feed rations for rapid growth • Construct drying racks for some fish species e.g. silver fish (mukene)

(continued)

Table 19.2 (continued)

Sub-sector	Areas expected to receive above normal rainfall	Areas expected to receive normal rainfall
	• Carry enough ice to preserve fish • Use of marker buoys to minimize fishing gears thus reduce ghost fishing	
Livestock sector-advisories	• Monitoring and surveillance of vectors and disease epidemics • Vaccinate and treat animals • Control of vectors such as ticks • Move the animals to less flooded areas • Restock the farms with animals • Proper disposal of dead animals to minimize contamination and disease spread • Water harvesting and construction of water dams • Provide animals with safe/clean water-treatment of water on the farm • Provide animals with adequate quality feeds and water (ad libitum/regularly) to increase production • Plant and preserve pastures (hay and silage making) • Properly store animal feeds under dry conditions • Construct quality/stable animal structures with waterproof roofs and non-slippery ground	• Monitoring and carry out continuous disease surveillance and report any epidemics • Vaccinate and treat animals • Control of vectors • Harvest water for animals • Provide animals with adequate quality feeds and water to increase the production • Plant early maturing pastures • Preserve pastures (hay and silage making) • Proper storage of animal feeds under dry conditions to avoid aflatoxins
Apiary sector-advisories	• Plant more flowering crops around the apiaries to anticipate peak honey production in December 2018–February 2019 • Provide shades to beehives against the harsh weather • Set more beehives for increased production • Controlled use of pesticides • Use of more efficient Beehives (Kenyan Top Bar)	• Plant more flowering crops around the apiaries to anticipate peak honey production in December 2018–February 2019 • Provide shades to beehives against the any weather eventuality • Set more beehives for increased production • Plan for water sources near beehives settings • Controlled application of pesticides

Source UNMA weather forecast September–December 2018

The Local names of the calendar months provide the initial climate weather forecasting information. In Central Uganda like in other regions, the calendar months have local names which carry information on weather forecasting and it continues to be used widely (see Table 19.3).

Table 19.3 shows some of the local calendar names and their implication on the weather forecasts. These local names are used to guide the farm activities for example preparing gardens, planting, weeding, harvesting and post-harvest handling. For example, the month of September and November are named after white aunts (a delicacy in Uganda) and linked to the rainfall densities. In this regard, the white aunts in September are known to leave their nests when there is receipt of occasional rainfall and corresponding sunshine, while November is the peak month for the white aunts (*Nsenene*) and heavy rainfall. White aunts leave their nests in large swarms after their nests are soaked by the heavy rains. Farmers make their decisions based on their traditional knowledge arising over time that has been inculcated by the elders.

Other indicators used in forecasting weather majorly focus on expectations of a dry season as well as a wet season (see Table 19.4).

Table 19.4 shows how the local community interpret the atmospheric conditions, plants, insects and birds' migration to determine the onset of rain and the dry season. For the appearance and movement of insects is an indicator of approaching dry season. Other indicators used by the local farmers include the patterns of the stars,

Table 19.3 Local names of calendar months and associated meaning related to climate information in Buganda (Central region)

Month (English name)	Month (Luganda name)	Meaning
January	Gatonya	Bumper harvest/post-harvesting handling
February	Mukutulansanja	Drought, crops shedding
March	Mugalansigo	Preparing gardens, buying seeds, planting
April	Kafuumuulampawu	White aunts, light rains, planting
May	Muzigo	Heavy rains, weeding
June	Ssebo aseka	Harvesting time, post-harvest handling
July	Kasambula	Preparing fields, dry season, clearing gardens, weeding
August	Muwakanya	Lightning and thunderstorm, transition from dry to wet season light/first rains, planting
September	Mutunda	White aunts, dry/wet season, weeding
October	Mukulukusa bitungotungo	Heavy rains/weeding
November	Musenene	Continuous heavy rains, white aunts, planting
December	Ntenvu	Insects, light rains, cessation of rainfall, planting

Table 19.4 Early warning signs of weather and climatic events in Uganda

Indicators for of the dry season	Indicators for the onset of the rainy season
• A clear sky	• Occurrence of whirlwinds
• Strong winds in the morning and evening	• Appearance of migratory birds
• Appearance of rainbow frequently	• Frogs in swampy areas start croaking at night
• Warm winds blowing	• presence of dew on plants in the morning
• Winds blowing from east to west	• Appearance of nimbus clouds in the morning, evening and night
• Strong winds with rain in a storm	• New leaves of trees sprout
• Movement of cumulus clouds from the east to the west	• Termites/white aunts leave their nests
• Winds blowing from north to south	• Occurrence of thunderstorm
• Presence of red clouds at sunset	• Birds like grey crowned crane start to call
• Moons appear bright	• Appearance of millipedes
• Moon appears black in color	• Presence of cool winds
• Appearance of fog in the morning	• A feel of excess heat during day, evening and night
• New moon appears red without a lining	• Movement of clouds from west to east
• Coldness during day and night	
• Trees shed their leaves	
• A lot of cloudiness in the morning and evening	
• Appearance of migratory birds	
• Appearance and movement of insects	

temperature changes/body temperature, flowering of plants which are interpreted to tell approaching drought, normal rains and floods. For example, an increase in night time temperature, changes in the smell of the environment and strong whirl winds is an indicator of approaching rains in a few days.

Challenges of Climate Information Services

The need for climate information in this era of climate change is high and more so relevant climate information. While a lot of effort has been taken to make scientific forecasts relevant through interaction on seasonal forecasts by national, international and regional climate scientists under the auspices of the Climate Outlook Forums, the climate information services are dodged by various challenges discussed below.

Climate forecasts both scientific and those based on IK have been found to be inaccurate and these are a major challenge to farmers. Farmers rely on IK to forecast weather but the indicators/symbols are no longer reliable resulting into inaccurate predictions. Farmers integrate scientific information into the indigenous knowledge but does not improve the decision making as it also sometimes turns out to be inaccurate. In the end, farmers make decisions based on inaccurate forecasts which drudge their adaptive capacity and mitigation potentials. There is evidence to show that IK is no longer accurate and reliable however with no other option, it is taking the farmers a long time to understand the situation and change their ways. A case in point is Kayunga Districts, where farmers rely on calendar months to plan their farming activities. Time immemorial the local names of the calendar months carried meaning attached to different weather information for different seasons and it was useful to farmers. The local calendar months precisely predicted the season for preparing the gardens, planting, weeding, harvesting however they are no longer accurate and the continued reliance on IK is a precursor for food insecurity, wastage of farm resources and disaster.

Even some members of the present generation lack the requisite skills to interpret the various signs with precision. Without documentation of the indigenous knowledge systems, the IK forecasting is under threat of extinction. Nonetheless IK is the basis for local decision making in Uganda. IK can be improved over time depending on the influence of outside information or it can be abandoned in favour of new technology only if it is considered to be better. The continued reliance on traditional calendar months and the integration of inaccurate scientific forecasts has resulted into negative yield impacts and therefore more efforts need to be done to accurately forecast scientifically because the farmers have demonstrated the potential to incorporate scientific forecasts in making farm decision.

Scientific climate forecasts are generated in time and available but hardly accessible to farmers. The generation and availability of climate information is more less to fulfil a statutory obligation than assisting farmers to productively engage in agriculture that is reliant on climate and rainfall in particular. Dissemination of scientific climate information in Uganda remains a major challenge. UNMA basically uses newspapers to offer comprehensive forecasts. However, newspapers circulation in Uganda is low and concentrated in urban areas. Majority of the urban population are not engaged in agriculture and although these weather casts touches other areas, but the forecasts are of less important to them. The UNMA website is also used for dissemination but access to internet and the skills to navigate the website and dig out the information is low. Besides, internet fees are high and the farmers cannot afford to pay for it. Fagbamiye (2015) observes that the cost of internet connectivity in Africa is high specifically citing Uganda where internet services is said to be 150% higher than the same service cost in United States of America. Therefore, there is limited and inequitable access for climate information and this complicates the problems of efficiency of seasonal forecasts (Mapfumo et al. 2015; Roudier et al. 2014). Besides, the aspect of timeliness in delivery of climate information is a major problem. Information is not disseminated in a timely manner and farmers hardly receive it in time to guide their decision making. The extension workers that interact with the farmers at the grassroots lack information on weather and climate which limit their ability to support farmers effectively. The Local government structure has a position of environment officers at district level who would ideally transmit such information but they are detached from the Meteorological authority due to funding challenges. The media is paying little attention to disseminating climate forecasts for example daily weather forecasts are on UNMA website but no longer on Local Television channels and radio. Women compose the majority of the small holder farmers and need the climate information but they live in poverty and access to the various media outlets is limited. Therefore, there is need to improve the dissemination pathways through multiple channels in order to reduce the barriers that tend to limit climate information uptake.

The scientific climate forecasts are presented in a scientific language and many farmers do not comprehend them. Description of expected rains such as “above normal rains”, “near normal rains”, “normal rains”, “near normal to above normal rains” are vague and meaningless to majority of the farmers. The failure by the climate scientists to tone down these terminologies and going an extra mile to use simple and local terms to explain the weather forecast is a missed opportunity to increase uptake of climate information. Government lacks requisite staff at the grass roots to interpret the forecasts and given the low literacy levels of the farmers they cannot interpret the forecasts. This compounds the problem of efficiency of climate information. This partly explains why the uptake of scientific forecasts is low because the end users are not involved in the process of generation of climate information. Scientific language is used to relay the forecasts which many farmers cannot understand. The scientists are not accessible to interpret the information to farmers. Scientists don’t relate their forecasts to the indigenous knowledge which forms the foundation for weather forecasting in the local communities. The failure by the scientists to link their forecasting to IK is a barrier to uptake of scientific information.

Some of the available scientific information has been scaled down to sub-regions posing the potential of giving more accurate forecasts. Although this seems localized, in practice the regions are still big for production of precise information. Scientific forecasting is generating information without the input of the end users and the farmers’ knowledge banks and interests are not considered when developing the forecasts. For ownership of these forecasts a participatory approach is recommended that involves scientists, end-users (farmers, fisher folks, pastoralists, etc.), extension services in generation, analysis and interpretation of climate information. This will help to scale up the accuracy of the climate forecasts and increase the uptake of climate information services by the end-users.

Climate Services and Climate Change Adaptation and Mitigation in Uganda

Climate information services both scientific and from the indigenous knowledge play a central role in enhancing adaptive capacities and mitigation strategies. In Uganda the uptake of scientific forecasts is low. The inaccuracy of scientific forecasts has limited its uptake. To a large extent, farmers rely on IK forecasting which is no longer reliable. The farmers continue to plan the planting seasons basing on the local names of the calendar months yet the climate has changed. The local names of the calendar months remain but their meaning has been distorted by climate change. Penetration of scientific climate information is low. Therefore, farmers basically rely on indigenous knowledge indicators to plan the farm activities from time to time. For example, when farmers project an approaching dry season, they devise water storage strategies in their gardens deploying a variety of agriculture practices such as mulching, digging ditches, storing food in granaries. Other agriculture practices adopted by the farmers include decisions on cropping patterns especially early planting which has been helpful to reduce the farmers' vulnerability to climate change.

The National Agricultural Research Organisation (NARO) has produced high yielding crop varieties of cassava, coffee, banana that have a short growing period and are resistant to pests and drought. The farmers have abandoned the traditional long season varieties and adopted short season varieties in response to the longer drier periods. However, due to poverty and lack of information on the changing climate, some farmers continue to plant traditional crop varieties affecting agricultural production. In addition, farmers are planting crops in swampland where water is available even during the dry season (Okonya and Kroschel 2013).

Conclusion

Climate change is a reality in Uganda and farmers need climate information to make appropriate farm decisions. Farmers basically use IK such as the local calendar months in Central Uganda in weather forecasting however it is no longer reliable because of the changing climate. Scientific climate information is generated by experts without involvement of the end users. Scientists should adapt climate information to end users' knowledge and practice as people are better able to adopt to new ideas that are seen in the context of existing practices. Because the Agriculture Extension workers are close to farmers, they should be trained to interpret the climate information to improve accessibility and uptake of climate information; and ultimately enhance the adaptive capacity of the farmers.

References

Chengula F, Nyambo B (2016) The significance of indigenous weather forecast knowledge and practices under weather variability and climate change: a case study of smallholder farmers on the slopes of Mount Kilimanjaro. Int J Agric Educ Ext 2(2):31–43

Fagbamiye EO (2015) ICT and teacher education in East Africa. In: Adegoke B, Oni A (eds) Teacher education systems in Africa in the digital era. CODESRIA, Dakar, pp 153–162

FAO (Food and Agriculture Organization of the United Nations) (2009) The state of food insecurity in the world, 2009: Economic crises—impacts and lessons learned. Food and Agriculture Organization of the United Nations, Rome

Gissila T, Black E, Grimes DIF, Slingo JM (2004) Seasonal forecasting of the Ethiopian summer rains. Int J Climatol 24:1345–1358

Goddard L, Aitchellouche Y, Baethgen W, Dettinger M, Graham R, Hayman P, Conrad E (2010) Providing seasonal-to-interannual climate information for risk management and decision-making. Procedia Environ Sci 1:81–101. https://doi.org/10.1016/j.proenv.2010.09.007

GoU (2007) Climate change: Uganda National adaptation programmes of action (NAPA). Environmental Alert, GEF, UNEP, Kampala. http://www.adaptationlearning.net/node/522

Government of Uganda (GoU) (2013) Uganda Vision, 2040. National Planning Authority, Kampala. Retrieved 11 Apr 2019 from http://npa.ug/wp-content/themes/npatheme/documents/vision2040.pdf

Government of Uganda (2015) National Development Plan II (2015/16–2019/20). Government of Uganda, Kampala

Gukurume S (2014) Climate change, variability and sustainable agriculture in Zimbabwe's rural communities. Russ J Agric Socio-Econ Sci 2(14):89–100

Hepworth N, Goulden M (2008) Climate change in Uganda: understanding the implications and appraising the response. LTS International, Edinburgh. Retrieved 14 Apr 2019 from http://reliefweb.int/report/uganda/climate-change-ugandaunderstanding-implications-and-appraising-response

IPCC (Intergovernmental Panel on Climate Change) (2007) Climate change 2007: the physical science basis. In: Averyt KB, Tignor M, Miller HL (eds) Contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge. http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg1_report_the_physical_science_basis.htm

IPCC (2014) Climate Change 2014: synthesis report. In: Core Writing Team, Pachauri RK, Meyer LA (eds) Contribution of working groups I, II and III to the fifth assessment report of the intergovernmental panel on climate change. IPCC, Geneva, Switzerland, 151 pp

Jiri O, Mafongoya PL, Mubaya C, Mafongoya O (2016) Seasonal climate prediction and adaptation using indigenous knowledge systems in agriculture systems in Southern Africa: a review. J Agric Sci 8(5):156–172. https://doi.org/10.5539/jas.v8n5p156

Johnston PA, Archer ER, Vogel CH, Bezuidenhout CN, Tennant WJ, Kuschke R (2004) Review of seasonal forecasting in South Africa: producer to end user. Clin Res 28:67–82

Jones RN, Preston BL (2011) Adaptation and risk management. Wiley Interdis Rev 2:296–308. https://doi.org/10.1002/wcc.97

Kagunyu A, Wandibba S, Wanjohi JG (2016) The use of indigenous climate forecasting methods by the pastoralists of Northern Kenya. Pastor: Res Policy Pract 6:7. https://doi.org/10.1186/s13570-016-0054-0

Lourenço TC, Swart R, Goosen H, Street R (2016) The rise of demand-driven climate services. Nat Clim Change 6:13–14. https://doi.org/10.1038/nclimate2836

Manyanhaire IO, Chitura M (2015) Integrating indigenous knowledge systems into climate change interpretation: perspectives relevant to Zimbabwe. Greener J Educ Res 5(2):27–36. https://doi.org/10.15580/GJER.2015.2.012715022

Mapfumo P, Mtambanengwe F, Chikowo R (2015) Building on indigenous knowledge to strengthen the capacity of smallholder farming communities to adapt to climate change and variability in southern Africa. Clim Dev. https://doi.org/10.1080/17565529.2014.998604

Mark WR, Mandy E, Gary Y, Lan B, Saleemul H, Rowena VS (2008) Climate change and agriculture: threats and opportunities. Federal Ministry for Economic Cooperation and Development, Germany

McDowell G, Ford J, Jones J (2016) Community-level climate change vulnerability research: trends, progress, and future directions. Environ Res Lett 11:033001. https://doi.org/10.1088/1748-9326/11/3/033001

McSweeney C, New M, Lizcano G (2010) UNDP climate change country profiles: Uganda. Retrieved 24 Mar 2015 from http://country-profiles.geog.ox.ac.uk/
Moeletsi ME, Mellaart EAR, Mpandeli NS, Hamandawana H (2013) The use of rainfall forecasts as a decision guide for small-scale farming in Limpopo Province, South Africa. J Agric Educ Ext 19(2):133–145. https://doi.org/10.1080/1389224X.2012.734253
Netherland Commission for Environment Assessment (NCEA) (2015) Climate Change Profiles, Dutch Sustainability Unit, 9 July
Nyong A, Adesina F, Elasha O (2007) The value of indigenous knowledge in climate change mitigation and adaptation strategies in African Sahel. Mitig Adapt Strat Glob Change 12:787–797. https://doi.org/10.1007/s11027-007-9099-0
Okonya JS, Kroschel J (2013) Indigenous knowledge of seasonal weather forecasting: a case study in six regions of Uganda. Agric Sci 4(12):641–648. https://doi.org/10.4236/as.2013.412086
Orlove B, Roncoli C, Kabugo M, Majugu A (2010) Indigenous climate knowledge in southern Uganda: the multiple components of a dynamic regional systems. Clim Change 100:243–265. https://doi.org/10.1007/s10584-009-9586-2
Padgham J (2009) Agricultural development under a changing climate: opportunities and challenges for adaptation, joint departmental discussion paper-issue 1, agriculture and rural development & environment departments. The World Bank, Washington, DC
Population Secretariat (2009) The state of Uganda's population report 2009, Kampala
Räsänen A, Jurgilevich A, Haanpää S, Heikkinen M, Groundstroem F, Juhola S (2017) The need for non-climate services—empirical evidence from Finnish municipalities. Clim Risk Manag 16:29–42. https://doi.org/10.1016/j.crm.2017.03.004
Ribot J (2014) Cause and response: vulnerability and climate in the Anthropocene. J Peasant Stud 41:667–705. https://doi.org/10.1080/03066150.2014.894911
Roncoli C, Jost C, Kirshen P, Sanon M, Ingram KT, Woodin M, Hoogenboom G (2009) From accessing to assessing forecasts: an end-to-end study of participatory climate forecast dissemination in Burkina Faso (West Africa). Clim Change 92:433–460. https://doi.org/10.1007/s10584-008-9445-6
Roudier P, Muller B, d'Aquino P, Roncoli C, Soumaré MA, Batté L, Sultan B (2014) The role of climate forecasts in smallholder agriculture: lessons from participatory research in two communities in Senegal. Clim Risk Manag 2:42–55. https://doi.org/10.1016/j.crm.2014.02.001
Soropa G, Gwatibaya S, Musiyiwa K, Rusere F, Mavima GA, Kasasa P (2015) Indegenous knowledge system weather forecasts as a climate change adaptation strategy in smallholder farming systems of Zimbabwe: Case study of Murehwa, Tsholotsho and Chiredzi districts. Afr J Agric Res 10(10):1067–1075. https://doi.org/10.5897/AJAR2013.7205
Swart R, Robinson J, Cohen S (2003) Climate change and sustainable development: expanding the options. Clim Policy 3(S1):S19–S40
Tadesse T, Haile M, Senay G, Wardlow BD, Knutson CL (2008) The need for integration of drought monitoring tools for proactive food security management in sub-Saharan Africa. Nat Resour Forum 32:265–279. https://doi.org/10.1111/j.1477-8947.2008.00211.x
Thornton PK, Jones PG, Ericksen PJ, Challinor AJ (2011) Agriculture and food systems in sub-Saharan Africa in a 4 °C+ world. Philos Trans A 369:117–136. https://doi.org/10.1098/rsta.2010.0246
Uganda Bureau of Statistics (UBOS) (2016) National population and housing census, 2014, Kampala
World Bank (2010) Economics of adaptation to climate change, Washington, DC
Zillman J (2009) Adaptation to a variable and changing climate: challenges and opportunities for NMHSs. Scientific Lecture, World Meteorological Organisation, EC-LXI, Geneva, 11 June 2009

Chapter 20
Communicating Climate Change Impacts as Manifested in Extreme Weather: A Case of Newspapers' Reports in Nigeria

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Abstract This paper examines the public reports on extreme weather events and climate change in Nigeria. The investigation was conducted to show how national media have been reporting extreme weather events in Nigeria. The report on extreme weather events from two major national dailies were assessed. The results showed that extreme weather events reports are not properly described by most national media. The total articles of extreme weather events reported by Vanguard newspaper were 118 and 78 were from the Punch newspaper over the period. The percentages of specific extreme events reported during the study period by the Vanguard are—Flood (75.42%), Rainstorm (21.19%), Windstorm (3.39%), but no report for thunderstorm and drought, while the Punch reported 66.67% of Flood cases, Rainstorm (28.21%), Windstorm (3.84%), thunderstorm (1.28%), but no report for drought. The study concludes that more actions should be taken to sensitize the public about the occurrences of weather events, which is frequent nowadays as evidence of change in the climate.

Introduction

Discussions on climate change are a global issue and its impacts are obvious in all parts of the world. Study of extreme weather event is very useful for predicting the occurrence of such events and this information will be of help in saving lives and properties (IPCC 2014). Typical examples of such extreme events in Africa

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include drought and flooding which are affecting various sectors of the economy. The impacts of climate change and its associated extreme weather events are obvious in the world. Both developed and developing countries are affected. Climate change constitutes a major threat to socio-economic development, especially in African countries, though it is a global phenomenon and has no regard for national boundaries. The major evidences of climate variability/change in the African continent are increasing occurrences and intensity of the extreme weather events, such as flooding, drought, storms, desertification, increasing rainfall variability, among others (Haines et al. 2006; Brooks and Adger 2003; Mupedziswa and Kubanga 2017; Zhang et al. 2014). Although, studies have shown that the distribution of the precipitation over time and space is very complex and irregular in Nigeria (Olaniran 2002; Odekunle 2001; Odekunle et al. 2005; Ayanlade et al. 2010; Ologunorisa and Tersoo 2006). These extreme events are especially pronounced with respect to the occurrence of the exceptionally heavy storm and flood events which have an impact in both cities and rural areas. In other part of the world, studies have also reported extreme weather events. For instance, a study by Donat et al. (2014) has earlier stated the changes in extreme weather as a threat both to human and environment. Other studies have revealed that extreme weather events have the ability to disrupt ecosystems and the means of human livelihood (Berkes and Jolly 2002; Glantz 2001; Garden 2017). Besides, the consequences of these are the death of livestock, displacements of people, and economic hardship in many locations.

There are different opinions about climate variability, climate extreme events, with differs opinion issues of climate change in Africa. Some scholars have noted these phenomena as normal, recurrent feature of climate that occur in virtually all climate zones, from very wet to very dry. Regardless of the different views, the ability to predict the possibility of occurrence of such extreme eventualities as flood, drought, desertification, landslides and thunderstorms can help individuals and government authorities to plan (Gyireh 2011). This is because the impacts of the extreme events are noticeable at all levels. For example, drought disasters account for less than 20% of all disaster occurrences in Africa, but they account for more than 80% of all people affected by natural disasters (Guha-Sapir et al. 2011; Brooks and Adger 2003). Disasters brought by prolonged drought and flood in Africa are now affecting millions of people the majority of whom are in rural areas. This has contributed to a high rate of malnutrition, famine and loss of life and livestock (Rockström 2003; Steady 2014; Adeniyi 2016). Though drought is a momentary aberration from normal climatic conditions in Africa, it varies significantly from one region to another. Drought is one of the natural events that affect people's livelihood and socio-economic development (Ayanlade et al. 2018). Drought and flooding are two opposite hydrologic events, and this was made through review of rainfall data collected in the past years. And this extreme event must be guarded against because of the immeasurable havoc these events have on mankind (Loaiciga et al. 1993; Gasse 2000; Pielke et al. 2002; Alexander 2016). Also, studies have shown that desertification has deprived farmers in a number of ways which are deposition of sand dunes, insufficient water for agriculture lands and these result to low income on the part of the farmers. The impacts of desertification can be measured by the reduction in the productivity of plants and the undesirable alteration in the biomass and the diversity of fauna and flora, increased soil deterioration. One of the most major problems facing northern Nigeria is desertification and it has an awful consequence on their economic. Efforts have been made both at national and international levels to curb the impacts of desertification but still, desertification persists (Thelma 2015). All these are as results of extreme rainfall events, as the excess rainfall results to flooding, the decrease in rainfall results to drought while prolong drought could lead to desertification. Hence, there is a need for further studies on the rate at which Nigerian dailies reported such events and the lesson that could be learned for better actions. Thus, this paper aims at examining the report by daily newspapers on extreme weather events and climate change in Nigeria. The investigation was conducted to show how national media have been reporting extreme weather events in Nigeria. We examined the pattern of rainfall and temperature patterns in three major locations since heavy precipitation contributes to increased flooding, a pattern that has already been observed around the world. Floods generally develop over a period of days, when there is too much rainwater to fit in the rivers and water spreads over the land. Thus, runoff, or the surface water left over when the land cannot soak up any more, has also increased in many parts of the world, consistent with changes in precipitation (Parry et al. 2007; Gutowski et al. 2008).

Methods

This study used both meteorology and reported extreme/emergency data. Dataset was collected from the National Emergency Management Agency (NEMA) while climate data was collected from Nigeria Meteorological Station (NIMET) from 2008–2015. Also, the highly demanded newspaper was used to examine the extent to which the extreme weather events were reported. The first step of data collection was the acquisition of the secondary data, which was done by extracting the extreme weather events from the National Emergency Management Agency (NEMA) for the year 2001. This data showed the values for maximum temperature, minimum temperature and rainfall for three major locations; Sokoto, Port Harcourt and Ibadan. These locations were selected because they have the highest frequency of reported of extreme events, noted from the two top newspapers used (Vanguard and Punch). Also, 10 most widely read newspaper (both in paper and online) were selected, as not to be biased in the data collection for this research. Purposive sampling technique was adopted in this study to select the 10 most widely popular newspaper: Leadership Newspaper, National Mirror Newspaper, The Guardian Newspaper, Nigerian Tribune Newspaper, This Day Live Newspaper, Sun News Online, Sahara Reporters, The Nation Online Newspaper, The Punch Newspaper and lastly Vanguard Newspaper. The ranking method was used to select the first two top popular newspapers. The ranking methods and selection were based on their wide circulation and popularity. The first largest which is Vanguard newspaper, this newspaper in terms of circulation published about 120,000 copies daily and The Punch is the second largest newspaper in Nigeria in terms of circulation which published more than 80,000 copies of newspaper daily and also available online. Based on the wide circulation of these two newspapers and their popularity online, these two were chosen for this research work. The succeeding step was visiting the Hezekiah Oluwasanmi Library OAU to check for the foremost two newspapers (Vanguard and Punch newspapers) that have the highest popularity. The same newspapers were checked electronically by visiting the website of the newspapers.

The extreme weather events examined in this study include flooding, drought, rainstorm, windstorm, and thunderstorm. Every article in these two newspapers that addressed the issue of flooding, drought, rainstorm, windstorm, and thunderstorm were noted to make up the population of this research work. And the time frame was chosen which is between 2008 and 2015. The time period was chosen because these were the years that were made available in these two newspapers' archive. The rainfall and reported extreme events data collected for the years were compared with the actual data collected by NEMA. Descriptive and inference statistics were used. The comparative analysis was performed using the data obtained from the reports in the two top-rated newspapers and this was compared with the data collected from NEMA.

Results and Discussion

Examination of the Extent of Extreme Weather Events Reported

Figure 20.1a depicts the reported extreme events of floods; rainstorms, windstorms, thunderstorms and droughts in Nigeria by Punch newspaper while Fig. 20.1b depicts the reported extreme events of flood, rainstorm, windstorm, thunderstorm and drought in Nigeria by Vanguard newspaper over the period of study. In the year 2008, no incidence of windstorm, thunderstorm and drought were reported. 3 occurrences of the flood, while only 1 occurrence of a rainstorm was reported in Punch (Fig. 20.1a). Comparing this result with Vanguard in the year 2008 (Fig. 20.1b), no incidence of windstorm, thunderstorm and drought were reported; 6 occurrences of the floods were reported, and 5 occurrences of rainstorms. In the year 2009, there were 4 major occurrences of the flood reported in Punch; 1 incidence of rainstorm was also reported, and there were no reported records of windstorm, thunderstorm and drought. For Vanguard, the year 2009, there were 5 occurrences of the flood that were reported, while 4 incidences of rainstorm were also reported, only 1 record of windstorm and no occurrence of thunderstorm and drought (Fig. 20.1). Punch newspaper in the year 2010, however, reported 8 occurrences of floods and just 1 rainstorm were reported and no records of windstorm, thunderstorm and drought were reported. Likewise, 8 records of the flood were reported, that of rainstorm and

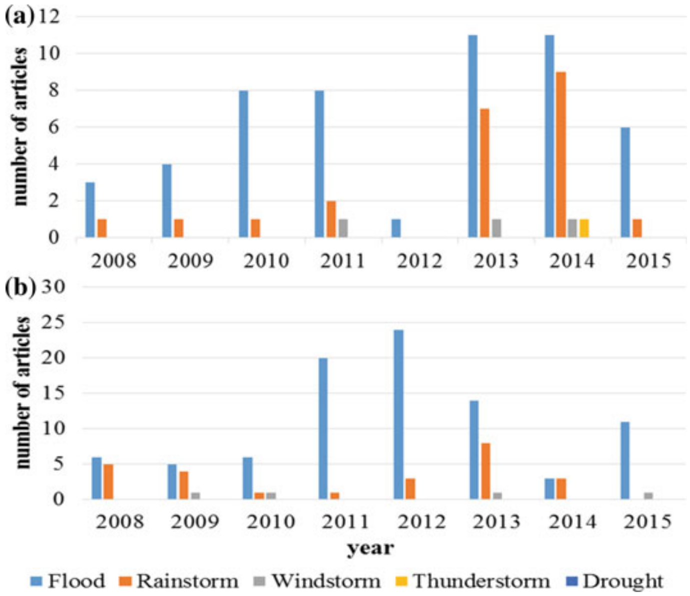

Fig. 20.1 The annual reports of floods, rainstorms, windstorms, thunderstorms and droughts in the punch (**a**) and Vanguard (**b**) newspapers between 2008 and 2015

windstorm were 2 and 1 reported occurrences respectively, but just 1 extreme event of the flood was reported in the year 2012 (Fig. 20.1a). However, Vanguard records in the year 2010 show 6 occurrences of reported floods and just 1 rainstorm was reported and 1 record of windstorm, and no report on thunderstorm and drought (Fig. 20.1b). In the 2011 Vanguard reports; 20 records of the flood were reported in the following location, while that of a rainstorm was 1 and no report on windstorm, thunderstorm, and drought. In the year 2012, Vanguard further reported 24 extreme events of the flood, 3 events of a rainstorm and no records of windstorm, thunderstorm, and drought (Fig. 20.1).

Much more climatic extreme events were reported for the year 2013, 2014 and 2015 generally for the top two newspapers. For example, in the year 2013 Punch reported 11 floods incidence; Rainstorm (7); Windstorm (1); while the reported event of thunderstorm and drought (Fig. 20.1). The year 2014 reports; floods (11), rainstorm (9), windstorm (1), thunderstorm (1) and drought (0), Year 2015 reports; floods (6), rainstorm (1), windstorm (0), thunderstorm (0) and drought (0). The year 2013 Vanguard records revealed; floods (14), rainstorm (8) Windstorm (1). Thunderstorm (0), and drought (0); and for the year 2014 reports; floods (3), rainstorm (3), windstorm (0), thunderstorm (0) and drought (0), Year 2015 reports; floods (11), rainstorm (0), windstorm (1), thunderstorm (1) and drought (0), as presented in Fig. 20.1.

The above results showed that the year with very little disturbance as reported by punch newspaper is the year 2012 because only one occurrence of the extreme event was recorded. And the year with the highest disturbance 2014 with 22 total events reported and this is followed by the year 2013 with 19 records of occurrences. It is obvious from the results derived for these years; that is 2008–2015, that emphases were not placed on thunderstorm and even drought issues were not addressed, indicating that these events were taken with flippancy and this may account for the low level of recognition of these extreme events by the public. It can be inferred from these results that year 2011, 2013 and 2015 experience much of floods and rainstorm, as reported by the top two newspaper. However, little or no reported cases of windstorm, thunderstorm and drought were informed in the newspapers (Fig. 20.1). In vanguard report also throughout the whole years of temporal variation that is 2008–2015, there was no incidence of drought reported meaning that no relevance was placed on this event and this will directly affect people perception about this weather phenomenon and the level of their level of awareness and recognition of these extreme events by the public. In all, Punch Newspaper reported much of the extreme weather event much more than vanguard (Fig. 20.1).

Monthly and Seasonal Extreme Weather Events Reported

The monthly reported cases of weather events generally follow the rainfall patterns in the study area. The monthly reports on the flood and storms from 2008 to 2015 in punch newspaper are shown in Fig. 20.2b and Tables 20.1 and 20.2. The results show that the month of January 2008 to 2015 was 0, meaning there was no flood occurrence in the month of January. Series 1–8 in Fig. 20.2 indicated the yearly series. The report for February 2008–2015 was 1 and this 1 occurrence was reported in 2013 while there was no record in February the other years. For March 2008–2015 was 1 and this was reported in 2013. For April 2008–2015, the number of the occurrence was 3 and this was reported 2013 (1) and 2014 (2). In the month of May 2008–2015 (Fig. 20.2b), the reports recorded were 4 and there were 2012 (1), 2013 (1) and 2014 (2). For the month of June 2008–2015, the number of the reports was 5 and these were reported 2009 (1), 2011 (1), and 2013 (3). July 2008–2015, the reports recorded were 4 and these were 8 and these were reported 2009 (2), 2010 (2), 2011 (1), 2013 (1), 2014 (1) and 2015 (1). For August 2008–2015 the reports recorded were 6 and these happened in 2008 (1), 2011 (2), 2014 (1) and 2015 (2). For September 2008–2015, the reports recorded were 15 (Fig. 20.2) these happened in 2008 (2), 2010 (4), 2011 (3), 2014 (2), 2015 (4). For October 2008–2015, the reports recorded 6 these happened in 2009 (1), 2010 (1), 2011 (1), and 2015 (3) (Fig. 20.2b). For November 2008–2015, the report recorded was 1 and this happened in 2013 and lastly December 2008–2015, the report recorded were 2 and these happened 2010 (1), and 2013 (1). Based on the analyses of the monthly report on the flood it showed that flood reports have the highest articles which were 52 in total compared to storms' report which were 26 articles in total (Table 20.1). When looking at the results of the floods' report, it was found out that a large proportion of the articles published by the Punch newspaper reported flooded (Fig. 20.2c), which indicates strong interest in the incidence of flood events.

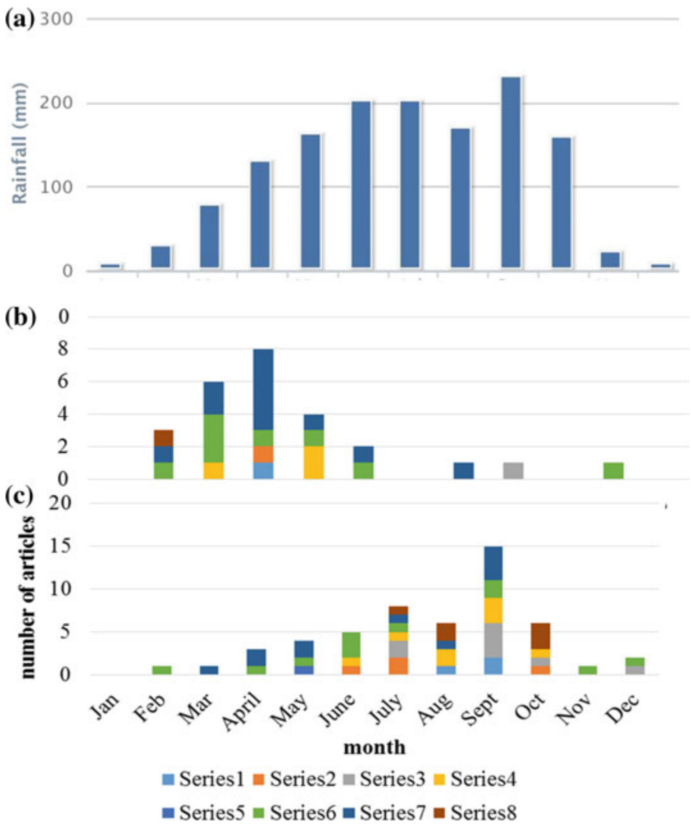

Fig. 20.2 Rainfall patterns in the study area and monthly reports on Flood between the years 2008–2015. **a** represent Monthly rainfall (Climatology data), **b** and **c** are reported cases of floods in Punch and vanguard newspaper respectively

This indicates that the public are less aware of storm events happening in their surroundings. Table 20.2 and Fig. 20.2b depict the monthly reports on the storm in punch newspaper from 2008 to 2015. The records in the month of January 2008–2015 were 0 meaning there was no storm occurrence in the month of January. The report for February 2008–2015 was 3 and these 3 occurrences were reported in 2013 (1), 2014 (1) and 2015 (1). For March 2008–2015 was 6 and this was reported in 2011 (1), 2013 (3) and 2014 (2). For April 2008–2015, the number of the occurrence was 8 and these were reported 2008 (1) and 2009 (1), 2013 (1), and 2014 (5). In the month of May 2008–2015, the reports recorded were 4 and these were 2011 (2), 2013 (1) and 2014 (1). For the month of June 2008–2015, the number of the reports was 2 and these were reported 2013 (1) and 2014 (1). July 2008–2015 there was no record of storm reported. For August 2008–2015, the report recorded is 1 and this happened in 2014. For September 2008–2015 the report recorded was 1 this happened in 2010. For October 2008–2015, no occurrence of the storm was reported.

Table 20.1 Monthly reports on flood

Year	Event	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
2008	Flood	0	0	0	0	0	0	0	1	2	0	0	0	3
2009	Flood	0	0	0	0	0	1	2	0	0	1	0	0	4
2010	Flood	0	0	0	0	0	0	2	0	4	1	0	1	8
2011	Flood	0	0	0	0	0	1	1	2	3	1	0	0	8
2012	Flood	0	0	0	0	1	0	0	0	0	0	0	0	1
2013	Flood	0	1	0	1	1	3	1	0	2	0	1	1	11
2014	Flood	0	0	1	2	2	0	1	1	4	0	0	0	11
2015	Flood	0	0	0	0	0	0	1	2	0	3	0	0	6
Total		0	1	1	3	4	5	8	6	15	6	1	2	52

Table 20.2 Monthly reports on storms

Year	Event	Jan	Feb	Mar	Apr.	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
2008	Storms	0	0	0	1	0	0	0	0	0	0	0	0	1
2009	Storms	0	0	0	1	0	0	0	0	0	0	0	0	1
2010	Storms	0	0	0	0	0	0	0	0	1	0	0	0	1
2011	Storms	0	0	1	0	2	0	0	0	0	0	0	0	3
2012	Storms	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	Storms	0	1	3	1	1	1	0	0	0	0	1	0	8
2014	Storms	0	1	2	5	1	1	0	1	0	0	0	0	11
2015	Storms	0	1	0	0	0	0	0	0	0	0	0	0	1
Total		0	3	6	8	4	2	0	1	1	0	1	0	26

For November 2008–2015, the report recorded was 1 and this happened in 2013 and lastly, December 2008–2015, no incidence of the storm was reported (Fig. 20.2c).

Figure 20.3c and Table 20.3 depict the monthly reports on the flood in vanguard newspaper from 2008 to 2015. The records in the month of January 2008–2015 was 0 meaning there was no flood occurrence in the month of January. The report for February 2008–2015 was 0 and this means no occurrence was reported. For March 2008–2015, there was also 0 report that is no reported of any of the extreme weather events was reported. For April 2008–2015, the number of the occurrence was 2 and this was reported 2012 (1) and 2013 (1). In the month of May 2008–2015, the reports recorded were 5 and these were reported in 2011 (2), 2013 (3). For the month of June 2008–2015, the number of the reports were 7 and these were reported 2008 (2), 2011 (2), 2012 (1), 2013 (1) and 2014 (1). July 2008–2015, the reports recorded were 19 and these were reported 2008 (1), 2010 (3), 2011 (7), 2012 (4), 2013 (1) and 2015 (3). For August 2008–2015 the reports recorded were 16 and these happened in 2010 (2), 2011 (4), 2012 (5), 2013 (4) and 2014 (1). For September 2008–2015, the reports

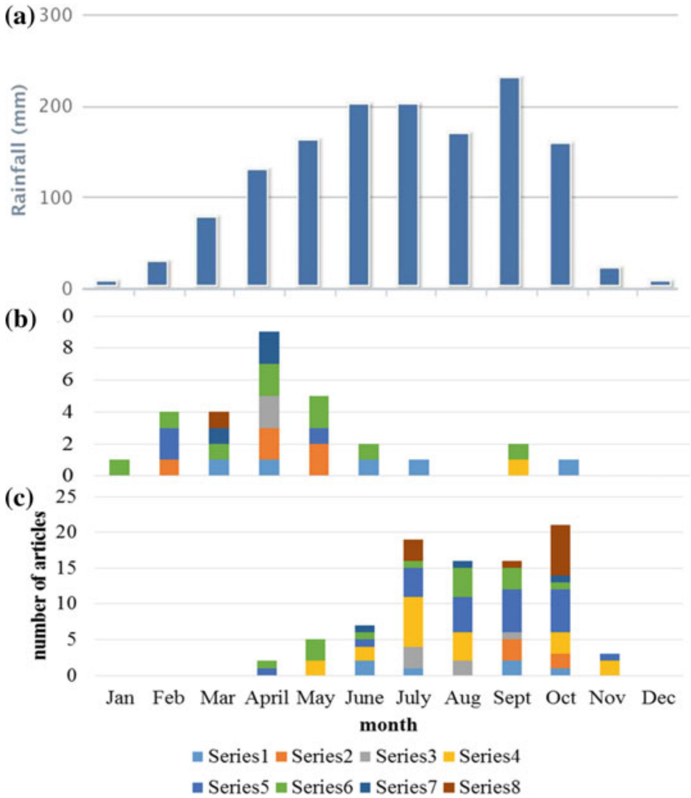

Fig. 20.3 Rainfall patterns in the study area and monthly reports on storms between the years 2008–2015. **a** represent Monthly rainfall (Climatology data), **b** and **c** are reported cases of storms in Punch and vanguard newspaper respectively

Table 20.3 Monthly report on flood

Year	Event	Jan	Feb	Mar	Apr.	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
2008	Flood	0	0	0	0	0	2	1	0	2	1	0	0	6
2009	Flood	0	0	0	0	0	0	0	0	3	2	0	0	5
2010	Flood	0	0	0	0	0	0	3	2	1	0	0	0	6
2011	Flood	0	0	0	0	2	2	7	4	0	3	2	0	20
2012	Flood	0	0	0	1	0	1	4	5	6	6	1	0	24
2013	Flood	0	0	0	1	3	1	1	4	3	1	0	0	14
2014	Flood	0	0	0	0	0	1	0	1	0	1	0	0	3
2015	Flood	0	0	0	0	0	0	3	0	1	7	0	0	11
Total		0	0	0	2	5	7	19	16	16	21	3	0	89

recorded were 16 these happened in 2008 (2), 2009 (3), 2010 (1), 2012 (6), 2013 (3), and 2015 (1). For October 2008–2015 the reports recorded 21 these happened in 2008 (1), 2009 (2), 2010 (1), 2011 (3), 2012 (6), 2013 (1), 2014 (1) and 2015 (7). For November 2008–2015, the reports recorded were 3 and this happened in 2011 (2) and 2013 (1). And lastly December 2008–2015, there was 0 report of flood events. From Fig. 20.3, it can be seen that the month, with the highest record of the flood, is July and this might directly sensitize people in finding ways to adapt to this events or find a way of reducing this events. And also this results in building bridges in order to pave way for flood so as to reduce loss of lives and properties (Fig. 20.3c).

Figure 20.3b and Table 20.4 depict the monthly reports on the storm in vanguard newspaper from 2008 to 2015. The records in the month of January 2008–2015 were 1 and this was reported in 2013 (1). The reports for February 2008–2015 were 4 and these 4 occurrences were reported in 2013 (1), 2014 (1) and 2015 (1). For March 2008–2015 was 4 and these were reported in 2008 (1), 2013 (1) 2014 (1) and 2015 (1). For April 2008–2015, the number of the occurrences were 9 and these were reported 2008 (1), 2009 (2), 2010 (2), 2013 (2), and 2014 (2). In the month of May 2008–2015, the reports recorded were 5 and these were 2009 (2), 2012 (1) and 2013 (2). For the month of June 2008–2015, the number of the reports was 2 and these were reported 2008 (1) and 2013 (1). July 2008–2015 there was 1 record of storm reported in 2008 (1). For August 2008–2015, there was no report on the storm (Fig. 20.3). For September 2008–2015, the report recorded was 2 these happened in 2011 (1) and 2013 (1). For October 2008–2015, there was just only 1 report in 2008 (Table 20.4). For November 2008–2015, there was no report and lastly, December 2008–2015, no incidence of the storm was reported (Fig. 20.3b).

Generally, the months with the highest reported cases of flooding correlate with months with the highest rainfall amount. Rainfall in the study area usually has two peaks: in the month of June/July and September (Figs. 20.2c and 20.3c). Thus, flooding incidence occurred mainly in the months of June/July and September as reported in both newspapers while Storms were commonly reported at the beginning of rainy seasons, mostly in the months of April (Figs. 20.2b and 20.3b).

Comparison of the Media Information with the Actual Extreme Weather Events Data from the National Emergency Management Agency (NEMA) for the Year 2001

The results of specific date of occurrences of extreme weather events, obtained from the archives of National Emergency Management Agency (NEMA) were compared with the reported weather events in the media. It is apparent from the study that the information from NEMA captured what happened in reality and the date of the occurrence. The highlighted/underlined date in red color was used in this research work because they showed the exact date of the occurrences (Table 20.5). The following steps were taken to compare the media information with the information from

Table 20.4 Monthly report on storms

Year	Event	Jan	Feb	Mar	Apr.	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
2008	Storm	0	0	1	1	0	1	1	0	0	1	0	0	5
2009	Storm	0	1	0	2	2	0	0	0	0	0	0	0	5
2010	Storm	0	0	0	2	0	0	0	0	0	0	0	0	2
2011	Storm	0	0	0	0	0	0	0	0	1	0	0	0	1
2012	Storm	0	2	0	0	1	0	0	0	0	0	0	0	3
2013	Storm	1	1	1	2	2	1	0	0	1	0	0	0	9
2014	Storm	0	0	1	2	0	0	0	0	0	0	0	0	3
2015	Storm	0	0	1	0	0	0	0	0	0	0	0	0	1
Total		1	4	4	9	5	2	1	0	2	1	0	0	29

Table 20.5 Reported cases of extreme weather events by NEMA

State	L/Gov.	Disaster	Date	Damages	No. of people affected
Abia	Arochukwu	Rainstorm	Jul-01	Houses	500
Adamawa	Toungo	Armed banditry, flood	April	Houses, farmland	500
Akwa Ibom	Uyo, Okorottes Ikot	Flood, rainstorm	Mar-01	367 houses	4000
Anambra	–	–	–	–	–
Bauchi	Zaki, Gamawa, Misau, Shura, Kirfi, Toro, Akaleri Katagun, Tafawa Balewa, Bauchi	Fire and windstorm religious crisis	January and April	1468 houses, 1218 fire, 250 rainstorm	2000 persons
Bayelsa	Tombia Ekpetem Kauna Igbedi, Ogu, Trofami	Flood	March	Houses, farmland	300
Benue	Daudo Local Govt	Communal clash	May/June	Houses, farmland	72,000 persons
Borno	–	Fire and flood	–	–	
Cross River	Bakassi	Fire disaster at Atabong town	9 and 10th February 2001	Houses	3000
Delta	Ndokwa West, Isoko South, Isoko North, Asaba	Flood, rainstorm, flood, rainstorm	15/3/2001; 1/4/2001; 25/2/2001	Houses, farmland	554
Ebonyi	Nil	–	–	–	–
Edo	Owan East and West, Estsako West	Flood and/rainstorm	Mar-01	560 houses destroyed	820 persons
Enugu					

(continued)

Table 20.5 (continued)

State	L/Gov.	Disaster	Date	Damages	No. of people affected
Ekiti	Ekiti West, Ido-Osi, Ise-orun, Ikere, Ilemeje, Ikole, Moba, Oye	Rainstorm and flood	1/4/2001	890 houses destroyed and public schools	2100 persons
Gombe	Nil	–	–	–	–
Imo	Orsu	Rain/windstorm	17/4/2001	1000 houses destroyed, 150 electric poles, 40,000 oil palm	
Jigawa	Jahun, Kiyawa, Birnin Kudu, Auyo, Miga, Taura	Flood, fire, windstorm, flood	March, April, August	Farmlands, houses animals	450; 150
Kaduna	Kaduna North and South, Soba, Zaria, kachia, Kafancha	Fire, rainstorm, windstorm; communal clash	Apr-01	Houses, lands, vehicles	1300
Kano	Bebeji, Kura, Kano, Bichi, W, Wudil, Garko, Takai, Gaya, Albasu	Flood, fire and windstorm, communal clash		House, schools, animals	20,445
Katsina	Katsina, Zango, Baure and Funtua	Fire, windstorm	March/April	House, lands	900
Kebbi	–	–	–	–	–
Kogi	Katsina, Zango, Baure and Funtua	Flood, fire, rainstorm	March, April, May	Houses, schools, farmlands	1500
Kwara	–	–	–	–	–
Lagos	–	–	–	–	–

(continued)

Table 20.5 (continued)

State	L/Gov.	Disaster	Date	Damages	No. of people affected
Nasarawa	Obi, Keana, Awe, Lafia	Communal clash	12 June, 2001	Houses, business premises, vehicles	30,000
Niger	–	–	–	–	–
Ogun	–	–	–	–	–
Ondo	Owo	Rainstorm	28/29 April, 2001	Houses, schools	800
Osun	Ifelodun, Ilesa-West, Ilesha-East, Boripe, Ife-North, Ife-Central Obokun	Rainstorm	27th April, 2001		About 1700
Oyo	–	–	–		–
Plateau	Jos North, Jos South	Communal clash	Sep-01	Houses, places of worship, shops, vehicles burnt	250,000
Rivers	Obua Odua Ogu/Bolo	Communal clash	1999, February May, September	300 houses destroyed 550 ha destroyed	30 people
Sokoto	Rabah, Wamakko, Isa, Wumo, Ture, Silame, Gada Yabo, Gwadabawa Sokoto, Goronyo North, S/Bimi, Gambuwal; Shagari	Flood, Quelea birds fire and windstorm	Jul-01	Houses, farm areas damaged	16,000
Taraba	–	–	–	–	–

(continued)

Table 20.5 (continued)

State	L/Gov.	Disaster	Date	Damages	No. of people affected
Yobe	Potiskum, Damaturu, Jakusko, Gedam, Damaturu, Tarmawa, Busari, Nguru	Fire, drought flood	April, 2001 20th September	Houses, razed houses, farms, submerged, animals killed	2000–88,000
Zamfara	Talata Mafara, Gusau	Flood	July, 2001	Buildings, submerged farmlands destroyed properties damaged	12,398
Fct	Abuja Municipal	Windstorm, fire	15th March 2001	Windstorm	

Source NEMA

NEMA: (1) the date of the occurrence and the date were noted and (2) 3 major consecutive date were checked in both the vanguard and punch newspaper respectively to confirm if these two media reported the occurrence.

The results of the analysis showed that none of the media effectually captured the extreme weather events over the study periods. The majority of extreme weather events were reported after more than two days of occurrences, though the probability of dry spell at the on-set and towards the end of the rainy season is usually very high in Northern Nigeria (Adeoye 1986, Usman and AbdulKadir 2014). It is evident the results of this study that majority of extreme weather events were not properly reported while some were not reported at all in Nigeria daily newspapers.

Previous studies have reported similar findings in other part of the world. Such studies have reported floods, as in Nashville, Tennessee in early 2010, in Pakistan in mid-2010, and in Australia in late 2010, were driven in part by the human-influenced trend toward heavy precipitation (Greenough et al. 2001; Felton et al. 2013; Moore et al. 2012; Anjum et al. 2012; Boening et al. 2012). Changes in large-scale patterns of atmospheric pressure also contributed to the Pakistan flooding. Increasing flood risk is now being recognized as the most important sectorial threat from climate change in most parts of the world. For instance, the summer of 2002 in Europe brought widespread floods, but was followed a year later in 2003 by record-breaking heat waves and drought. In the summer of 2007, widespread flooding in central England (the wettest since records began in 1766) was accompanied by drought and record-breaking heat waves in southeast Europe (Trenberth 2005, 2011), This has prompted public debate on the apparent increased frequency of extreme, and in particular, on perceived increases in rainfall intensities (Ologunorisa and Tersoo 2006). Several studies have adduced extreme weather events to be the major cause of flood and drought worldwide. Such studies include Ologunorisa and Tersoo (2006), Olagunju (2015), Rosenzweig et al. (2001), Lesk et al. (2016), Sisco et al. (2016), Khan et al. (2017) among others.Templeton and Scherr (1999) observes that beyond the effects of erosion and demographic pressures on land, deforestation is another primary cause of desertification. Other studies have identified the characteristics of extreme rainfall that are associated with flood frequency to include duration, intensity, frequency, seasonality, variability, trend and fluctuation (Rosenzweig et al. 2001; Olagunju 2015; Zhang et al. 2014; Thelma 2015; Gasse 2000). The interesting point to note in the present study, however, is that the year to year variations in the news papers' reports are not only due to a year to year variation in the occurrence of extreme weather events but might also be due to other reasons such as rising/shrinking awareness about climate extremes, changes in political agenda of the newspaper.

Conclusion

This study aims at assessing rate at which newspapers report and communicate extreme weather events resulting from climate change in Nigeria. The archives of several newspapers were examined but only two major and widely read newspapers outlets were fully assessed. The major findings of this study are that the extent of reporting in vanguard was higher than that of the punch. Information of extreme events for 2012 was not reliable when compared with NEMA reports and the report from vanguard in the same year. The major implication of these results is that the general populaces were not well informed about the occurrences of extreme weather events around, although not many people in the country have enough money to purchase dailies. In all the data collected vanguard has more information than the punch. The findings from this study showed that Vanguard newspapers have highest reports on extreme events than the Punch newspapers. The total article of extreme weather events reported by Vanguard newspaper was 118 and that of the Punch newspaper was 78 over the period. The percentages of specific extreme events reported during the study period by the Vanguard are—Flood (75.42%), Rainstorm (21.19%), Windstorm (3.39%), but no report for thunderstorm and drought. While the Punch reported 66.67% of Flood cases, Rainstorm (28.21%), Windstorm (3.84%), thunderstorm (1.28%), but no report for drought. This demonstrates that Vanguard paid more attention to extreme weather events in the country and thus sensitizing the public about weather events. Finally, the data collected from NEMA for 2001 was used to compare the report from the two top national Newspapers for 2001. The results showed that extreme weather events report is not properly described because what happened in reality were not captured by most of national dailies.

The results of the study showed that there are some extreme weather events that do occur in reality with great impacts but not reported at all in the two newspapers. An example of such is drought; there were very low reported cases of dry spell and prolong dry seasons (drought) over the study periods. This maybe due to the fact that the impacts of this event are mostly felt by selected population, mainly the farmers. They are majorly the rural people with low living standard and high level of poverty. Also, cases of thunderstorm was not reported at all in the vanguard, thus, public reading may not be aware of this occurrence in their surrounding area. For example, the results for Punch 2012 showed only 1 occurrence of extreme weather event throughout the whole year while vanguard reported 27 of extreme weather events. Despite low in the reported cases of extreme weather events resulting from climate change as presented in this study, actions should be taken to sensitize and educate (Ayanlade and Jegede 2016) the public about the climatic extreme events, which is frequent nowadays as an evidence of change in climate.

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References

Adeniyi PA (2016) Climate change induced hunger and poverty in Africa. J Global Biosci 5(3):3711–3724

Adeoye K (1986) An evaluation of drought incidence and Hazard in Northern Nigeria. In 22nd Annual Conference of the Agricultural Society of Nigeria, Zaria 1st–3rd September

Alexander LV (2016) Global observed long-term changes in temperature and precipitation extremes: a review of progress and limitations in IPCC assessments and beyond. Weather Clim Extremes 11:4–16

Anjum S, Saleem M, Cheema M, Bilal M, Khaliq T (2012) An assessment to vulnerability, extent, characteristics and severity of drought hazard in Pakistan. Pak J Sci 64(2)

Ayanlade A, Jegede MO (2016) Climate change education and knowledge among Nigerian university graduates. Weather Clim Soc 8(4):465–473

Ayanlade A, Odekunle T, Orimoogunje O (2010) Impacts of climate variability on tuber crops in Guinea Savanna part of Nigeria: a GIS approach. J Geogr Geol 2(1):27

Ayanlade A, Radeny M, Morton JF, Muchaba T (2018) Rainfall variability and drought characteristics in two agro-climatic zones: an assessment of climate change challenges in Africa. Sci Total Environ 630:728–737

Berkes F, Jolly D (2002) Adapting to climate change: social-ecological resilience in a Canadian western Arctic community. Conserv Ecol 5(2):18

Boening C, Willis JK, Landerer FW, Nerem RS, Fasullo J (2012) The 2011 La Niña: so strong, the oceans fell. Geophys Res Lett 39(19)

Brooks N, Adger WN (2003) Country level risk measures of climate-related natural disasters and implications for adaptation to climate change. Tyndall Centre for Climate Change Research, Norwich

Donat M, Peterson T, Brunet M, King A, Almazroui M, Kolli R, Boucherf D, Al-Mulla AY, Nour AY, Aly AA (2014) Changes in extreme temperature and precipitation in the Arab region: long-term trends and variability related to ENSO and NAO. Int J Climatol 34(3):581–592

Felton JW, Cole DA, Martin NC (2013) Effects of rumination on child and adolescent depressive reactions to a natural disaster: the 2010 Nashville flood. J Abnorm Psychol 122(1):64

Garden D (2017) Droughts, cyclones & floods: El Niños that shaped our colonial past. Australian Scholarly Publishing, North Melbourne

Gasse F (2000) Hydrological changes in the African tropics since the Last Glacial Maximum. Quat Sci Rev 19(1):189–211

Glantz MH (2001) Currents of change: impacts of El Niño and La Niña on climate and society. Cambridge University Press, Cambridge

Greenough G, McGeehin M, Bernard SM, Trtanj J, Riad J, Engelberg D (2001) The potential impacts of climate variability and change on health impacts of extreme weather events in the United States. Environ Health Perspect 109(Suppl 2):191

Guha-Sapir D, Vos F, Below R, Ponserre S (2011) Annual disaster statistical review 2010. Centre for Research on the Epidemiology of Disasters

Gutowski W, Hegerl G, Holland G, Knutson T, Mearns L, Stouffer R, Webster P, Wehner M, Zwiers F (2008) Causes of observed changes in extremes and projections of future changes in weather and climate extremes in a changing climate. Regions of focus: North America, Hawaii, Caribbean, and US Pacific Islands. A report by the US Climate Change Science Program and the Subcommittee on Global Change Research, Washington, DC

Gyireh PF-V (2011) Sustainable management of flood disasters in the Upper East Region, Ghana. Unpublished thesis, Kwame Nkrumah University of Science and Technology

Haines A, Kovats RS, Campbell-Lendrum D, Corvalán C (2006) Climate change and human health: impacts, vulnerability and public health. Public Health 120(7):585–596

IPCC (2014) Climate change 2014–impacts, adaptation and vulnerability: regional aspects. Cambridge University Press, Cambridge

Khan SJ, Deere D, Leusch FD, Humpage A, Jenkins M, Cunliffe D, Fitzgerald SK, Stanford BD (2017) Lessons and guidance for the management of safe drinking water during extreme weather events. Environ Sci: Water Res Technol 3(2):262–277

Lesk C, Rowhani P, Ramankutty N (2016) Influence of extreme weather disasters on global crop production. Nature 529(7584):84–87

Loaiciga HA, Haston L, Michaelsen J (1993) Dendrohydrology and long-term hydrologic phenomena. Rev Geophys 31(2):151–171

Moore BJ, Neiman PJ, Ralph FM, Barthold FE (2012) Physical processes associated with heavy flooding rainfall in Nashville, Tennessee, and vicinity during 1–2 May 2010: the role of an atmospheric river and mesoscale convective systems. Mon Weather Rev 140(2):358–378

Mupedziswa R, Kubanga KP (2017) Climate change, urban settlements and quality of life: the case of the Southern African Development Community region. Dev South Afr 34(2):196–209

Odekunle T (2001) The magnitude–frequency characteristic of rainfall in Ondo, southwestern Nigeria. Ife Res Publ Geogr 8:36–41

Odekunle T, Balogun E, Ogunkoya O (2005) On the prediction of rainfall onset and retreat dates in Nigeria. Theor Appl Climatol 81(1–2):101–112

Olagunju TE (2015) Drought, desertification and the Nigerian environment: a review. J Ecol Nat Environ 7(7):196–209

Olaniran O (2002) Rainfall anomalies in Nigeria: the contemporary understanding. University of Ilorin, Ilorin, Nigeria

Ologunorisa TE, Tersoo T (2006) The changing rainfall pattern and its implication for flood frequency in Makurdi, Northern Nigeria. J Appl Sci Environ Manag 10(3):97–102

Parry M, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (2007) Climate change 2007: impacts, adaptation and vulnerability. Cambridge University Press, Cambridge

Pielke RA, Downton MW, Miller JB (2002) Flood damage in the United States, 1926–2000: a reanalysis of National Weather Service estimates. University Corporation for Atmospheric Research, Boulder, CO

Rockström J (2003) Resilience building and water demand management for drought mitigation. Phys Chem Earth Parts A/B/C 28(20):869–877

Rosenzweig C, Iglesias A, Yang X, Epstein PR, Chivian E (2001) Climate change and extreme weather events; implications for food production, plant diseases, and pests. Global Change Hum Health 2(2):90–104

Sisco MR, Bosetti V, Weber EU (2016) Do extreme weather events generate attention to climate change?

Steady FC (2014) Women, climate change and liberation in Africa. Race Gender Class 21(1/2):312

Templeton SR, Scherr SJ (1999) Effects of demographic and related microeconomic change on land quality in hills and mountains of developing countries. World Dev 27(6):903–918

Thelma MN (2015) Desertification in northern Nigeria: causes and implications for national food security. Peak J Soc Sci Hum 3(2):22–31

Trenberth KE (2005) The impact of climate change and variability on heavy precipitation, floods, and droughts. Encyclopedia of hydrological sciences. Wiley, Chichester

Trenberth KE (2011) Changes in precipitation with climate change. Clim Res 47(1–2):123–138

Usman M, AbdulKadir A (2014) An experiment in intra-seasonal agricultural drought monitoring and early warning in the Sudano-Sahelian Belt of Nigeria. Int J Climatol 34(7):2129–2135

Zhang X, Hegerl G, Seneviratne S, Stewart R, Zwiers F, Alexander L (2014) WCRP grand challenge: understanding and predicting weather and climate extremes. Tech. rep., World Climate Research Program. http://www.wcrp-climate.org/images/documents/grand_challenges/GC_Extremes_v2.pdf (White Paper)

Chapter 21
Climate-Indexed Insurance as a Climate Service to Drought-Prone Farmers: Evidence from a Discrete Choice Experiment in Sri Lanka

D. V. P. Prasada

Abstract The droughts of 2016–2017 caused nearly 25% reduction in harvest and nearly 30% reduction in the area cultivated in Sri Lanka. As a result, renewed attention is being paid to farmer income smoothing and adaptation strategies, among which insurance contends as one of the more viable solutions. This study assesses the willingness to pay for a climate-indexed agricultural insurance package through a discrete choice experiment. We use the 'stated preference' approach by offering farmers choice scenarios constructed as a fractional-factorial assignment. The attributes include the coverage area for weather index calculation (village, divisional-secretariat area, or district), the managing authority for the insurance scheme (government, a commercial bank, or an agribusiness company), the method of calculation of compensation (fixed rate, based on cost of inputs or based on the value of output/revenue) and the premium per term (at three levels). We analyzed a total of 2583 choice scenarios evaluated by 287 individuals using a conditional-logit model and estimated the 'marginal willingness to pay' (MWTP) for each attribute. The results of the choice experiment reveal the following. The smaller-sized administrative area level is preferred by respondents as a reference area for weather-index calculation while the government is preferred as the managing authority. The revenue-based compensation approach is preferred as the method of calculating compensation. Negative MWTP was observed for larger area indices and for insurance administered by an agribusiness company. The MWTP for revenue-based compensation is LKR 326 while the MWTP for fixed rate compensation schemes is LKR -420.

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Introduction

Climate services encompass diverse activities and processes (Vaughan and Dessai 2014). This is why the World Climate Conference in 2009 called for an "international framework for climate services that links science-based climate predictions and information with the management of climate-related risks and opportunities in support of adaptation to climate variability and change" (GFCS 2017). Climate finance comes under climate services as it involves the use of climate knowledge and information in decision-making and climate-smart policy and planning. Climate insurance, especially when it is weather-indexed, translates climate information into an economic tool targeting risk mitigation and income smoothing.

In low income settings where farming is the main livelihood, climate change presents significant threats to livelihoods. Conventionally, farmers respond to climate induced shocks through crop diversification, crop rotation and water sharing. But the relative efficacy of these responses has been poor and they have not generated sufficient income safeguards. In the absence of suitable risk management options, farmers tend to adopt unsustainable and environmentally hazardous practices such as overuse of agrochemicals, misuse of water resources, and excess postharvest treatment of agricultural produce as coping strategies (Panda et al. 2013).

There are similarities between the adoption of climate services and that of other technologies. As is the case with the penetration of any other service, reception of the service among the intended beneficiaries depends on the demand for various attributes of the service. We adopt a choice experiment methodology in this study to investigate the factors contributing to farmer adoption of climate-indexed insurance as a climate service. The special focus of the study is the effectiveness of climate-indexed insurance in smallholder agriculture in Sri Lanka. For this purpose, a sample of locations covering five agro-ecological regions was randomly targeted. After calculating the sample size needed to match the dimensions of the choice experiment, we approached 300 farmers of whom complete choices were available for only 287 participants.

The Role of Insurance as a Climate Service

Weather-indexed insurance instruments moderate the yield and income risks of farming resulting from climate and weather variations. Only a few climate services are able to address the mismatch between information and revenue shocks as clearly as climate insurance.

The exposure to risk even at the subsistence and smallholder levels is too large to ignore. In a survey-based analysis, Rosenzweig and Binswanger (1993) reported that smaller and poorer farmers in a semi-arid region in India sacrificed 27% of their expected income to reduce risk. Further evidence on the limitations of traditional risk management tools can be seen in the long-standing poverty traps in smallholder agriculture. While poverty traps do not spring entirely from climate risk in farming, they are indirectly perpetuated by the inadequacy of traditional risk mitigation methods. As such, income smoothing instruments such as insurance can play a significant role in the climate service landscape.

Farmer adaptation to climate change can take many forms. One potential approach is to introduce strategies that can help mitigate output and price risks. A key policy issue is how such risk mitigation strategies are to be financed. Government interventions often come in the form of subsidies for climate services and compensation for climate-induced harvest losses. In either case, the cost of intervention is borne by the tax payer, leading inevitably to welfare losses. In contrast, privately-financed insurance schemes can be deemed as market-based climate services.

Additionally, Climate Indexed Insurance (CII) solves key problems related to traditional indemnity-based insurance making the transaction costs of CII considerably lower relative to traditional insurance (Tadesse et al. 2015). This makes CII schemes attractive to private insurers. From the client's (i.e., farmer's) side, CII is more transparent than traditional insurance. In addition to its direct role in managing risk and uncertainty, insurance instruments will also help smooth household agricultural income.

Agricultural Insurance in Sri Lanka

The first experimental crop insurance scheme in Sri Lanka was established in 1958 as a pilot project covering rice cultivation only. The scheme was legislated under the Crop Insurance Act No. 13 of 1961. The scheme covered 26,000 acres of paddy in five districts (out of a total of 25 districts). The experience during the first 15-year period was quite favorable. By 1973, 16% of the total area cultivated with paddy had been insured under this scheme for the two cultivating seasons (Sandaratne 1974). The penetration of insurance has, however, fallen since then to an overall 4% according to government statistics (AAIB 2015). The extent of the paddy area under voluntary insurance as a percentage of the area cultivated is recorded at 1% by the Agricultural Insurance Board of Sri Lanka (Fig. 21.1).

The Crop Insurance Board was established in 1973 under the Parliamentary Act No. 27 of 1973 (Agricultural Insurance Law No. 27 of 1973) to operate a comprehensive agricultural crop insurance scheme covering all major crops and livestock. In the case of rice and other crops, insurance protection was provided against drought, floods, disease, insect infestation, and damage by wild animals as well as losses incurred due to non-adherence to approved methods of farming recommended by the Department of Agriculture. This scheme was partially subsidized with the Government of Sri Lanka (GoSL) bearing the administration costs. The other objectives were to stabilize farmer incomes, thereby promoting agricultural production while undertaking at the same time research for the promotion and development of agricultural insurance. Other crops like green gram, cowpea, chili, and soya bean, even livestock, especially cattle and poultry, came under the program in 1985. The total

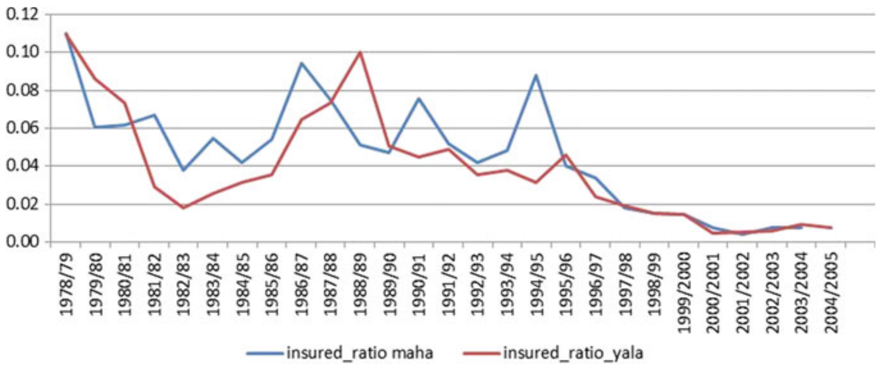


Fig. 21.1 Insurance penetration (percentage of the paddy cultivated area) in the two cultivation seasons: *Yala* (May–September) and *Maha* (November–February). *Source data* Agricultural and Agrarian Insurance Board Annual Reports

area under insurance cover increased to 200,000 acres. A large percentage (85%) of the total acreage insured was paddy. The coverage of agricultural insurance was further expanded by the Agricultural and Agrarian Insurance Board (AAIB) Act No. 20 of 1999 which had the objective of running the scheme on a self-financed basis.

Although paddy insurance is compulsory under Section 11 of the Agricultural Insurance Law, insurance subscription remains effectively voluntary, with participation by farmers hovering around 10%. Indeed, the area under crop insurance was only about one percent of the total paddy lands in 2005. But the direct focus of the Amendment to the Act in the 1999 Agricultural Insurance Act was to make provisions for private sector involvement in crop insurance. However, the intended outcome has not been achieved since there has been no private sector participation except for one general insurance company.

As mentioned above, in the case of Sri Lanka, crop insurance has mainly targeted rice which is the staple crop of the country. Paddy/rice insurance covers the total or partial loss of yield due to flood, drought, plant diseases, pest damage, and damages by wild animals. The period of insurance covers the span from the date of planting to the date of harvest of the crop. The coverage and the premium vary depending on the risk level and the land class (i.e., whether under major irrigation, minor irrigation or rain-fed systems). The three tiers of risk exposure has been classified and the premium rate of low risk is set at 5% of the coverage, medium risk at 7.5% of the coverage and high risk at 10% of the coverage. The calculation of indemnity has been based on the cost of cultivation under each land class. Under major irrigation schemes, the insurance coverage has ranged between LKR 10,000 and LKR 15,000 per acre while the premium rates have varied between LKR 500 and LKR 750 per acre.

Review of Literature

Crop insurance is not a new topic in the wider development discourse. However, its role as a climate service is rather new. Even when insurance options are present, the uptake by poor farmers is low. Insurance solutions may not be very popular because farmers rely more on traditional methods of averting risk. But given the inadequacy of traditional solutions, the question is why insurance is not adopted in the agricultural sector in parallel to its extensive use in other areas of economic activity. Insurance is a market-based service carrying important economic and behavioral properties that are indispensable in a modernized agricultural sector. For this reason, the unwillingness to adopt insurance, especially in smallholder agriculture has been identified for long as a concern requiring attention by policy makers and the business community alike.

The role that insurance can potentially play can only be understood if placed within the broader context of financial management in smallholder agriculture. Insurance markets do not function in isolation. Instead, they are closely linked with the function of credit. Farm households, especially smallholders, do not make adequate investments due to difficulties in accessing credit from formal credit suppliers such as banks. This, in turn, limits the capacity of smallholders to link to other financial services such as insurance. On the other hand, those who do have access to insurance are unwilling to seek credit because the collateral requirements would expose them to further risk. Thus, under-developed insurance markets trigger a vicious cycle of under-investment, poor productivity and rural poverty (Boucher et al. 2008).

Indexed insurance has a long history in crop insurance where specific periodic droughts can affect the lifecycle of the total crop (Hill et al. 2013). An indexed insurance contract makes the agreed payout to beneficiaries whenever the data source indicates that the index reaches the insurance activation level. In traditional insurance schemes that cover crop losses owing to climate-related damages, an insured farmer receives compensation for the verifiable loss at the end of the growing season (Barnett and Mahul 2007). Unlike traditional insurance, which makes payouts based on separate assessment of client claims, index-based insurance pays out based on an external indicator that triggers payment to all insured clients within a geographically-defined space (Chantarat et al. 2013). Linking indemnity payments to external indicators eliminates the need to verify claims. Verification of claims is costly in low income farming environments (Barnett and Mahul 2007). The most significant downside in traditional schemes is the verifiability and delay in processing the claim. In a climate-indexed insurance setting, while the scope of insurance is limited to climate-induced losses compared to traditional crop insurance, it has a clear advantage with regard to verifiability and promptness of claim settlement.

When clients have only low or modest assets, the exogenous determination of compensation mitigates the information asymmetries associated with traditional insurance products, i.e. moral hazard and adverse selection. The relative merits of climate-indexed insurance in comparison with traditional insurance thus give it an edge in the context of smallholder agriculture and fisheries.

Observing farmer preferences for different attributes of a climate-indexed insurance scheme is not always possible in rural settings where the rates of insurance adoption are low and general payout rates are high. Moreover, in almost all cases, existing insurance services function as part of a larger package of farmer support. Therefore, it is impossible to collect observational data with suitable variations in insurance service agreements. As an alternative, choice experiments can be conducted to analyze preferences for hypothetical contract features.

Several choice experiment studies have examined farmer attitudes towards climate insurance in high income countries (Liesivaara and Myyrä 2014). These studies consider the insurance premium, deductible, type of verification, and level of expected indemnity as attributes. The focus on the deductible is motivated by the EU legislation,[1] its emphasis especially on the nature of the deductibles in the light of high subsidization of crop insurance premiums. These studies reveal that both the deductible and the expected indemnity had a major effect on the willingness of farmers to pay for crop insurance. Other key determinants identified in the literature include trust (Cole et al. 2013), effect of client group size on collective insurance purchase (Wollni and Fischer 2015), and information on payment trigger mechanisms in the case of climate insurance (Elabed et al. 2013).

As discussed above, climate-indexed insurance has clear advantages. However, adoption rates by smallholders depend on the insurance package being designed in a locally relevant and an incentive-compatible manner (Marr et al. 2016; Wairimu et al. 2016). Any analysis of client needs in a climate-indexed insurance package should take into account the potential trade-offs between the attributes and levels faced by the farmer. The failure of previous trials of farmer insurance has been mainly due to the poor design (i.e. lack of customized packages) and targeting.

Methodology

In designing the choice experiment, we carried out a preliminary literature survey and a series of focus group/key informant interviews to validate the relevant attributes and their levels. A key element of an index-based insurance package is the measurement of climate indicators that trigger the payout. We chose the sample sites for carrying out the study after considering the agro-climatology and land use patterns of Sri Lanka. The following geographical locations were selected as the primary study locations based on agro-climatology[2]: Polonnaruwa, Ampara, Batticoloa and Hambanntota in the Dry Zone, Matara and Kurunegala in the Intermediate Zone, and Galle and

[1]EU. 'Regulation (EU) No 1305/2013 of the European Parliament and of the Council of 17 December 2013 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) and repealing Council Regulation (EC) No 1698/2005' (2013).

[2]Three main climatic zones have been identified in Sri Lanka, demarcated mainly based on annual precipitation: Dry Zone (less than 1000 mm); Intermediate Zone (between 1000 and 2500 mm); Wet Zone (above 2500 mm).

Matale in the Wet Zone. We obtained participation of a total sample of 287 farmers in the choice experiment.

Four attributes of an insurance scheme were tested in the discrete choice experiment:

a. Premium
b. Reference spatial boundary for measurement of climate/weather indicator (i.e., index)
c. Method of calculating compensation
d. Institutional authority managing the insurance scheme.

We assigned three levels to each attribute based on feedback from focus group discussions and key informant interviews. The premium was set at three levels: LKR 200, 400, or 600. The range of values was motivated by the subsidized rate applicable to the insurance premium bound up with the fertilizer subsidy as there is no precedent in terms of a standard insurance premium in the Sri Lankan context. The insurance program attached to the fertilizer subsidy is active at a payment of LKR 350 and is applicable up to a maximum compensation of LKR 10,000 per acre per season.

The weather index selected was the rainfall index which is the most common indicator of climate variability in tropical settings. The levels of the second attribute refer to the size of the reference area for which the weather index is calculated. The smallest unit was the Grama Niladari Division (GND), corresponding to the command area coming under the local government administrative officer, which typically covers approximately 1500 individuals in Sri Lanka. Historically, a GND area corresponded to a single village. The second unit constituted the Divisional Secretariat area which is an administrative service area catering to approximately 50,000 individuals. In terms of the land area, this is approximately the size of a small township having a 5–8 km radius. The largest reference area type is the Administrative District, which has no natural or social boundary but usually comprises around 10 Divisional Secretariat (DS) divisions within it. In the public administration structure of Sri Lanka, this is the functional unit of administrative and policy decisions.

The compensation in traditional agricultural insurance is calculated using an indemnity approach. When index insurance is introduced, the determination of compensation has to take an alternative basis. The third attribute of the choice scenario refers to the method of determining maximum compensation. Levels include a fixed cap for compensation, compensation calculated based on the cost of production or compensation based on forgone revenue (or value of output).

The fourth attribute considers the type of institution that is managing the indexed insurance. The levels include the government (usually the Agrarian Insurance Board or the Department of Agrarian Services), an agribusiness company, or a commercial bank. The public has experience of all three parties when it comes to provision of indemnity-based insurance.

The experimental design included a ‘four by three’ design generating 81 choice alternatives. The implementation of the experiment followed a fractional factorial design in order to reduce the cognitive burden on the respondent while maintaining

Table 21.1 Summary statistics of key variables

Variable	Mean	Std. Dev.
Gender (female = 1)	0.26	0.44
Age	52.74	12.08
Education level	3	1.02
Monthly income (LKR)	32,741.37	25,185.87
Acreage cropped (acres)	2.41	2.33
Ownership (private = 1)	0.79	0.40
Distance to market (km)	6.45	7.97
Early planting (incidence)	0.23	0.42
Early harvesting	0.16	0.37
Irrigation availability	0.41	0.49
Awareness (weather insurance)	0.66	0.47
Previous insurance exposure	0.41	0.49
Perceived climate impact (ratio)	0.75	0.43

adequate degrees of freedom for estimating the main effects. The number of choice scenarios evaluated by each respondent thus came down to nine scenarios.

Sample Selection and Data Collection

We selected the farmers randomly after selecting the locations based on agro-ecological variation. The study area covers paddy/rice cultivation and, to a lesser degree, other field crops. The type of cropping activity was mainly categorized as annual/short term mono-crops. The study adopted a data collection framework covering the varying agro-climatic conditions as broadly as possible as the main objective was to test the acceptance of climate-indexed insurance services with wider agro-ecological relevance in terms of accuracy and farmer coverage. The sample represented all three main agro-climatic zones of the country. Table 21.1 lists the descriptive statistics of the key variables.

Distribution of Key Indicators of Farmer Behavior Over the Five Agro-Ecological Regions in the Sample

As previously mentioned, in obtaining the sample of respondents, we targeted the dominant agro-ecological regions of the country in order to ensure that the results were generalizable. Sri Lanka has three climatic zones (Wet, Intermediate and Dry) and the total land area is delineated into 24 agro-ecological regions.[3] Each agro-ecological region represents a particular combination of climate (mainly rainfall), soil and relief (Panabokke 1996). We considered five of the most agriculturally relevant agro-ecological regions, namely DL1 and DL2 in the Dry Zone, IL1 in the Intermediate Zone and WL3 and WL4 in the Wet Zone. The dominant crop mix of these zones generally depends on the pattern of precipitation and topography. DL1 and DL2 are low-lying areas of the Dry Zone that receive significant seasonal precipitation. Compared to the rest of the Dry Zone, in these two zones, both the flat topography and the intense monsoon exposure enable cultivation of paddy and other field crops at least during one season per year. On the other hand, WL3 and WL4 are the drier regions of the low-lying lands of the Wet Zone. In comparison, other Wet Zone areas receive rainfall exceeding the levels suitable for paddy and other field crops. IL1, again, is the more widely spread low-lying area of the Intermediate Zone enabling rainfall-based cultivation in at least one season. The differences within were mainly differences in soil types. For instance, the difference between the DL1 and DL2 is based on soil type: DL1 is dominated by reddish brown earths and DL2 is dominated by non-calcic brown soils.

Proactive Responses in Terms of Date of Planting and Harvesting

One of the noticeable examples of adaptation to climate-induced shocks, mainly in rain-fed open-field cultivation contexts, is change of timing of planting as farmers have more flexibility with the planting date than the harvesting date. But under rain-fed conditions, early harvesting is practiced by certain farmers in anticipation of drought shocks. Thus, the plan is to have the shock occur in a less vulnerable stage of the annual crop's duration. Early or delayed planting also could be a response by farmers to anticipated market conditions. Figure 21.2 displays how these two decisions varied across the agro-ecological regions considered.

Degree of Resilience to Climate Shocks

One criterion determining the willingness to purchase insurance is farmers' belief of the speed of recovery from a climate shock. The survey enumerated farmer expectations regarding the speed of recovery after a climate-related shock. The speed of recovery from a shock is not conditional on the agro-ecological identity. Agro-ecological variation of early recovery (within 1 year) and late recovery (within 2 years) appear similar (see Fig. 21.3).

[3]There was a reclassification into 46 agro-ecological regions in 2003 after subdividing some of the initial agro-ecological regions of the 24-part classification.

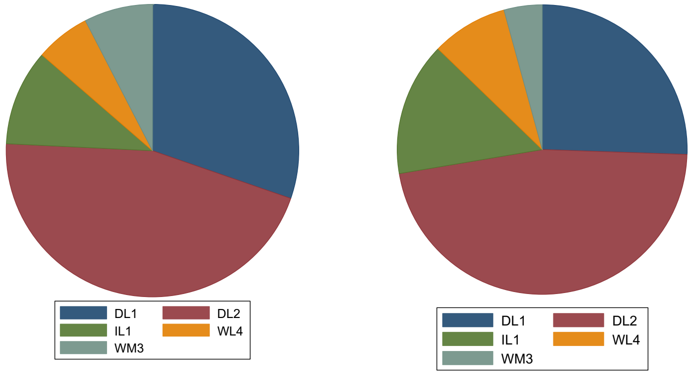


Fig. 21.2 Early planting (left) and early harvesting (right) decision by agro ecology

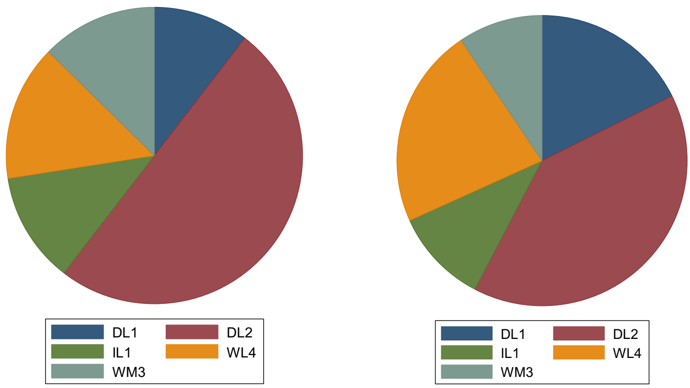
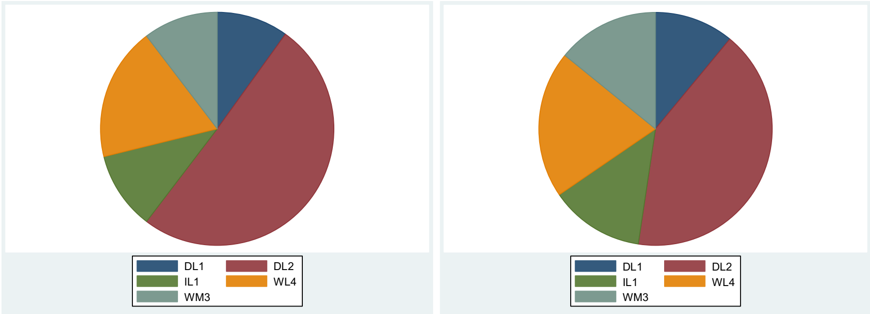


Fig. 21.3 Perceived potential to recover from climate-related crop loss within one year (left) and between 1 and 2 years (right)

Familiarity with Insurance Solutions as a Climate Service

It is noteworthy that Dry Zone farmers identified agricultural insurance as a priority. The farmers in other agro-climatic areas who did not give the same priority to it (see Fig. 21.4). However, when asked about their familiarity with weather-indexed insurance, farmers from all the five agro-ecological areas displayed knowledge about indexed insurance. The Dry Zone farmers' knowledge of weather-indexed insurance is weaker than their knowledge of general crop insurance.



(A) Agricultural insurance as a priority (B) Weather-indexed insurance as a priority

Fig. 21.4 Importance of agricultural insurance (**a**) and weather-indexed insurance (**b**) by agro-ecological region

Descriptive and Analytical Results

Land Use Characteristics of the Sample

The respondents who will potentially benefit from an insurance framework are predominantly smallholders who are often sidelined in the formal financial sector. Since the sample selection was random within selected agro-ecological areas, we conducted an analysis to see the land holding size of the farmers who participated in the experiment. Figure 21.5a plots the distribution of acreage cultivated by farmers. The mean value of land size is 2 acres.

Figure 21.5b looks at the mean land size by agro-ecological region. The lowland Dry Zone has a mean land size of 3 acres while the mean land holding is approximately 1 acre in the Intermediate and Wet Zones where pressure on land due to other land uses is high.

The landholdings referred to above were not necessarily all privately–owned land. Figure 21.6a gives the breakdown of ownership. As seen, the majority of the farmers were cultivating their own holdings while the rest were either renting land or cultivating government-owned land.

As seen with regard to the mean land holding size, the higher pressure on land in the Wet and Intermediate Zones has resulted in a better property rights regime as evident from the] significantly higher prevalence of private deeds (Fig. 21.6b).

A wide variety of crops were observed across the sample. Except in the case of the Dry Zone, home-garden-based vegetable cultivation was observed across the agro-ecological regions. Figure 21.7 gives the crop distribution in the sample. Given the relatively large extent of land cultivated (approx. 1 million ha), paddy is the crop which is primarily targeted in insurance schemes.

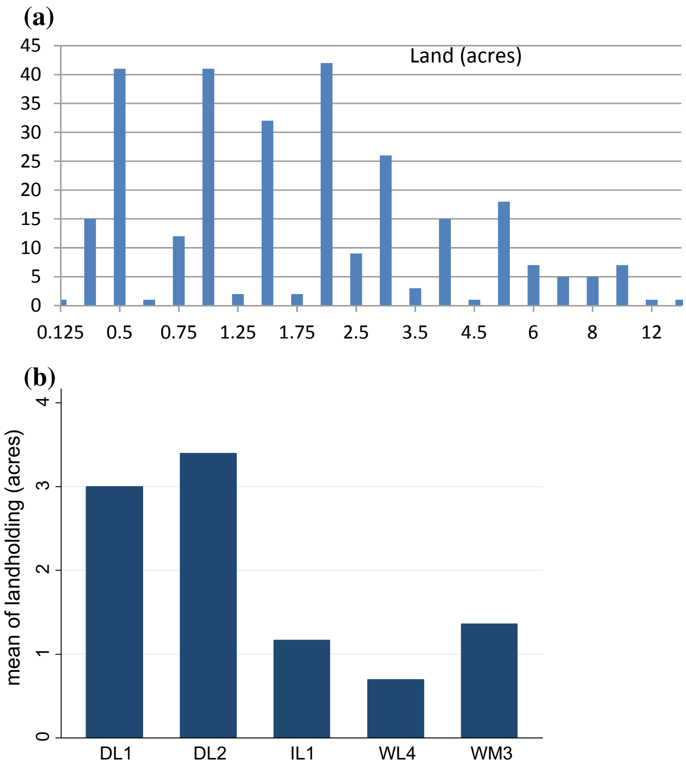


Fig. 21.5 **a** Land holding size (in acres). **b** Average land holding size by agro-ecological region

Socio-economic Profile of the Respondent Farmers

The respondents declared their occupational identities as either fulltime farmers or part-time farmers or as those employed in the public/private sectors or self-employed. Part-time farmers are those who practice agriculture as an additional income generation method or as a family food support strategy. Figure 21.8 displays the vocational commitments of the respondents. A large majority of the respondents are full-time cultivators while part-time cultivators constitute approximately 20% of the sample.

The agricultural income of the respondents is based on self-reported values. We observed varying levels of income with no clear central tendency. However, it was evident that 90% of the sample had a monthly income less than LKR 50,000 (approx. USD 300) with the most frequent value being LKR 30,000. Figure 21.9a displays the distribution of income in the sample.

We treated the utilization of income separately in terms of expenses and savings. The data shows that farming households operate on a balanced budget while the management of household finances did not seem all that much different across

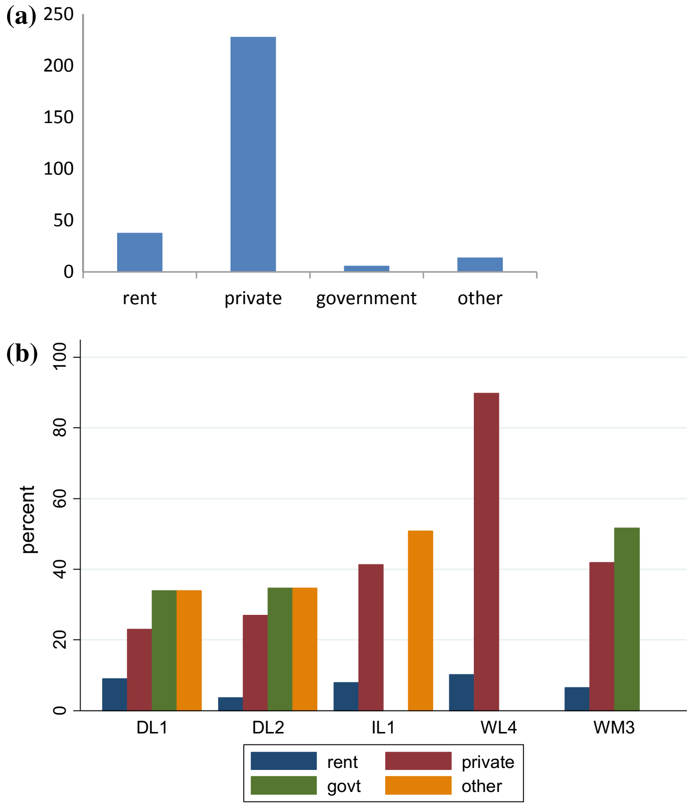


Fig. 21.6 **a** Nature of land ownership. **b** Land ownership status by agro-ecological region

various agro-ecological regions. On average, Dry Zone farmers reported higher revenues (Fig. 21.9b) compared to the revenues reported by Intermediate and Wet Zone farmers.

Financial Penetration

The financial exposure of farmers is a key variable of interest in the present study. We surveyed the sources of capital for agricultural investments made by each farmer. The results are summarized in Fig. 21.10a. The most common source of capital for a majority of farmers was their own savings while the second most common source was lending from banks and other financial institutions. The third most common category constituted investments made by agribusiness companies with farmers under forward contracting arrangements. But it is to be noted that while forward contract agreements are widely observable in the field, the survey data shows that these contracts do not

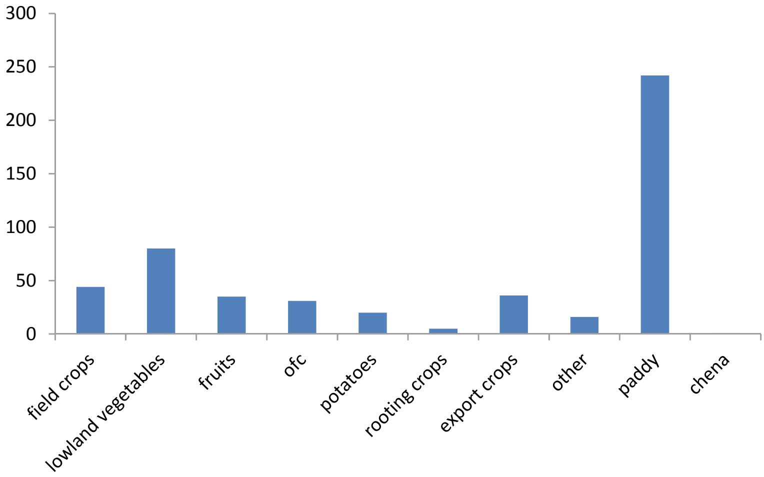


Fig. 21.7 Main types of agriculture activity (Note: 'ofc' in the legend refers to 'other field crops' that include annual crops grown along with paddy during the main paddy cultivating season)

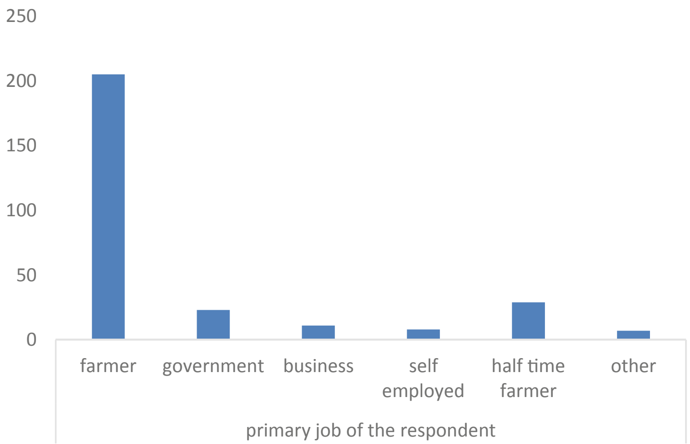


Fig. 21.8 Occupational identity of the respondents

carry a significant investment by the agribusiness companies. Even when inputs are provided by agribusinesses, it is on a credit basis while the costs are eventually recovered by the firms. Therefore, the forward contracts are largely limited to buying agreements for farm output.

When we disaggregate the source of funds by agro-ecological zone (Fig. 21.10b), external investments are predominantly observed in the Dry Zone settings. In Wet and Intermediate Zones, savings and loans are the main source of capital.

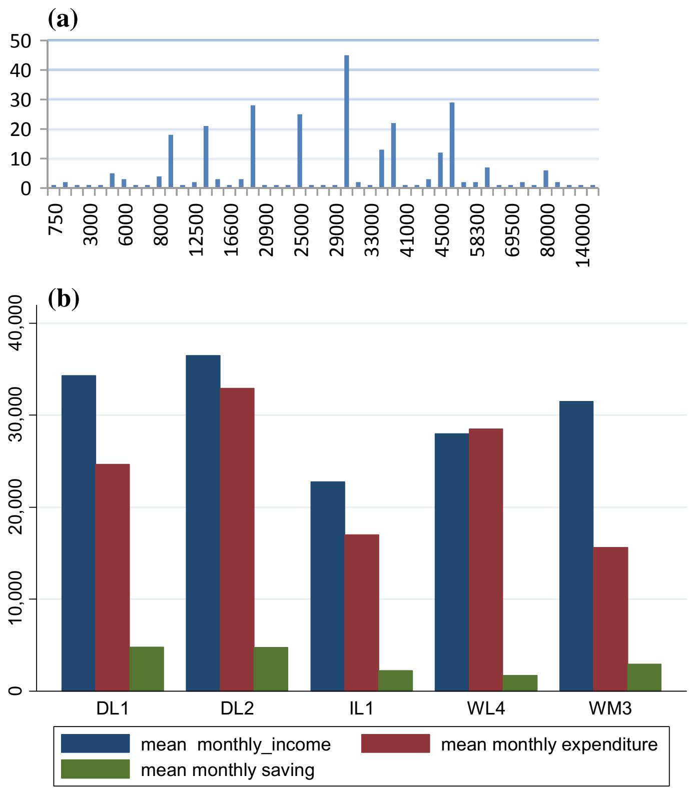


Fig. 21.9 **a** Monthly agricultural income variation among the respondents (LKR). **b** Variation in monthly agricultural income, expenditure and savings among the respondents (LKR)

The level of savings (Fig. 21.11) provides evidence of the depth of household accumulated capital. Although there was wide variation, almost all annual savings were below LKR 250,000 (approx. USD 1600) with the most frequent value being LKR 10,000.

Exposure to Insurance

The survey specifically enumerated the penetration of general insurance in order to evaluate the financial literacy of the respondents in terms of their ability to comprehend easily the nature of the proposed insurance scheme. Figure 21.12 shows the prevalence of life insurance in the sample, followed by other types of insurance coverage (Fig. 21.13).

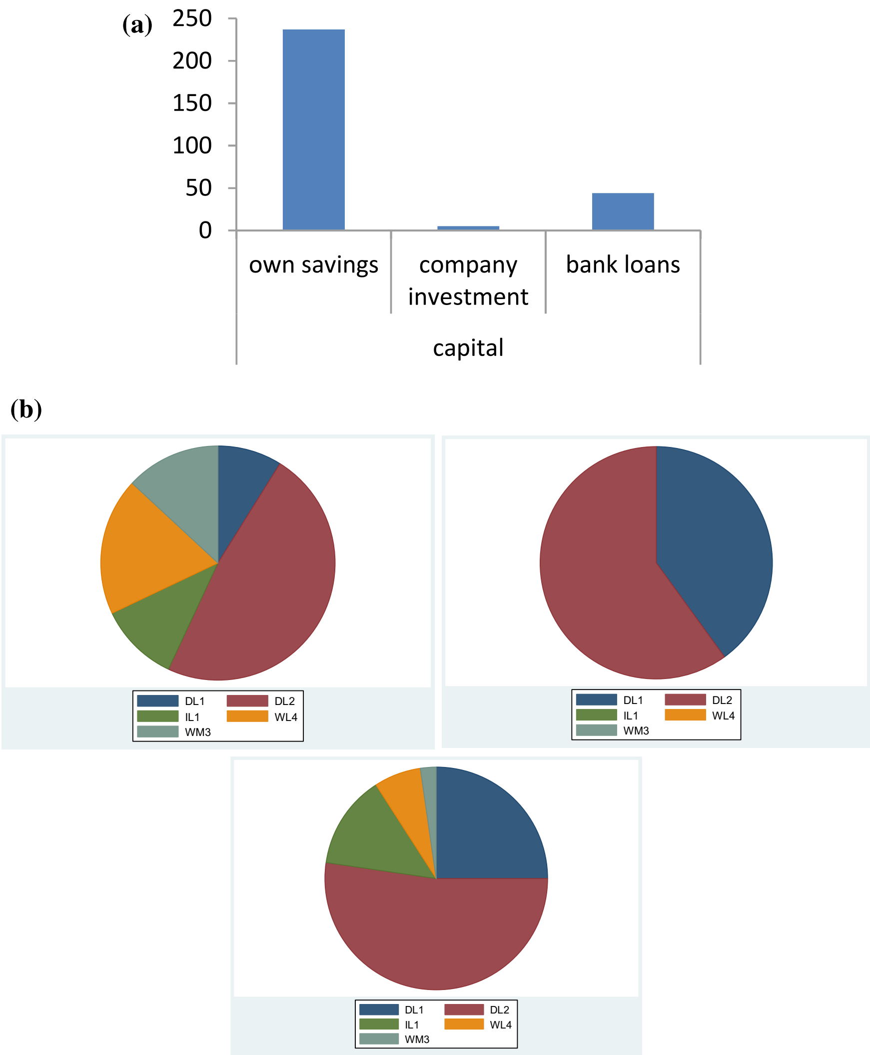


Fig. 21.10 **a** Source of funds for agricultural investment. **b** Capital from savings (upper left), agribusiness company investment (upper right), and loans (lower) by agro-ecological region

While a majority of the respondents lacked experience with insurance as shown in Figs. 21.12 and 21.13, nearly all the respondents agreed that agricultural insurance was important (Fig. 21.14).

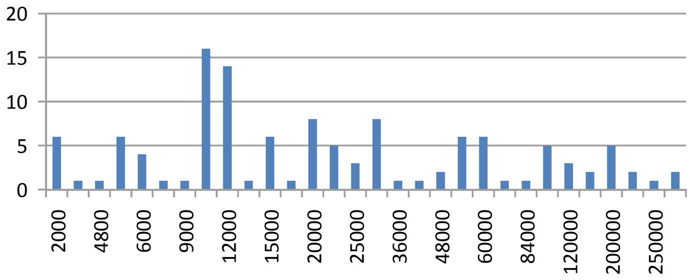


Fig. 21.11 Variation in savings levels among respondents (LKR)

Fig. 21.12 Exposure to life/health insurance

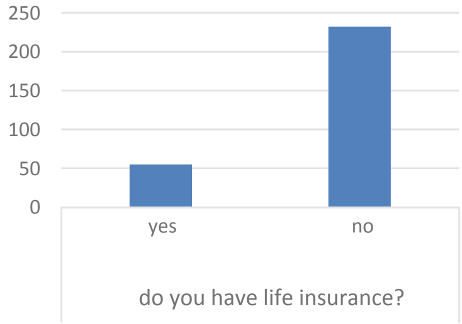
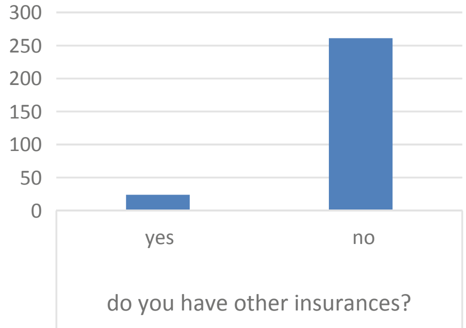


Fig. 21.13 Exposure to other insurance



Agricultural Risk Perception and Preferences for Climate Services

The random sample of respondents came from farming settings under different types of water availability. We found that the main agricultural water sources, namely, large reservoirs, village tanks and only precipitation (i.e., rain-fed), were equally distributed within the samples area (Fig. 21.15).

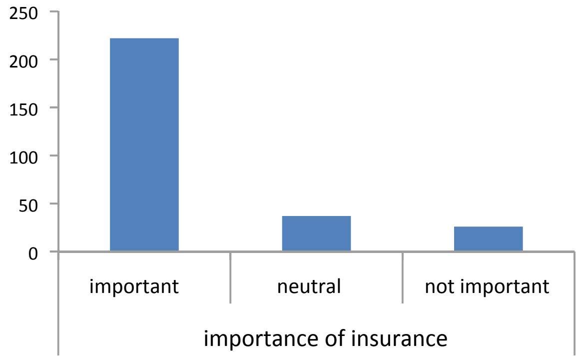


Fig. 21.14 Attitudes and opinions on the importance of agricultural insurance

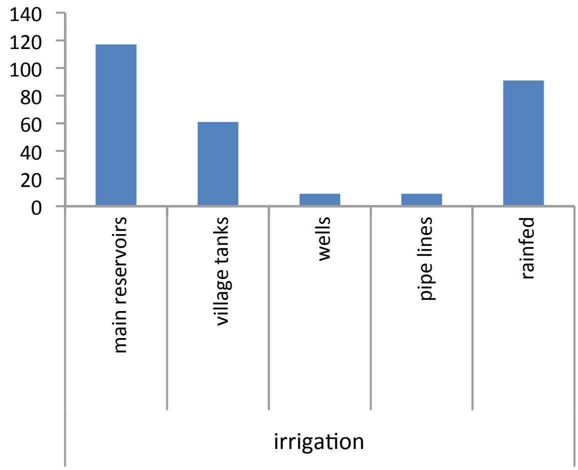


Fig. 21.15 Frequency of water use by source

Considering that farmers in the sample had exposure to all major sources of water availability as seen in Fig. 21.15, we enumerate the perceptions of farmers towards adaptation to climate-related risks when given several options to choose from taking into account what is of relevance in their own circumstances. The four optional paths listed in the survey included choosing crops with low irrigation needs, short term crops, efficient irrigation technologies, and purchase of insurance to cover the risk. Of the four paths, efficient irrigation technology was the most frequent choice while insurance was the least frequent choice (Fig. 21.16).

We further ascertained how each farmer reacts to the potential of floods and droughts. In this instance, farmers were given four options to choose from, namely, changing the crop, early or late crop establishment, consulting a Farmer Organization (FO), and consulting field extension officers (see Fig. 21.17). Their responses indicate that FO opinion and extension advice were the most preferred.

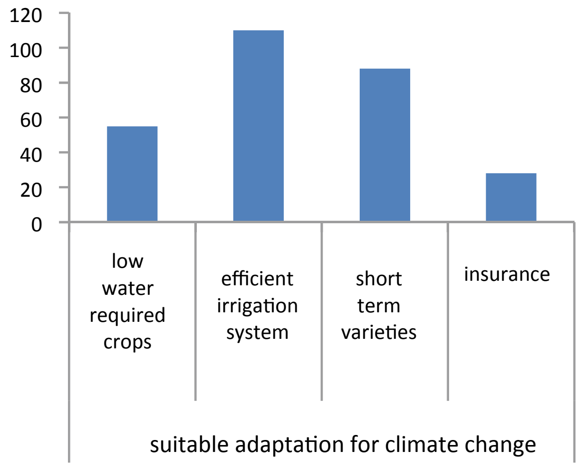


Fig. 21.16 Perception of the relative importance of adaptation mechanisms

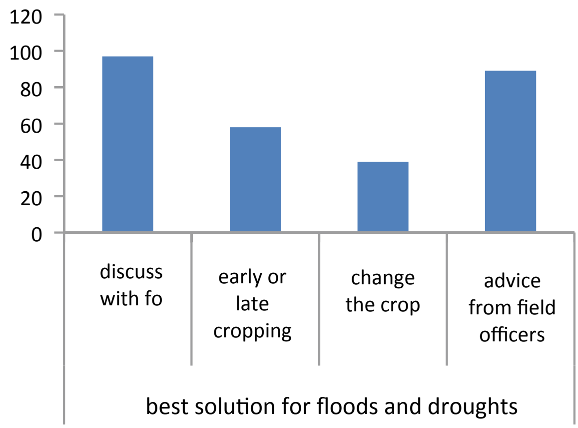


Fig. 21.17 Frequency of different methods of seeking adaptation solutions

Estimates from the Discrete Choice Model

Analysis of discrete choices requires theoretically-founded estimation techniques. Previous work on choice modeling has specific recommendations on the appropriate methods. Conditional logit models (McFadden 1974) are the most appropriate when the choice from among the alternatives is modeled as a function of the characteristics of the alternatives rather than (or in addition to) the characteristics of the individual making the choice. We adopt the conditional logit approach in this study.

Table 21.2 outlines the estimation of the conditional logit model for choice data. The village is the base level for spatial area in measuring the climate index. As seen, the data supports a negative willingness by farmers for weather indices benchmarked at larger administrative areas, namely, the divisional secretary area and the

Table 21.2 Results of the conditional logit estimation

	Coefficient	Std. error	Z statistic	P value
Alternative Specific Constant	4.181	0.310	13.470	0.001
Index reference—Divisional secretariat area	−0.673	0.205	−3.280	0.001
Index reference—District area	−1.872	0.287	−6.520	0.000
Bank-managed scheme	−0.111	0.196	−0.570	0.571
Company-managed scheme	−1.041	0.146	−7.120	0.000
Revenue-based compensation scheme	0.324	0.146	2.220	0.026
Fixed compensation scheme	−0.416	0.111	−3.730	0.000
Price/premium	−0.001	0.001	−1.900	0.058

Table 21.3 Marginal WTP values

	Marginal WTP (in LKR)
Index calculation on Divisional Secretariat area	−678.9
Index calculation on District area	−1889.1
Bank-managed scheme	−112.2
Private company-managed scheme	−1050.5
Revenue-based compensation	326.9
Fixed compensation	−420.1

district boundary. In terms of the management of insurance schemes, there is overwhelming support for government-managed programs (which is the base preference) against private company- or commercial bank-managed schemes. In terms of how the compensation is calculated, the respondents display negative willingness for fixed compensation schemes (where the maximum payout is predetermined or fixed at the beginning of the contract). Instead, there is a statistically significant positive willingness towards a revenue-based compensation scheme. The base level of this attribute is compensation calculated based on the cost of inputs. We obtain negative values for the coefficient for the rate of premium, as should be expected for the sign for the price attribute.

Table 21.3 outlines the marginal willingness to pay (WTP) values estimated for each of the above levels calculated in terms of LKR. The calculations refer to the base scenario of village-level indexed, government-managed, and cost-based compensation schemes.

Limitations

Discrete choice experiments have several limitations though they provide concrete evidence of valuation. In the context of the present study, where the financial literacy of the farmers is on average poor, it is not possible to ascertain the accuracy of their understanding of how insurance premiums and compensations work and whether they clearly understand the implications underlying the different levels specified for each attribute. While this limitation is general to all choice experiment settings, such variations in understanding among participants become especially acute in rural settings.

As the policy environment for agricultural insurance happened to undergo a change during the time-period when our field survey was being carried, this too could have affected the choices of the farmers, especially with regard to the price/premium attribute. The price attribute was given equally-spaced levels of LKR 200, 400 and 600 at the outset. However, during the course of the study, a country-wide policy was introduced to cover paddy lands for compensation of LKR 40,000 per acre for a subsidized premium of LKR 650. Since this was widely advertised, the range of premium levels that was incorporated in the choice experiment may have appeared redundant to farmers. In other words, in light of the policy change, the values included in the experiment may not have communicated to them a significant trade-off among the three levels.

Conclusions and Implications

In a context where there is little understanding of the low uptake of insurance and absence of insurance product suppliers targeting climate risks in agriculture, this study contributes empirical evidence about the factors determining choices and the utility associated with climate-indexed insurance in the case of small-holder faming in Sri Lanka. The study sheds light on the key factors that determine such adoption.

We used four attributes to describe the indexed insurance package proposed. These included index coverage area, managing institution, method of determining compensation, and the premium. Results of the study indicate that farmers prefer the smaller administrative division (as opposed to larger administrative boundaries) as the reference area for weather-index calculation. They also prefer the government (as opposed to banks and agribusiness companies) as the managing authority. The revenue-based compensation approach (as opposed to a cost-based approach and fixed compensation) is statistically significant as the preferred method of calculating compensation.

The average negative marginal willingness-to-pay (MWTP) for an index based on medium and larger administrative areas is LKR -678 and -1889 (USD 1 = LKR 150), respectively. In other words, the respondents have expressed a dislike for large area indices. A similar significant dislike is recorded for schemes managed by agribusiness companies as the MWTP for insurance administered by a private company is LKR -1050. The results show that the MWTP for a revenue-based approach is LKR 326 while the MWTP for the currently-practiced fixed compensation schemes is LKR -420. Thus, respondents, on average, have shown a preference for a small-area-based rainfall index, a government-administered insurance scheme, and a scheme that compensates based on forgone revenue. The marginal WTP values are indicative of the degree of preferences in monetary terms.

Given the fact that the liquidity of farmer finances in the event of climate-based disasters is limited, the introduction of appropriate insurance tools would help mitigate short-term liquidity issues. The credibility of indemnity-based insurance, which is the conventional type of insurance, has long suffered due to lapses in damage assessment and timeliness of compensation payment. In such a context, weather-indexed insurance provides a viable alternative if it is targeted using the willingness-to-pay estimates given above. The study thus highlights the potential of indexed insurance uptake as a climate service if it is appropriately targeted. Farmers seem to grasp the merits of indexing the weather events and measurement of the index in small geographical areas as the desirable attributes of climate services such as insurance.

References

Agrarian and Agricultural Insurance Board of Sri Lanka (AAIB) (2015) Annual report. Agrarian and agricultural insurance Board of Sri Lanka, Colombo

Barnett BJ, Mahul O (2007) Weather index insurance for agriculture and rural areas in lower-income countries. Am J Agr Econ 89(5):1241–1247

Boucher S, Carter M, Guirkinger C (2008) Risk rationing and wealth effects in credit markets: implications for agricultural development. Am J Agr Econ 90(2):409–423

Chantarat Sommarat, Mude Andrew G, Barrett Christopher B, Carter Michael R (2013) Designing index-based livestock insurance for managing asset risk in northern Kenya. J Risk Insur 80(1):205–237

Cole S, Giné X, Tobacman J, Topalova P, Townsend R, Vickery J (2013) Barriers to household risk management: evidence from India. Am Econ J Appl Econ 5(1):104–135

Elabed G, Bellemare MF, Carter MR, Guirkinger C (2013) Managing basis risk with multiscale index insurance. Agric Econ 44(4–5):419–431

GFCS (Global Framework for Climate Services) (2017) World Climate Conference3 (WCC-3). http://www.wmo.int/gfcs/wwc_3. Downloaded 3 Aug 2018

Hill RV, Hoddinott John, Kumar Neha (2013) Adoption of weather-index insurance: learning from willingness to pay among a panel of households in rural Ethiopia. Agric Econ 44(4-5):385–398

Liesivaara P, Myyrä S (2014) Willingness to pay for agricultural crop insurance in the northern EU. Agric Financ Rev 74(4):539–554

Marr A, Winkel A, van Asseldonk M, Lensink R, Bulte E (2016) Adoption and impact of index-insurance and credit for smallholder farmers in developing countries: a systematic review. Agric Financ Rev 76(1):94–118

McFadden D (1974) Conditional logit analysis of qualitative choice behavior. Front Econometrics 105–142

Panabokke CR (1996) Soils and Agro-ecological environments of Sri Lanka. Natural Resources Series—No. 2. Natural Resources, Energy and Science Authority, 47/5, Maitland Place, Colombo 7

Panda A, Sharma U, Ninan KN, Patt A (2013) Adaptive capacity contributing to improved agricultural productivity at the household level: empirical findings highlighting the importance of crop insurance. Glob Environ Change 23(4):782–790

Rosenzweig MR, Binswanger HP (1993) Wealth, weather risk and the profitability of agricultural investment. Econ J 103:56–78

Sandaratne N (1974) Using insurance to reduce risks in peasant agriculture. The Agricultural Development Council, U.S.A.
Tadesse MA, Shiferaw BA, Erenstein O (2015) Weather index insurance for managing drought risk in smallholder agriculture: lessons and policy implications for sub-Saharan Africa. Agric Food Econ 3(1):26
Vaughan C, Dessai S (2014) Climate services for society: origins, institutional arrangements, and design elements for an evaluation framework. WIREs Clim Change 5:587–603
Wairimu E, Obare G, Odendo M (2016) Factors affecting weather index-based crop insurance in Laikipia County, Kenya. J Agric Extension Rural Dev 8(7):111–121
Wollni M, Fischer E (2015) Member deliveries in collective marketing relationships: evidence from coffee cooperatives in Costa Rica. Eur Rev Agric Econ 42(2):287–314

Chapter 22
A Participatory Approach to Developing Community Based Climate Services in Zimbabwe: A Case Study of Uzumba Maramba Pfungwe (UMP) District

Juliet Gwenzi, Emmanuel Mashonjowa and Paramu L. Mafongoya

Abstract Climate change is projected to intensify the problems already faced by agricultural production systems. Tactical and strategic decisions are required to minimise agricultural losses while building resilience. Climate services focus on providing tailor-made climate information from grassroots levels. Therefore, this study focused on understanding climate information reaching smallholder farmers in Zimbabwe, the limitations and gaps, creating dialogue between scientists and climate information users in agriculture and development of an end-to-end community based climate services. A participatory approach was designed bringing together smallholder farmers as the users of climate information, agricultural extension officers and decision makers to identify extreme events and to develop guidelines for a scalable climate services in agriculture. Products developed were (a) a hot spot map of extreme events, (b) customised climate information for agriculture that is actionable and the establishment of a community weather observation hub. The study showed that smallholder farmers have potential to boost available climate information through observation and experience when actively involved. The use of climate information improved their agricultural output. We recommend that establishment of national climate services for agriculture be an iterative process that is continuously developed with full participation of smallholder farmers.

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Introduction

Climate change is projected to intensify the problems already faced by agricultural production systems. Sub-Saharan Africa (SSA) has been found to be highly vulnerable to the impacts of climate shocks due to its overdependence on rainfed agriculture with at least 63% of the population depending on agriculture (Fadina and Barjolle 2018). Climate change and extreme weather represent significant challenges to smallholder farmers in developing nations (Vedeld et al. 2016) whose adaptive capacity has been eroded by increased climate variability (Nhemachena and Hassan 2007). In many of these countries, agriculture production is core to achieving food security yet significantly weakened by the absence of support systems and policies favouring smallholder farmers who are in the majority and who are often negatively impacted by climate extremes. These farmers often occupy fragile land, are poorly resourced and often miss out on technology transfer. Frequent droughts, unpredictable start of season, shrinking length of growing season further exacerbate the situation. Sometimes, uncoordinated efforts in climate change adaptation, disaster risk reduction, climate smart programs, for example, have not brought coherence to push sustainable development agenda that is all encompassing (O'Brien 2012) because there is no ownership from the farmers. The degree to which farmers can adapt to climate change and increased climate variability depends on their capacity to take actions that lessen negative impacts on their agricultural operations (Antwi-Agyei et al. 2016). The absence of actionable climate information, which can assist farmers in clear short to long term decision-making increases their vulnerability to climate shocks and therefore food insecurity remains inherent in such communities.

Zimbabwe's economy is largely agro-based and agriculture is the main livelihood for at least 80% of the population and contributing 21% to the Gross Domestic Product (GDP) (ZIMSTAT 2014). By 2050, SSA is expected to experience a reduction of 50% in maize production (Schlenker and Lobell 2010) while Zimbabwe maize production is expected to reduce by at least 30% (Masanganise et al. 2012). This calls for new approaches that harness available technologies such as climate services in order to respond to climate shocks in a way that reduces loses in the agriculture sector while maximising on benefits. Currently, the country uses seasonal climate forecasts (SCF) as an entry point to using climate information. The SCF are generated by the Meteorological Services Department (MSD) based on statistical relationships between rainfall and sea surface temperatures. Oftentimes, the forecasts are given for regions of large covariation but with different rainfall regimes and hardly at micro-scale level. The forecasts are given as probabilities of occurrence (Mason and Chidzambwa 2009) and, therefore, do not account for spatial and temporal variation limiting the uptake of the forecasts (Gwenzi et al. 2016). To complement the SCF, the MSD produces daily weather forecasts, a weekly rainfall bulletin and forghtnightly agromet bulletin. However, the dissemination of the bulletins is limited to organisations and individuals who are able to pay a premium and the format in which they are presented do not allow direct use by smallholder farmers. The SCF is generated using a tercile method which yields three categories namely Above Normal (AN), Normal

(N) and Below Normal (BN) given as probabilities of occurence. The lack of clear and credible climate information has been highlighted as a major barrier to adaptation (Pasquini et al. 2013) thus creating bottlenecks in interventions to building resilient agricultural systems (Patt and Gwata 2002). Climate information can actively influence important farm decisions and activities (Pennesi 2011) and provision of climate information and services require robust systems with full participation of end users in the co-production of the information (Stigter et al. 2013). Farm decision-making requires climate information at different timescales ranging from daily to seasonal forecasts.

Climate services refer to the dissemination of climate information for the purpose of influencing decision making (Machingura et al. 2018). The importance of climate information services have been recognised by the World Meteorological Organisation (WMO) resulting in the birth of the Global Framework for Climate Services (GFCS). The thrust of climate services is generation, timeous provision, customization of information for decision-making for multiple sectors and at all levels of society in order to minimise climate related losses while enhancing the benefits (Vaughan et al. 2017). The success of climate services contributes towards achieving some of the Sustainable Development Goals (SDGs) such as poverty reduction (SDG1), promotion of sustainable agriculture (SDG2) and climate action (SDG13). In the absence of climate services and support from national policies and enabling institutions, agriculture systems will continue to be operated under compromised conditions resulting in significant losses.

This paper contributes to an understanding of how climate services can be established at local level though participatory approaches that identify the strengths of end-users and offer solutions relating to their particular needs in agriculture while incorporating the science at the center of climate services framework. The study was designed as an analysis of extreme weather events, access and dissemination of weather and climate information and the gaps and challenges thereof. Helping the farmers understand their vulnerability and involving the farmers provides a platform for ownership of the solutions. Through participatory approaches, a framework for provision of customised and action oriented climate services was developed at local level in Uzumba Maramba Pfungwe (UMP). The focus on the local level was influenced by the fact that climate change impacts locally and differentially across socioeconomic activities, providing room to understanding local needs and demands for transformative pathways in agriculture. We argue that it is not the size and scale that influence a functional climate services program but rather the relationship between users of climate information, scientists and policy makers that best explain approaches in the development of the services.

Study Area

The study was carried out in UMP district (Fig. 22.1) which is to the northeast of Zimbabwe. The district has a population of nearly 113,000 people and over 20,000

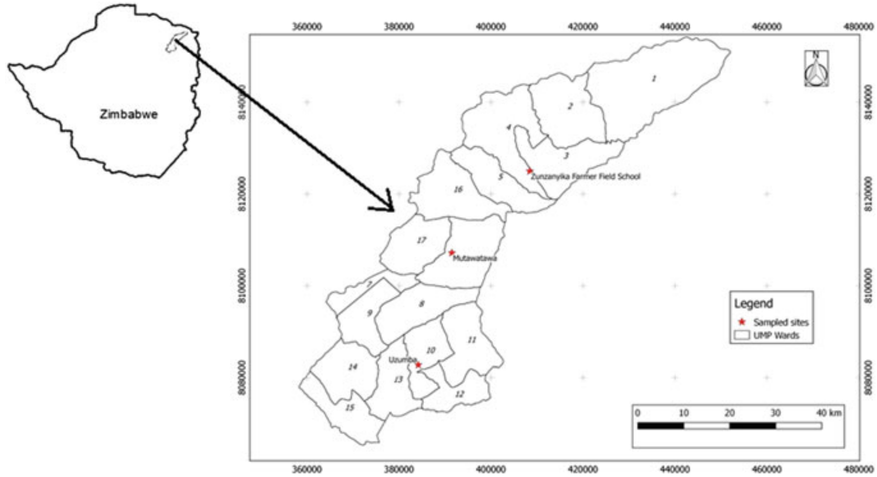

Fig. 22.1 Map of UMP District in Zimbabwe (insert) and the sampling points used in the project

households (ZIMSTAT 2014). UMP spans over three natural farming regions, that is, Agroecological region IIb, III and IV derived from using annual rainfall, length of growing period, temperature and soil type (Mugandani et al. 2012; Mberego and Sanga-Ngoie 2014; Vincent and Thomas 1960). The majority of UMP district (Maramba and Pfungwe) is in agro-ecological region IV which is characterized by low rainfall, high temperatures and usually long dry spells even during rainy periods. Maramba and Pfungwe thus have low potential for rain-fed crop production which are the major livelihood crops of the communities here. About 20% of the district (Uzumba north) is in agro-ecological region III characterized by frequent droughts, dry summer spells and short rainy seasons. Only 16% of UMP (Uzumba south) is in agro-ecological region IIB which has good granitic loamy soils and receives fairly good rains but is sometimes subject to mid-season dry spells (Mujaju et al. 2017). According to data collected during the study, the rain season stretches from October of one year to March of the following calendar year with a peak in January when monthly rainfall exceeds 100 mm over almost the entire district. Whilst no synoptic station or other (agro)meteorological stations exist in the district, the significant spatial variation in rainfall amounts received in the district is evidenced by the variation in vegetation. Information from the District Agricultural Extension Officer (DAEO) and from ZIMSTAT data (ZIMSTAT 2014), showed the livelihoods in UMP are strongly dependent on rainfed agriculture with major crops being maize, sorghum and, to a lesser extent, pearl and finger millet, as well as legumes. Market gardening is common in Upper UMP (Uzumba). The district was chosen for its lack of studies as a way to understand the intricacies of rainfed agriculture in semi-arid locations vis-à-vis the hope pinned on climate services to provide solutions to the vulnerable smallholder farmers living in such fragile environments (Haines 2018).

Data and Methods

Data were collected over three seasons from 2013/2014 season to 2017/2018. Several participatory rural appraisal exercises including key informant interviews, focus group discussions (FGDs), observation, participatory mapping, transact walks and seasonality trend analysis and household interviews set a platform for discussion between users of climate information, scientists, policy makers and other stakeholders. Each activity was inclusive of all social groups and recognised equity on gender. A semi-structured questionnaire was designed to extract knowledge on (i) hazards experienced and severity, (ii) access to available climate information, gaps and challenges to using the information and (iii) requirements and guidelines for a local climate service. Some of the guidelines were tested in the second and third season.

A total of 8 FGDS consisting of 20 people with equal representation of men and women of ages at least 25 years were held. These people were perceived to have gained enough knowledge of their environment such as to be able to give finer details of topics under discussion. The most vulnerable in the community were given voice where necessary. Results from key informant interviews were used to triangulate findings from FGDs. Among the key informants were the elderly who were considered to be the repository of community environmental knowledge and history as the well as district agricultural extension officers. Household surveys were conducted in 200 households across the district with an equal number in Uzumba and Pfungwe while less interviews were held in Maramba by virtue of it being a growth point whose greater population relied more on vending than agriculture. The choice of households was made with support from agricultural extension staff in the wards using random sampling techniques.

The MSD does not have a synoptic weather station in UMP. Therefore, gauged data used in this project was obtained from Mutawatawa Agritex office in Maramba starting from 1989. Automatic weather stations installed at Zunzanyika Farmer Field and Mashambanhaka provided data starting from 2013 and 2014 respectively. In order to supplement the gauged data, satellite rainfall estimates (RFE) for 15 sites, as shown in Fig. 22.1, were obtained from the National Aeronautics and Space Administration (NASA) Prediction of Worldwide Energy Resource (POWER) Climatology Resource for Agroclimatology. Coordinates of each point were used to retrieve the data. A comparison of satellite derived data and gauged data at Mutoko, a synoptic station 50 km away from the district, gave a correlation of 90% and therefore the data could be used with confidence. Similar studies done by Bolvin et al. (2009) gave a correlation of 85% in East Africa, Ethiopia and Zimbabwe. The data was analysed for hazards (dry spells, high temperatures, frost prevalence and droughts) using Instat+. The findings from the analysis and participatory approaches were synthesized to produce a map of the hot spots in UMP. The results shaped the discussions on the development of climate services required at the local scale in UMP.

To develop the framework for climate services, we engaged the scientists, policy makers at district level, government extension agents at ward level, councilors, NGOs and the smallholder farmers to identify entry points and to initiate dialogue on the development and provision of local climate services. A cross-fertilization of ideas from the different institutions identified training as the first and major component missing in having operational climate services in place. Training was done using the concepts in the Climate Field School (Winarto and Stigter 2013) approach being centered on developing and strengthening the ability of agricultural extension officers and smallholder farmers to utilise climate services beyond current levels. In order to improve the prominence of weather and climate information in terms of the format, timeliness and dissemination mechanisms, some guidelines for training for each layer were designed. Three levels of training were done.

The top layer consisted of the district Agricultural Extension officer (DAEO), support staff and heads of agricultural extension officers in the wards. The officers came together at Mutawatawa, where their offices are. Lectures were given on basic weather and climate information, approaches in climate services and overall management of the processes in the district. Practicals were done during the training of the second layer and during field work done from 2014 to 2018. The second layer consisted of the extension agents who interacted with farmers at grassroots levels. Concepts taught included meteorological data measurement with practicals, collection and analysis of meteorological data, generation of forecasts, terminology in weather and climate forecasts, weather systems affecting Zimbabwe and downscaling forecasts for local use. Rain gauges and rainfall registers were provided for practicals. The third layer consisted of a composition of extension agents and lead farmers. Training included data collection, record keeping and a means to making the smallholder farmers participate in tailored product development. Participatory games were used to demonstrate the meaning of some of the terms, for example defining AN, N and BN categories given in seasonal forecasts. A number of people stood in a line according to height. They were divided into 3 groups according to height. The tallest were said to represent AN rainfall, the middle group represented N category and the short ones represented BN rainfall. A cautionary statement was included, “it was uncommon to have one short person in a family of tall people neither was it uncommon to have average or tall person in a family of short people”. These heights were likened to representing the climate drivers for a location and how they could influence seasonal climate patterns. Attention was paid to developing farmer language for the purposes of effectively communicating climate information thereby influencing both short and long term decisions in agriculture. Components of the community weather observatory hub were discussed and validated in a forum with farmers from around the district. Further evaluation was done three years later (2017/18 season) to assess the impact of developed climate service on the community, identify new gaps and improve framework for climate services.

Results

The rainfall season in Zimbabwe is influenced by large scale atmospheric circulations such as westerly waves presenting as cloud bands in October–December and the Intertropical Convergence Zone (ITCZ) (Mamombe et al. 2016) which is most active in the period January to March. The establishment of the Angolan low pressure and another low in the Mozambican channel greatly influence weather over Zimbabwe and Southern Africa region (Munday and Washington 2017). Overall, the El Nino Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD) control the characteristics of the aforementioned systems (Manatsa and Mukwada 2012). An initial analysis by MSD, show that whenever an El Nino event was forecast, at least 60% of the times, BN rains occurred over Zimbabwe, with semi-arid areas being the most affected. Therefore, climatic hazards such as drought and dry spells are not uncommon in Zimbabwe. Semi-arid areas such as UMP are the worst affected and would require urgent support to be able to respond to climate extremes. Identifying the hot sports provided an understanding of vulnerability which informed the climate services requirements in the district.

Climatic Hazards Experienced in UMP

Findings from the participatory approaches revealed droughts, dry spells and high temperatures as the major climatic hazards experienced in UMP. Smallholder farmers in UMP indicated that prior to the year 2000, droughts had a return period of once in 5 years but there had been an increase in their frequency in recent years. Dry spells which used to occur usually after Christmas until early January had since increased in frequency and severity. To validate the smallholder farmers' perceptions, an analysis of rainfall and temperature data from Uzumba, Mutawatata and Zunzanyika revealed the following; long dry periods were being punctuated by short wet spells. Rainfall was concentrated towards end of January into February. For Upper UMP, [Uzumba (wards 8–15)], 10% of the time, rainfall season started around 18th November but in 90% of the time, the rains started by 11th December, a trend observed after the year 2010. For lower UMP [Pfungwe (wards 1–4)], the earliest time that rains could start was 27th November but 90%, of the time the rains started about 19 December. Length of growing season had shrunk to an average of 121 days in Upper UMP down from 146 days, while in Lower UMP, the length of growing period had reduced to 101 days from 135 days. Temperatures increased significantly during the summer months since the year 2012 resulting in high evaporative losses. Temperature spikes were now common in the period October to March. In Upper UMP, temperatures sometimes increased by as much as 3 °C, while in Lower UMP, temperatures sometimes increased by up to 5 °C for example in 2013 and 2014. Aphids were observed to affect legumes when temperatures were high. These evidences indicated Lower UMP as the most vulnerable. The map in Fig. 22.2 shows the vulnerability of UMP to drought, dry spells and high temperatures, where Lower UMP is in a hot spot. The evidence made the farmers realise why there was a continuous weakening and breakdown of rainfed agricultural systems under the prevailing harsh conditions. The provision of timely, accurate and action oriented information was envisaged to minimise the impact of these hazards on agricultural systems.

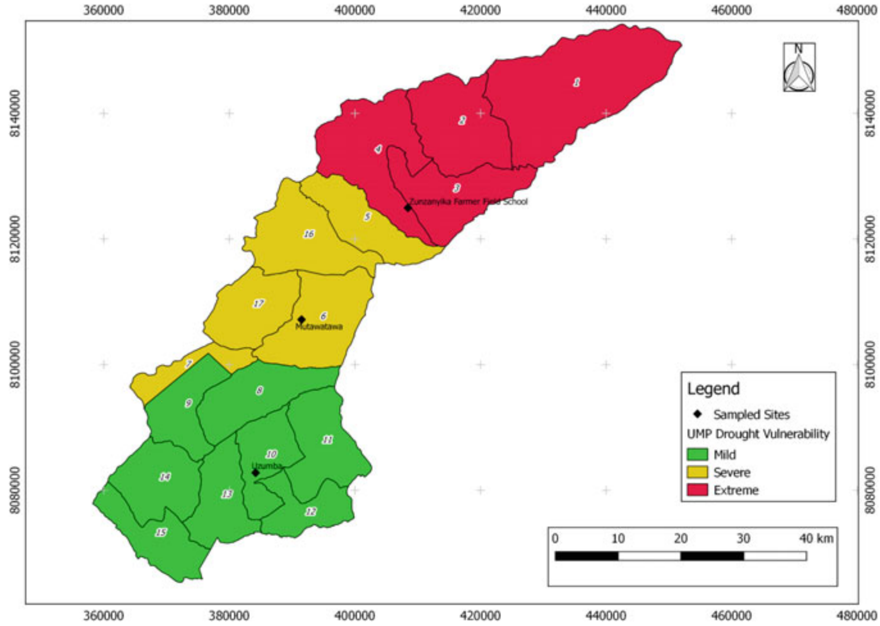

Fig. 22.2 Vulnerability of UMP district to droughts, dry spells and high temperatures

Climate Information Access, Gaps and Challenges

The most common climate information provided to farmers was SCF and daily forecasts. Information was received through radios (at least 50%) and Agricultural extension officers usually at farmer gatherings. It was observed that 67% of farmers in Uzumba accessed weather information compared to 30% in Pfungwe. While more people (nearly 80%) had access to the radio in Maramba, most of them did not pay particular attention to forecasts as their livelihood was focused on buying and selling. Overally, more males (61%) received climate information compared to their female counterparts at 37%. While rainfall and Agromet bulletins were produced by MSD, they were only available through subscription after paying a premium. The payment was beyond farmers reach apart from them being unable to access internet-based forecasts. As such, most of the vulnerable households had very limited access to climate information. They relied on social networks to access weather and climate information. The farmers indicated they preferred simple text based messages send through their mobile phones. They also preferred a local observing station to provide local data rather than from remote areas.

The farmers highlighted that climate information available lacked specificity in onset dates, dry spell and wet spell periods and end of season dates, information which the farmers considered very vital for decision-making. Although SCFs were disseminated ahead of the rainfall season, the absence of tailored and action oriented climate information presented challenges to fully utilise the forecasts, a challenge echoed from all quarters of society. Lack of such information resulted in agricultural losses as sometimes farmers had to replant in cases of poor germination and false start of season. The categories used in the SCF were obtained using sparse data and therefore could not allow for generation of locally specific climate information. Farmers preferred forecasts given at ward level. All the farmers wanted information of how the 'normal/average' value was generated so they could actively participate in improving the value. The terms used in daily weather forecasts were technical apart from referring to large areas. Farmers were not sure what 'isolated, scattered, widespread and numerous thundershowers' meant resulting in low utilisation of the forecasts. These concepts were explained during training sessions. Similar observations were made in Tanzania (Coulibaly et al. 2015).

Dissemination challenges added to the burden on UMP smallholder farmers. Weather and climate information were disseminated in English through the radio, TV and print media yet the UMP community had marginal technological infrastructure to access the forecasts. Where the forecasts were given in a local language, the radio station or newspaper shouldered the responsibility of interpretation, sometimes distorting the original meaning. With nearly everyone living under the footprint of a mobile phone, at least 90% of the farmers preferred an SMS based forecast. The farmers interacted with extension agents nearly every week and at least 75% preferred messages given through trained extension agents. Messages could also be disseminated through schools for daily transmission to farmers with learners being the conduit. In order to provide climate information in which the communities actively participated, farmers suggested the setting up of a community weather observation hub. A mini weather station manned by an extension agent would provide data to be fed into the national database and used in the generation of forecasts. To increase density of observations, lead farmers were proposed as the active players in the community who could provide rainfall data after following the training they had received. Such data would be useful in calculation of 'normals/average' for locals and for the district. Basic plastic rain gauges were given to farmers to achieve this goal. In the absence of climate forecasts, the farmers relied on indigenous knowledge indicators to make decisions, which too were also being affected by climate change. The farmers called for an integration of scientific forecasts which were mature with indigenous knowledge systems which still required further investigation.

Demand for Climate Products

Having created a local database from own observations, the farmers requested for higher resolution weather and climate information. For the development and implementation of a functional climate service the farmers suggested activities that would promote a functional and useful locally driven climate service:

a. Active participation in data collection by lead farmers.
b. At least one month lead time in dissemination of SCF.
c. Provision of accurate information on the start of season with a lead time of at least one week.
d. Provision and dissemination of advisories and warnings with at least one week lead time.
e. Support for crop suitability study.
f. Provision of tailor-made Agromet and Rainfall bulletins.
g. Provision of advisories and warnings targeted at livestock production.
h. Future climate scenarios and expected impacts on crop production.
i. An accessible community weather observation hub.
j. Provision of advisories to support non-farm livelihood systems.

Framework for Development of Climate Services

Following the consultations, guidelines were produced on the provision of local climate services. The end-to-end process is given in Table 22.1. District staff take the oversight role and they address governance and institutional arrangements. Training on processes and procedures would help the staff to understand linkages between institutions and to liaise with policy makers. Scientists and agricultural extension agents work together through institutional arrangements transforming weather and climate information into a service. Advisories and warning were designed as part of training of extension staff. For example, advisories on fertilizer application, spraying of crops and pest and disease management were given based on prevailing weather

Table 22.1 Steps in the development of climate service framework as identified during field work

Activity	Objective	Challenge addressed
1. Training of district staff	Establishing institutional arrangements and address governance issues	Accountability and sustained interaction with policy makers
2. Training of extension agents	Delivery of climate services at local scale	Cascading climate information to grassroots levels
3. Training of lead farmers	Giving farmers ownership in design, production and evaluation of climate services	Empowering communities leading to legitimacy of climate services that transform agricultural systems
4. Evaluation of climate service	Identifying new gaps and continuous improvement of activity 2	Sustainability of climate services Poverty alleviation

conditions. Through extension agents and lead farmers, such information was cascaded to grassroots levels. The community responded by taking corrective measures and providing feedback at the weekly meetings held at community observation hub. The meeting started with an evaluation of forecast given in the previous week, the actual observations made, forecast for the following week and the actions to be taken.

Figure 22.3 provides a non-hierarchical framework of actors and their relationship in the development of a climate service. The ultimate objective is the provision of seamless climate information which gives the farmer the power to demand for services at different time scales in order to manage the risks evolving in each season. Explaining the probabilistic nature of the forecasts helped the farmers manage the uncertainty in the information provided throughout each season and therefore minimising the losses that they would have incurred without climate information.

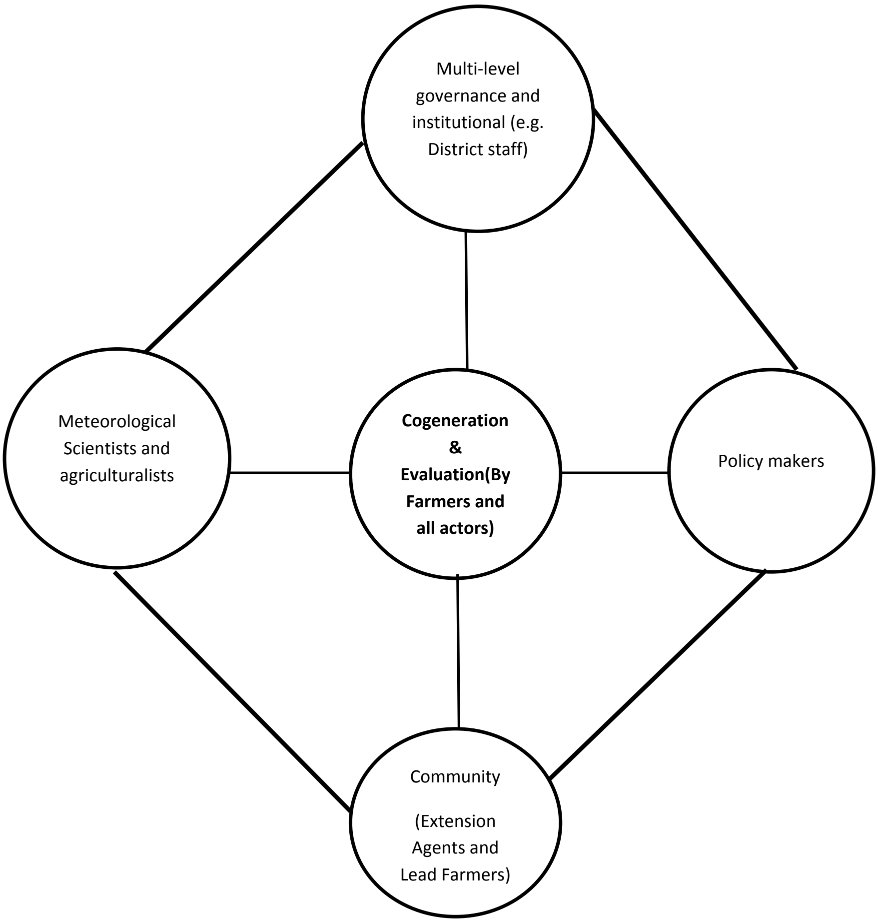

Fig. 22.3 Actors and their non-hierarchical interactions in the development of a climate service

Discussion

The climatic hazards experienced in UMP gave insights into the extent of the influence of climate extremes on agriculture. Droughts, severe dry spells and high temperatures were of major concern among the farmers as these reduced production to one third causing food insecurity especially in the lean months (September to January). In good years farmers sold part of their harvests. The income generated would be invested in a community bank to earn some interest. Low production had a ripple effect on the farmers. Since community banks were strongly linked to the production levels, poor harvests led to a collapse of the banks. Once the community banks collapsed, farmers were not able to supplement food and to buy seed for the following season. Most livelihoods in UMP being farm-related and rainfed, climate services will provide a backbone for building resilience against climate change and increased climate variability.

The shrinking of length of growing season for UMP requires tactical decisions to be made based on available climate information. Seed systems needed a transformation to suit new conditions. Farmers responded to the climatic changes by adopting small grains, however, large portions of farmland were still being used for maize. Whilst climate information was being produced, the low numbers of farmers utilizing the information had to do with access issues and lack of trust (Patt and Gwata 2002). The farmers preferred forecasts which were in vernacular and providing information at ward level. The absence of dialogue between users and producers of climate information put legitimacy of the forecasts at stack. Farmers relied on local knowledge which included observation of biotic factors, however without science, the indigenous knowledge systems had no basis. To date the science of indigenous forecasts has not matured to give such level of detail missing in scientific forecasts especially in developing countries already dominated by data paucity. Climate services propose new approaches that do not focus merely on the use and usability of a product but on the performance of agricultural livelihoods supported by correct policies and active end-users (Roncoli 2006).

Farmers suggested training at all levels as a way of creating dialogue with other stakeholders in the development of climate services. The farmers recognised the need for intermediaries who would be locally available yet able to translate climate information into products readily usable by the smallholder farmers. The intermediaries, who are extension agents, would translate information to other understandable formats by farmers through the development of 'farmer language'. The participatory approach which led to the development of a hot spot map showed that communities can collaborate with scientists to provide solutions to climatic problems. Emerging from the discussions was the need for climate information at different spatial scales. Thus, early involvement of end-users of climate information and stakeholders provided a quick win through iterative training. Face to face dialogue gave room for farmers and experts to discuss complex intra-seasonal climate changes and their bearing on farm activities.

The weather systems outlined in the introductory part of the results were explained in great detail to give farmers an appreciation of the complexity of science involved in forecasting. It was a necessary step that set extension agents, farmers and scientists on the same level. Explaining terminology used in weather and climate forecasts became relatively easy as farmers could link local observations to circulations that brought rainfall or dry conditions over the country. Of major interest were the ITCZ and the El Nino phenomena as these were the most talked about during the rainfall season. The farmers in UMP identified the ITCZ as the major system bringing rainfall to the district. The training offered insights into the stability of the atmosphere resulting from persistently cold air being pumped into the country. Farmers could explain the changes in seasons based on heating experienced in the months of September and October. Also, the position and trajectory of cyclones and their influence on summer rainfall was articulated in the highly interactive training sessions. The information shaped the components of the climate services.

The community weather hub, when fully functional, would have a noticeboard on which the weather forecasts, advisories and warnings would be posted and also, a rain gauge for daily rainfall measurement. At agreed times during the day, the hub would be opened to community members. Local extension agents would meet to share rainfall information recorded around the locality. For a start, local farmers meet here once a week together with their local extension agents, to update each other on past and future weather events and to propose a cocktail of activities which could be done based on forecast information received. The agents provided guidance to the farmers. This showed that the farmers appreciated climate services more than before. Currently, farmers met under the operation of a Farmer Field School which had evolved into a Climate Field School. The willingness to apply climate information now shaped the farm operations.

Rainfall varies over short distances unlike temperature. Therefore, a dense rainfall network is necessary for operating climate services. The observations helped farmers understand microclimates in their locality. Using social networks, farmers could move livestock to areas with better pastures and more drinking water. Movement was based on the understanding that, if kept in impoverished pastures, cattle health got compromised as well as the breed size. Selling such cattle did not provide relief to farmers as they often would get low prices such that, during good years, they failed to buy back the livestock they would have sold. Less rainfall increased chances of pests and diseases such as aphids on cowpeas. Therefore, scouting was consistently done to minimise damage. High temperatures in the 2014/15 resulted in aphid infestation which had to be controlled using chemicals. Being poorly resourced, chemicals for spraying were not easily accessible. Based on available climate information, farmers decided on selling or retaining extra cereal. Post- harvest losses were carefully considered whenever cereal was retained. Control measures for the grain borer were more critical in lean years as happened in 2015/16 season when total crop failure was experienced. Every season, the farmers managed risk through crop diversification, a strategy suggested by Makate et al. (2016). There was an increase in land put under small grains and legumes.

Conclusion

In developing nations whose economies are based on agriculture, the influence of climate on agriculture means an increase in demand for easily accessible, tailored, accurate and timeous climate information will increase every year in response to climate fluctuations. The increase in temperatures, particularly in summer months, frequent droughts and dry spells called for action supported by the availability of climate services. Climate services will ensure that end-users make deliberate, informed decisions to minimise losses associated with vagaries of weather while making the most of the benefits of climate variability. Therefore, understanding climatic hazards was key to the development of climate services that meet local needs in UMP. Establishing a functional and seamless climate service calls for new approaches that combine diverse knowledge systems and sees the end user as a partner in the development and dissemination of climate information. When farmers become active partners, they evaluate the service with the purpose of improving products generated. Promoting inclusiveness created pathways for scientists and farmers to dialogue on critical issues in a non-hierarchical form thereby building trust which increased uptake of climate information. Farmers in UMP found an opportunity to dialogue vertically and horizontally without bottlenecks. Dissemination of climate information should not be limited to radio, Tv and print media but should combine with methods used by the most vulnerable farmers. From the results of this research we ascertain that the success of climate services program borders around the relationship between the end-users of information, the scientists and policymakers. Farmers are scientists in their own right, who have experimented and adjusted their systems to new climatic conditions and their engagement in climate services development is critical. We recommend that the establishment of national climate services for agriculture be an iterative process that will be continuously developed with the full participation of smallholder farmers.

References

Antwi-Agyei P, Quinn CH, Adiku SGK, Codjoe SNA, Dougill AJ, Lamboll R, Dovie DBK (2016) Perceived stressors of climate vulnerability across scales in the Savannah zone of Ghana: a participatory approach. Reg Environ Change 17:213–227

Bolvin DT, Adler RF, Huffman GJ, Nelkin EJ, Poutiainen JP (2009) Comparison of GPCP monthly and daily precipitation estimates with high-latitude gauge observations. J Appl Meteorol Climatol 48:1843–1857

Coulibaly JY, Mango J, Swamila M, Tall A, Kaur H, Hansen J (2015) What climate services do farmers and pastoralists need in Tanzania? Baseline study for the GFCS Adaptation Programme in Africa. CCAFS working paper no. 110. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), Copenhagen, Denmark

Fadina AMR, Barjolle D (2018) Farmers' adaptation strategies to climate change and their implications in the Zou department of South Benin. Environments 5:17

Gwenzi J, Mashonjowa E, Mafongoya PL, Rwasoka DT, Stighter K (2016) The use of indigenous knowledge systems for short and long range rainfall prediction and farmers' perceptions of science-based seasonal forecasts in Zimbabwe. Int J Clim Change Strat 8:440–462
Haines S (2018) Managing expectations: articulating expertise in climate services for agriculture in Belize. Clim Change 17
Machingura F, Nyamwanza A, Hulme D, Stuart E (2018) Climate information services, integrated knowledge systems and the 2030 Agenda for sustainable development. Sustain Earth 1:1–7
Makate C, Wang R, Makate M, Mango N (2016) Crop diversification and livelihoods of smallholder farmers in Zimbabwe: adaptive management for environmental change. SpringerPlus 5:2–18
Mamombe V, Kim W, Choi Y-S (2016) Rainfall variability over Zimbabwe and its relation to large-scale atmosphere–ocean processes. Int J Climatol 37:963–971
Manatsa D, Mukwada G (2012) Rainfall mechanisms for the dominant rainfall mode over Zimbabwe relative to ENSO and/or IODZM. Sci World J 2012:15
Masanganise J, Chipindu B, Mhizha T, Mashonjowa E (2012) Model prediction of maize yield responses to climate change in north-eastern Zimbabwe. Africa Crop Sci J 20:505–515
Mason SJ, Chidzambwa S (2009) Position paper: Verification of African RCOF forecasts. International Institute for Climate and Society, Palisades, New York
Mberego S, Sanga-Ngoie K (2014) Using locally captured climatic information for guiding local-level agriculturalists in Africa: a case study of Makonde district in Zimbabwe. J Land Use Sci 9:178–194
Mugandani R, Wuta M, Makarau A, Chipindu B, Gweru SR (2012) Re-classification of agro-ecological regions of Zimbabwe in conformity with climate variability and change. Afr Crop Sci J 20:361–369
Mujaju C, Mashonjowa E, Kasasa P, Otieno G (2017) Climate-resilient seed systems and access and benefit-sharing in Zimbabwe: exchanging genetic resources in a changing climate. Climate-resilient seed systems and access and benefit-sharing in Uganda. Integrated Seed Sector Development in Africa (ISSD-Africa), Uganda
Munday C, Washington R (2017) Circulation controls on southern African precipitation in coupled models: the role of the Angola low. J Geophys Res Atmos 122:861–877
Nhemachena C, Hassan R (2007) Micro-level analysis of farmers' adaptation to climate change in Southern Africa. International Food Policy Research Institute, Washington, DC
O'Brien K (2012) Global environmental change II: from adaptation to deliberate transformation. Prog Hum Geogr 36:667–676
Pasquini L, Cowling RM, Ziervogel G (2013) Facing the heat: barriers to mainstreaming climate change adaptation in local government in the Western Cape Province, South Africa. Habitat Int 40:225–232
Patt A, Gwata C (2002) Effective seasonal climate forecast applications: examining constraints for subsistence farmers in Zimbabwe. Glob Environ Change 12:185–195
Pennesi K (2011) Making forecasts meaningful: explanations of problematic predictions in Northeast Brazil. Weather Clim Soc 3:90–105
Roncoli C (2006) Ethnographic and participatory approaches to research on farmers' responses to climate predictions. Clim Res 33:81–99
Schlenker W, Lobell DB (2010) Robust negative impacts of climate change on African agriculture. Environ Res Lett 5:014010
Stigter K, Winarto Y, Ofori E, Zuma-Netshiukhwi G, Nanja D, Walker S (2013) Extension agrometeorology as the answer to stakeholder realities: response farming and the consequences of climate change. Atmosphere 4(3):237–253
Vaughan C, Hansen J, Roudier P, Watkiss P, Carr E (2017) Evaluating agricultural weather and climate services in Africa: evidence, methodology, and a "learning agenda a learning agenda. A Learning Agenda on Climate Information Services in Sub-Saharan Africa (USAID)
Vedeld T, Coly A, Ndour NM, Hellevik S (2016) Climate adaptation at what scale? Multi-level governance, resilience, and coproduction in Saint Louis, Senegal. Nat Hazards 82:S173–S199

Vincent V, Thomas RG (1960) An agroecological survey of Southern Rhodesia Part 1: agro-ecological survey. Government Printers, Salisbury

Winarto Y, Stigter K (2013) Science Field Shops to reduce climate vulnerabilities: an inter- and trans-disciplinary educational commitment. Collaborative Anthropol 4:419–441

ZIMSTAT (2014) Facts and figures—Zimbabwe: 2013. Government Printers, Harare

Chapter 23
Food Security in the Face of Climate Change at Kafa Biosphere Reserve, Ethiopia

Teowdroes Kassahun and Svane Bender

Abstract Diversification of crops is a critical risk management strategy for famers in the south-western part of Ethiopia and may play a vital role in adapting to a changing climate. This study explores opportunities of climate resilient and adaptive crops for farmers' adaptation for food security at Kafa Biosphere Reserve. In order to understand farmers' perception of local impacts of climate change and adaptation means through reintroduction and fostering of old and resilient crop varieties, a combination of qualitative and descriptive statistics methods have been used. Focus group discussions, Participatory Rural Appraisal and direct matrix methods were set in relation to the variety of crops grown in the area and other environmental, social and economic factors. A group of climate adaptive or resilient crops were identified by the farmers and favoured as tolerant against the increasingly variable rainfall and temperature. The study reveals that the farmers' perceptions are in accordance with the trend analysis done on the metrological variables using the Mann-Kendall test as well as the Sen's slope estimator. Against this background, NABU, a German based NGO, initiated an agricultural adaptation programme for local farmers aiming ultimately for long-term food security.

Introduction

Based on the assessment report from the Intergovernmental Panel on Climate change (IPCC 2013) the global average temperature is projected to reach 1.8–4 °C by the end of twenty-first century. Since the year 1906–2005, the temperature has increased already by 0.74 °C (IPCC 2007). Global warming and the resulting climate change is currently affecting millions of people, especially low income and agriculture dependent communities due to its severe impact on agricultural production (Mertz et al.

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2009). One of the regions that are expected to be hit intensively by extreme weather events both in frequency and intensity is Sub-Saharan Africa. The disproportionate reliance of the countries in this region on rain-fed agriculture makes them more vulnerable, as the agricultural productivity in the tropics is forecasted to shrink due to high frequency of drought (IPCC 2013). In the absence of a concerted international effort to curb greenhouse gas emissions, climate change will increase existing poverty levels and food security (Adger and Barnett 2009). Given that climate change predictions are much worse for the future, it will be challenging to increase agricultural productivity by 70% to meet the rising population demand by 2050 (FAO 2017). Countries like Ethiopia, where more than 40% of the country's national GDP, 90% of its exports, and 85% of the population's employment are dependent on rain-fed agriculture will be affected massively (MoFED 2007).

Several studies show Ethiopia as one of the most vulnerable countries to climate change and variability (World Bank 2010; Parry et al. 2007; Conway and Schipper 2011). This is based on historic climate events where rainfall variability and drought were the main cause for famine in recent memories (World Bank 2010) and the country's low capacity to cope and adapt to climate change (Stige et al. 2006). Moreover, its farmers' depend on rain-fed agriculture with traditional technologies and low input (Deressa 2007). Even in average rainfall years, 10% of the Ethiopian population faced chronic food shortages and was dependent on food assistance (Conway and Schipper 2011). Generally, climate change is projected to massively decrease the yields of cereal crops in East Africa by shortening growing seasons, increasing the incidence of crop diseases and intensifying water shortages (Niang et al. 2014). Thus, finding solution to this pressing issues and working on various adaptation strategies is critical (Deressa et al. 2011). One option is to promote climate—resilient crops which are considered as opportunity to tackle decreasing yields and thus food insecurity due to climate change (Kathuria et al. 2007).

This paper presents a study on potentials of climate adaptive crops in Kafa Biosphere Reserve (KBR) in Ethiopia. In particular, we assessed the local agriculture and flora of selected sites at KBR in order: (1) to identify 12 climate resilient commercial crops and (2) to identify five climate adaptive crops which are suitable for re-introduction to local agriculture. KBR offers optimum conditions for addressing and testing these issues due to its high rate of endemism and variability of ecosystems. Moreover, over time, people have indirectly shaped plant communities and species. Some have been domesticated in home gardens and in the fields together with farmers cultivated food and cash crops.

However, the potentials of alternative income-/food-/energy sources are generally unexploited and old, adapted crops are unused and slide into oblivion. Especially, the old adapted crops can contribute significantly to food security and an increased agricultural biodiversity ('agro-biodiversity'). In line with this local finding, FAO (1999) claims more than 90% of crop varieties have disappeared from farmers filed worldwide; and loss of forests cover and other uncultivated wild areas have exacerbated the genetic erosion of agrobiodiversity. At the same time the area is confronted by climate change from irregular rainfalls, extreme weather events and droughts. Challenged with this reality, The Nature and Biodiversity Conservation Union (NABU), a German NGO, initiated a study of the local flora and locally used crop species as climate resilient species for adaptation in and around KBR in 2015.

So far, a relevant number of papers and reports have been published addressing climate change as well as the rich biodiversity in and around KBR (e.g., NABU 2017; Hylander et al. 2013; Schmitt et al. 2010; Hylander and Nemomissa 2008). However, a study on impacts of climate change and adaptation measures such as climate adaptive crops has not been published for that area. This paper aims to fill this information gap.

Materials and Methods

Study Site

The KBR is located in the Kafa Zone (7.22° E–7.84° E and 35.59° N–37.17° N), in the Southern Nations, Nationalities and People's Regional State in South-western Ethiopia, covering an area of 760,000 ha (Fig. 23.1).

The area has a seasonal climate with annual rainfall of around 1800 mm and rainy season lasting from June to September. It has also an extremely diverse topography

Fig. 23.1 Location of study area in south-western Ethiopia, at Kafa biosphere reserve, Ethiopia (Bender and Tekle 2018)

with altitudes ranging from 1020 to 3350 m.a.s.l. and an average annual temperature 19.45 °C (Dresen 2014). The range of altitudes creates a transition of flora: at the highest altitudes, a complex vegetation structure of evergreen mountain forests and grasslands is dominant, while further down the mountain slopes, the Afromontane moist evergreen broadleaf forest or cloud forest is home to the wild *Coffea arabica*. The reserve harbours 45,000 ha of extensive wetlands and floodplains that are parts of the headwater of Gojeb, Baro and Gilo draining into the Omo-Gibe and Baro-Akobo river basins (NABU 2017).

The BR is part of the catchment area of the three large rivers (Gojeb, Dincha and Woshi). The area has a seasonal climate with annual rainfall of around 1800 mm and rainy season lasting from June to September. It has also an extremely diverse topography with altitudes ranging from 1020 to 3350 m.a.s.l. and an average annual temperature 19.45 °C (Dresen 2014). The KBR is an area of global significance as it relates to both its natural components (natural capital) and its human inhabitants and their cultures and traditions (human capital). Significant part of the population are rural community growing maize and teff *(Eragrostis tef)* on farmlands and different vegetables in their garden (Hylander and Nemomissa 2008). The area also contains genetic elements (such as the wild *Coffea arabica* populations) and a high degree of diversity and endemism that evolved over thousands of years (DMP 2009). It is host to Ethiopia's 50% of remaining moist montane forest. The area is rich in ecosystems and provides a unique habitat for more than 250 plants species, 300 mammal species and 300 kind of birds, under it dense primeval forests, grasslands and wetlands (NABU 2017). The area is also recognized as part of an Eastern Afromontane Biodiversity Hotspot and key Biodiversity Area. It was designated as UNESCO biosphere reserve in 2010. It has a forest cover of 47% with 4% (28,172 ha) being core zone serving as a refuge for endemic or endangered species. And has been recognised for its remarkable species endemism (NABU 2017). The area is particularly noteworthy as global in situ gene bank being the origin and centre of *Coffea arabica*'s genetic diversity.

650,000 people live in the premises of Kafa Biosphere Reserve. With an average of 98% inhabitation per km^2, the range extends from 52 to 210 inhabitants per km^2 (SNNPR 2013). More than 90% of the inhabitants' livelihoods depend on subsistence farming, the sale of coffee (10% forest coffee/65% garden coffee), forest honey and the use of natural resources e.g. for food, fuel, building material and medicinal plants or spices (SNNPR 2013). Mainly grain is being cultivated, including the local Ethiopian grain species teff (Eragrostis teff), legumes and the locally important Abyssinian banana (Ensete ventricosum), whose starch-rich stem is fermented for bread. The most common livestock is cattle (7.5 per household, 2011/2012, local government), followed by poultry, sheep and goats. Wild coffee harvesting has been practised over centuries; complex tenure arrangements and traditions and rites have been developed (Bender and Tekle 2018).

Sampling and Data Collection

A detailed household survey was conducted in July 2015, involving experienced and well-trained development agents as enumerators who are native to the area and fluent with the local language as well as the culture. A total of 47 farmers participated in the survey from the five selected districts located within the boundaries of KBR and neighbouring villages. The sampling site selection took into consideration agro-ecological variations of the study area. Accordingly, the three traditional major agro-ecology systems were included: lowland (<1500 m.a.s.l), midland (1500–2400 m.a.s.l) and upland (>2400 m.a.s.l). To ensure the accuracy of the collected information, Focus Group Discussion (FGDs), interviews with key informants and stakeholder workshops were conducted. Participants were selected based on their willingness and availability to take part in the survey within the specific population that amounts to a purposeful sampling (Patton 2005). The method used for selecting the 47 farmers for the survey was as follows: All participants on the survey had to live within the KBR or surrounding villages. The majority of the participants can be considered as key stakeholders who have already been involved by NABU during the zonation and demarcation process of KBR. Furthermore, knowledge on local crops and traditional agriculture schemes were considered as criteria for selection (Picture 1).

To address the question of climate change perception by the farmers, we relied on qualitative methods. Semi-structured questionnaires were used to understand the perception on climate change and its impacts. Furthermore, probing questions were also posed during the interview to go further in-depth and capture perceptions on specific characters such as the type of crops grown or the management applied in fields and home gardens. The set of open-ended questions encouraged conversations around two main themes: (1) farmers' traditional agricultural practice, crop management, their perception of their vulnerability to climate change and potential adaptation measures; and (2) Farmers' management with respect to the wild coffee forests. The semi structured questionnaires were developed in advance and pre tested using randomly chosen farmers in order to correct flows found in the questionnaires.

Common and scientific names of plant species were identified using Hedberg and Edwards (1989), Phillips (1995), Edwards et al. (1995, 1997), Hedberg et al. (2003) and Tadesse (2004). Finally, climate data from The Royal Netherlands Meteorological Institute (KNMI) was accessed for the entire study area.

The study was commissioned by NABU, and bound to specified time and budget limit. Hence, it was not possible to include other variables that require laboratory analysis that may have helped to enrich the study and give in-depth insight to climate change realities at KBR.

Picture 1 Local farmer in a typical home garden setting (NABU)

Data Analysis

A combination of qualitative analysis as well as descriptive statistics was used to analyse the data. The descriptive statistics included tables, minimum, maximum, frequency, percentage, ratio and means. By organizing and categorizing the data into similar themes, a qualitative analysis was conducted. Furthermore, crop ranking was undertaken through active participation of participants from KBR. The ranking followed pair wise ranking (Kumar 2002) and the direct matrix method. Other participatory methodologies such as the seasonal calendar and trend analysis were also conducted.

Drought/water stress tolerance, resistance to crop disease, pests, nutritional value and market demand in terms of income generation were used as a selection criteria for ranking crops in each category (cereals, pulses, vegetables, fruits, spices, roots and tubers and common commercial crops); cereals compared with cereals, pulses compared with pulses etc. Based on the criteria, farmers made the ranking of crop

Table 23.1 Results of the trend analysis on climatic variables

Variable	Mann-Kendall's tau	*P*-value	Sen's slope	Mean	SD
T Max	0.588	<0.0001*	0.026	19.704	0.53
T Min	0.587	<0.0001*	0.027	14.68	0.53
Annual rainfall	−0.202	0.018	−1.452	1597.90	84.22
January rainfall	−0.012	0.889	−0.018	47.23	14.49
December rainfall	−0.043	0.618	−0.062	68.40	13.84

*Two-tailed test at significance level; $\alpha = 0.05$

species in each category. Finally, the crop species that ranked at the top in the respective category from the direct matrix approach was then once more ranked using pair wise ranking, so that climate resilient commercial crops were clearly selected.

From the climate data, the Mann-Kendall test, a non-parametric test, was conducted in order to detect statistical significance in the long-term climate data. For evaluating the direction of trends and also to compare the farmers' perception with the climate data, the Sen's slope estimator was used. The Sen's estimator shows the direction and magnitude of slope in the weather trend, whereas the Mann-Kendall test checks the null hypothesis with no trends and alternative hypothesis of increasing or decreasing trend (Gadgil and Dhorde 2005) (Table 23.1).

Results and Discussion

Local agricultural crops and flora

A total of 77 species representing 32 flowering plant families were recorded, that are currently being used by the local community in the selected field sites. From these 6 are endemic to the locality, 19 are indigenous and the remaining 52 are introduced plants (Table 23.2). Among these, the Fabaceae and Poaceae plant families represented the highest number and the most commonly used crops species group in the study area (Picture 2).

The recorded species were further divided into cultivated (63), semi cultivated (7), wild (3) and escaped to the wild (4). For instance, plant species that escaped and naturalized in the natural habitat are *Colocasia esculenta, Capsicum frutescens and Psidium guajava*. Semi-cultivated plants are those plants which are partly cultivated for their socioeconomic values. Similarly, *Coffea arabica* and *Ensete ventricosum* are good examples of domesticated plants; plants that were primarily growing in the natural forest and then domesticated and cultivated on farm and/or around homesteads by the local communities. These plants have various uses for the community including medicinal value, nutrition and source of cash income. For instance, *Chata edulis, Coffea arabica*, *Rhamnus prinoides* and *Camellia sinensis* are some of the plant species preferred by the communities for clear commercial purpose. The KBR and

Table 23.2 Cumulative scoring of 30 species that were repeatedly selected by farmers

	Crops	Site 1	Site 2	Site 3	Site 4	Site 5	Total score
1	Ensete ventricosum	10	10	7	12	8	47
2	Coffea arabica	9	9			9	27
3	Persea americana	6	6		5	5	22
4	Zea mays	8	8				16
5	Colocasia esculenta	4		4	5	1	14
6	Triticum sp.	7			7		14
7	Pisum sativum		4		9		13
8	Vicia faba			4	8		12
9	Aframomum cororima	3	5			4	12
10	Eragrostis tef				11		11
11	Camellia sinensis	11					11
12	Hordeum vulgare				10		10
13	Sorghum bicolor			6		3	9
14	Brassica carinata	4	4				8
15	Capsicum annum					6	6
16	Zingiber officinale					6	6
17	Allium sativum					6	6
18	Xanthosoma sp.		4				4
19	Ipomoea batatas	2			2		4
20	Catha edulis	3					3
21	Humulus lupulus	0			3		3
22	Piper nigrum			2			2
23	Gobello/climber bean	2				0	2
24	Gobo/bean		2				2
25	Mangifera sp.			1			1
26	Linum usitatissimum		1				1
27	Musa sp.				1		1
28	Brassica napus			0		1	1
29	Malus pumila				0		0
30	Ruta chalepensis		0				0

its surrounding are part of the tropical forest ecosystems that have exceptional species richness and higher concentration of endemic species (Schmitt et al. 2010). The area is also recognized internationally as part of the Eastern Afromontane Biodiversity Hotspot (Mittermeier et al. 2004). A recent biodiversity assessment at KBR found around 50 species, which are new to science (NABU 2017). This implies that the number of species identified in the area are massively underrated and more species are to be expected, if the number of study sites would have been higher.

Picture 2 Local bean variety

Perception of climate change and trend analysis

The age distribution of the household members in this study is shown in Fig. 23.2. The average age of the farmers was 43. The majority of the respondents (46.8%) fell in the range of 18–37 years of age, which is generally referred to as young and productive members of the community. About 34.04% of the households' members were at the age of between 38 and 57 years (active and experienced members). And around 5% of the household members were retired and they were between 78 and 97 years of age. Given that almost all respondents were farmers, it is possible to say with certainty they are engaged in agricultural activities, which is likely to give them exposure to climate change impacts. The distribution of participants' education status versus age and gender is shown in Fig. 23.3. The illiteracy rate was very high for female participants, and this of course affects their perception as well as their

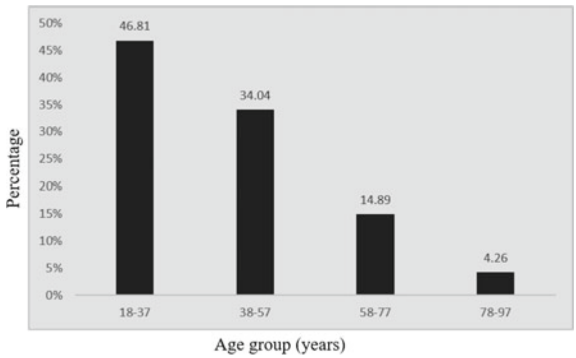

Fig. 23.2 Age distribution of household members in the study area

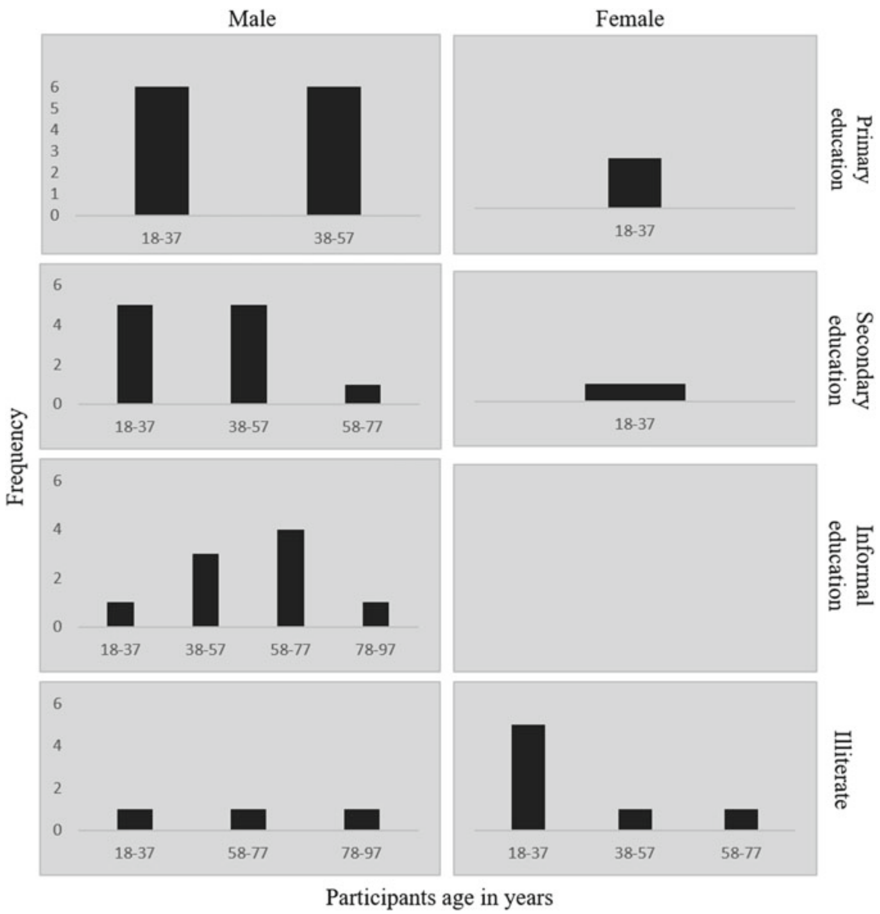

Fig. 23.3 Household participants age versus educational status in the study area

decision in taking measures for adapting to climate change, since there is a positive correlation between education and access to climate information (Maddison 2007; Le Dang et al. 2014).

A broad range of climate change indicators were identified by the participating farmers and how they were trying to cope with the challenges. The survey revealed that nearly all farmers are worried about the changing climate, particularly by drought periods. They especially emphasized on the observed changes in temperature and extreme events. In regards to rainfall and to the annual mean temperature, 89% of the respondents responded that the rainfall is decreasing and increasingly fluctuating, whereas 73% believed that the temperature has increased. Several studies have revealed similar challenges and indicators for climate change consistent to our study (such as Mengistu 2011; Agbo 2013; Wendimagegn and Lemma 2016) irrespective of their difference in analysis. Especially, rainfall decreasing from year to year and variability were the most frequently used indicators for climate change by these authors, which is consistent to our findings. The farmers' perception of climate change and variability was largely supported by the observed scientific data from the region. The rainfall data analysis indicated a significant variability in the annual rainfall and declining trend in the region during 1950–2013 (Fig. 23.4). Similarly, the trend analysis for temperature showed increasing trend with its minimum and maximum temperature increasing (statistically significant) which is matching with the farmers' perception (Fig. 23.5). It is clear from the Mann-Kendall test and the Sen's slope estimators test that both maximum and minimum temperatures have a significant positive trend (Table 23.1).

The respondents stressed the observed abnormalities in rainfall timing and uneven distribution as devastating for their production planning. For instance, the typical period for sowing Maize (*Zea mays*) used to be December/January, but nowadays there is a severe moisture deficit during these months which forced farmers to shift the sowing season and entire farming practice. This has forced many farmers to shift their farming calendar, which they claim affects their ability to grow diversified crops throughout the year. Again, the perceived abnormalities by the farmers in January and December did not show a statistically significant trend, but the Sen's slope estimator shows that the direction of slope in these months is downward (Table 23.1). Furthermore, the farmers claim the shift in their calendar has led to other climate related challenges such as climate born diseases and pests, which lower production of crops.

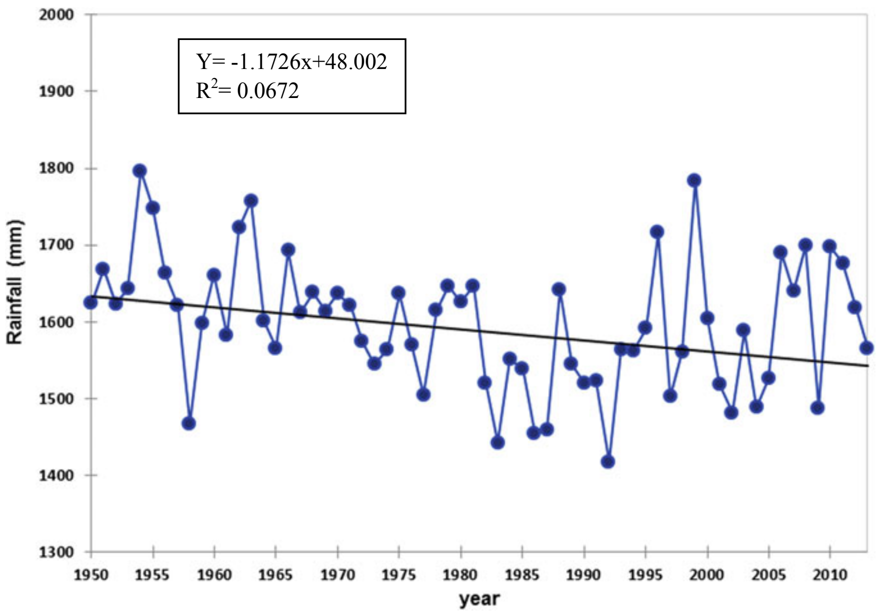

Fig. 23.4 Decreasing trend for precipitation at Kafa Biosphere Reserve (1950–2013)

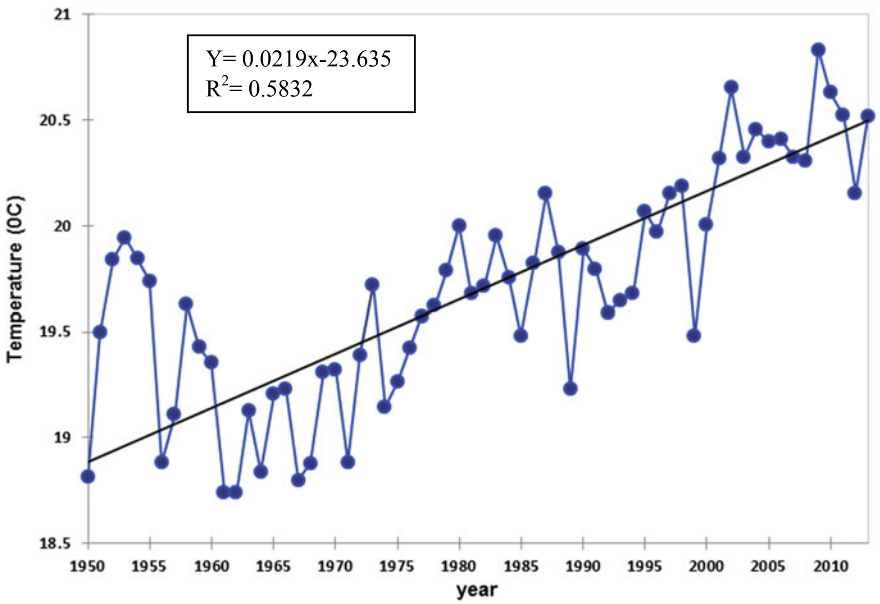

Fig. 23.5 Increasing annual average temperatures at Kafa Biosphere Reserve (1950—2013)

Selection of climate adaptive crops

Based on the agreed criteria (tolerance to drought or water stress, food or nutritional value, market/income and resistance to disease) farmers ranked cereals, fruits, pulses, root and tuber, vegetables and cash crops within their category using direct matrix ranking at the three agro-ecological zones. Furthermore, the selected crops, fruits and pulses were then compared and contrasted through pair wise ranking. The ranking resulted in 30 species that have been repeatedly selected and scored in the five sites. The total score of each crop from the five sites is summarized on Table 23.2. From this, 12 species were selected and recommended by the participants as climate resilient crops with commercial value. Out of the 12 crops, four are cereals (*Eragrostis tef*, *Triticum sp., Hordeum vulgare* and *Zea mays*). The rest includes two species of pulses (*Vicia faba* and *Pisum sativum*), one fruit tree (*Persea americana*), two vegetable species (*Capsicum annum* and *Brassica carinata*), two stimulant cash crops (*Coffea arabica* and *Camellia sinensis*) and one spice (*Aframomum cororima*).

It is not surprising to see the four cereals selected by the farmers as the best options as climate resilient commercial crops. For instance, *Zea mays* is a staple crop that has been cultivated for many generations in Sub-Saharan Africa (Smale et al. 2011) and millions of people depend on it for its protein and calorie content (Broughton et al. 2003). Even though there are large variations on impact of climate change on *Zea mays,* the different simulation models show Ethiopia to be one of those countries that could still see a rise in its yield with increase in temperature up to 29 °C, but ultimately declines with further increase in temperature. Similarly, *Eragrostis tef* is also very popular but at the same time one of the most ancient Ethiopian staple grains (Araya et al. 2011). It has several advantages compared to other cereals such as high tolerance to drought stress (Ketema 1997), early maturing before on set of dry spells (Takele 2001) and it can also survive diseases (Stewart and Dagnachew 1967). In contrast, *Triticum sp.* is a crop that is easily affected by abiotic factors such as low and poor rainfall distribution (Abate et al. 2018). A projected increase in temperature will likely result in a reduced yield due to a shortened growth period by accelerating phonological developments (Negassa et al. 2013). The crop is well known throughout the country and grown by millions of smallholder farmers typically in the highlands. This could be one of the reasons why farmers in KBR have selected it as a viable commercial crop.

When it comes to pulses, *Vicia faba* and *Pisum sativum* are not really new crops for Ethiopian farmers. They have been intercropping these pulses with *Eragrostis tef, Triticum sp.* and *Hordeum vulgare* (Agegnehu et al. 2008; Agegnehu et al. 2006a). For instance, mixed cropping of *Eragrostis tef* with *Vicia faba* provides a higher yield than growing the crops separately, which means higher revenue (Agegnehu et al. 2006b). Growing crops in mixture is not a new phenomenon in Ethiopia; it has been practiced in traditional agriculture for many years (Georgis et al. 1990). Therefore, the selection of these pulses might be due to the perceived advantages of cereal/pulse intercropping. But among the 12 commercial crops selected, *Coffea arabica* and *Camellia sinensi* are by far the most lucrative in KBR area. Especially, *Coffea arabica* is considered to be the most important crop in the lowland areas of the region. It supports the national economy and serves as key source for foreign currency supporting millions of people (one quarter of the population) directly or indirectly (Tefera 2012). Similar to other crops, *Coffea Arabica* is forecasted to be impacted severely by climate change reducing its suitable areas of growing by 50% globally in the year 2050 (Bunn et al. 2015). Locally there have not been any major challenges reported for coffee due to changing weather patterns. In fact, the participants described the current situation as favourable for *Coffea arabica* cultivation. This assessment is consistent to other studies that forecast a shift in climate but to remain suitable. More areas are even expected to start cultivating *Coffea Arabica* especially at higher elevations in East African countries like Kenya and Ethiopia (Ovalle-Rivera et al. 2015).

Similarly, the participants have ranked and selected five climate adaptive crops which they felt best suited for their area for cultivation. The selected crops are *Plectranthes edulis, Moringa stenopetala, Sorghum bicolor, Ensete ventricosum* and *Colocasia esculenta*. Among these crops *Ensete ventricosum* (Picture 3) is by far the most popular and it is ranked at the top in the pair wise ranking table combined for all the five study sites (Table 23.2).

This crop is largely cultivated in the area and in the neighbouring towns, and consumed as staple food (Olango et al. 2014). Altogether, more than 15 million people in Ethiopia depend on it for their food security (Yemataw et al. 2014). One reason for its popularity is its tolerance to drought and high yield (Andeta et al. 2018).

Picture 3 A farmer preparing *Ensete ventricosum* for the fermentation process (NABU/Nora Koim)

Conclusions and applicability for adaptation measures

This study attempted to collect both qualitative and quantitative information about farmers' awareness and perception on climate change and aimed to identify climate adaptive crops for KBR. In addition, an analysis using metrological data was conducted to investigate if the farmers' perceptions match with the reality. The evaluation of the perceptions show that the farmers are clearly aware of the variability and a changing climate, which is in accordance with the analysis of the metrological data. Furthermore, as adaption to these changes, the farmers have identified five climate adaptive crops and twelve climate resilient cash crops.

Following the study, the results were discussed by NABU with both governmental decision makers as well as spiritual leaders of the region preserving old species. These leaders added species to the list of potential climate resilient crops which they tend to preserve due to their values as heritage of ancestors. Together, a total of five species were selected and are now being tested for their climate resilience as well as easy cultivation and preservation in field studies with local farmers. An awareness creation campaign with posters and leaflets promote the species for reintroduction and use. The (re)introduction will increase the food security, value biodiversity and will make local communities less vulnerable to the effects of climate change.

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References

Abate GT, Bernard T, Brauw A, Minot N (2018) The impact of the use of new technologies on farmers' wheat yield in Ethiopia: evidence from randomized control trial. Agric Econ 49:409–421

Adger WN, Barnett J (2009) Four reasons for concern about adaptation to climate change. Environ Plann A: Econ Space 41(12):2800–2805

Agbo FU (2013) Framers perception of climate change in Ikwuano local government area of Abia State, Nigeria. J Biol, Agric Health Care 3(6):36–45

Agegnehu G, Ghizaw A, Sinebo W (2006a) Yield performance and land-use efficiency of barley and faba bean mixed cropping in Ethiopian highlands. Eur J Agron 25:202–207

Agegnehu G, Ghizaw A, Sinebo W (2006b) Crop productivity and land-use efficiency of a tef/faba bean mixed cropping system in a tropical highland environment. Exp Agric 42:495–504

Agegnehu G, Ghizaw A, Sinebo W (2008) Yield potential and land-use efficiency of wheat and faba bean mixed intercropping. Agron Sustain Dev 28:257–263

Andeta AF, Vandeweyer D, Woldesenbet F, Eshetu F, Hailemicael A, Woldeyes F, Crauwels S, Lievens B, Ceusters J, Vancampenhout K, Van Campenhout L (2018) Fermentation of enset (Ensete Ventricosum) n the Gamo highlands of ethiopia: physicochemical and microbial community dynamics. Food Microbiol 73:342–350

Araya A, Stroosnijder L, Girmay G, Keesstra S (2011) Crop coefficient, yield response to water stress and water productivity of teff (*Eragrostis tef*). Agric Water Manag 98:775–783

Bender S, Tekle M (2018) Community action for biodiversity and forest conservation and adaptation to climate change in the wild coffee forests (CAFA). In: Leal Filho W, Barbir J, Preziosi R (eds) Handbook of climate change and biodiversity. Climate Change Management, Springer, Cham

Broughton WJ, Hernandez G, Blair M, Beebe S, Gepts P, Vanderleyden J (2003) Beans (*Phaseolus spp.*) model food legumes. Plant Soil 252:55–128

Bunn C, Läderach P, Rivera OO, Kirschke D (2015) A bitter cup: climate change profile of global production of Arabica and robusta coffee. Clim Change 129:89–101

Conway D, Schipper ELF (2011) Adaptation to climate change in Africa: challenges and opportunities identified from ethiopia. Global Environ Change 21:227–237

Dennis Moss Partnership (DMP) (2009) Application for nomination of Kafa biosphere reserve. South Africa (unpublished), Stellenbosch

Deressa TT (2007) Measuring the economic impact of climate change on Ethiopian agriculture: Ricardian approach (English). Policy research working paper; no. WPS 4342. World Bank, Washington, DC. http://documents.worldbank.org/curated/en/143291468035673156/

Deressa TT, Hassan RM, Ringler C (2011) Perception of and adaptation to climate change by farmers in the Nile basin of Ethiopia. J Agric Sci 149(1):23–31

Dresen E (2014) Final report to NABU—mapping and analysis of wetlands and rivers at Kafa biosphere reserve. Berlin, Germany (unpublished)

Edwards S, Mesfin T, Hedberg I (eds) (1995) Flora of Ethiopia and Eritrea, vol 2 (2): Canellaceae to Euphorbiaceae. The National Herbarium, Addis Ababa University, Addis Ababa and Uppsala

Edwards S, Demissew Sebsebe, Hedberg I (eds) (1997) Flora of Ethiopia and Eritrea, vol 6. The National Herbarium, Addis Ababa University, Addis Ababa and Uppsala, Hydrocharitaceae to Arecaceae

FAO (1999) Women: users, preservers and managers of agrobiodiversity. Available at www.fao.org/FOCUS/E/Women/Biodiv-e.htm)

FAO (2017) The future of food and agriculture—trends and challenges. Food and Agriculture Organization of the United Nations, Rome, p 163

Gadgil A, Dhorde A (2005) Temperature trends in twentieth century at Pune. Atmos Environ 39(35):6550–6556

Georgis K, Abebe A, Negasi A, Dadi L, Sinebo W (1990) Research method for cereal/legume intercropping research in Ethiopia. In: Proceedings of a workshop on research methods for cereal/legume intercropping in Eastern and Southern Africa, CIMMYT, Mexico, pp 167–175

Hedberg I, Edwards S (eds) (1989) Flora of Ethiopia and Eritrea, vol 3: Pittosporaceae to Araliaceae. The National Herbarium, Addis Ababa and the Department of Systematic Botany, Uppsala

Hedberg I, Edwards S, Nemomissa S (eds) (2003) Flora of Ethiopia and Eritrea, vol 4 (2): Apiaceae to Dipsaceae. The National Herbarium, Addis Ababa University, Addis Ababa and Uppsala

http://documents.worldbank.org/curated/en/310391468340238724/Main-report

Hylander K, Nemomissa S (2008) Home garden coffee as a repository of epiphyte biodiversity in Ethiopia. Front Ecol Environ 6:524–528

Hylander K, Neomissa S, Delrue J, Enkosa W (2013) Effects of coffee management on deforestation rates and forest integrity. Conserv Biol 27(5):1031–1040

IPCC (2007) Climate change 2007: impacts, adaptation and vulnerability. Contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change, p 932

IPCC (2013) Climate change 2014: impacts, adaptation, and vulnerability. Working group II contribution to the IPCC fifth assessment report

Kathuria H, Giri J, Tyagi H, Tyagi AK (2007) Advances in transgenic rice biotechnology. Crit Rev Plant Sci 26:65–103

Ketema S (1997) Tef. Eragrostis tef (Zucc.) Trotter. Promoting the conservation and use of underutilized and neglected crops, vol 12. Institute of Plant Genetics and Crop Plant Research, Gattersleben/International Plant Genetic Resources Institute, Rome, Italy

Kumar S (ed) (2002) Methods for community participation: a complete guide for practitioners, p 333

Le Dang H, Li E, Bruwer J, Nuberg I (2014) Farmers' perceptions of climate variability and barriers to adaptation: lessons learned from an exploratory study in Vietnam. Mitig Adapt Strategy Global Change 2014(19):531–548

Maddison DJ (2007) The perception of and adaptation to climate change in Africa. World Bank, Washington, DC, USA, p 51

Mengistu DK (2011) Farmers perception and knowledge of climate change and their coping strategies to the related hazards: case study from Adiha, central Tigray, Ethiopia. Agric Sci 2:138–145

Mertz O, Halsnæs K, Olesen JE, Rasmussen K (2009) Adaptation to climate change in developing countries. Environ Manage 43(5):743–752

Mittermeier RA, Robles-Gil P, Hoffmann M, Pilgrim J, Brooks T, Mittermeier CG, Lamoreux J, Fonseca GA (2004) Biodiversity hotspots revisited. CEMEX, Mexico City, Mexico, p 390

MoFED (Ministry of Finance and Economic Development) (2007) Ethiopia: building on progress: a plan for accelerated and sustained development to end poverty (PASDEP). Annual Progress Report, Addis Ababa, Ethiopia, p 267

NABU (eds) (2017) NABU's biodiversity assessment at the Kafa biosphere reserve. Berlin, p 360

Negassa A, Koo J, Sonder K, Shiferaw B, Smale M, Braun HJ, Gbegbelegbe S, Gui Z, Hodson D, Wood S, Payne T, Abeyo B (2013) The potential for wheat production in Africa: analysis of biophysical suitability and economic profitability. International Maize and Wheat Improvement Center (CIMMYT), Addis Ababa, Ethiopia, p 64

Niang I, Ruppel OC, Abdrabo MA, Essel A, Lennard C, Padgham J, Urquhart P (2014) Africa. In: Barros VR, Field CB, Dokken DJ, Mastrandrea MD, Mach KJ, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR,White LL (eds) Climate change 2014: impacts, adaptation, and vulnerability. Part B: regional aspects.

contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change, Cambridge University Press, Cambridge, pp 1199–1265
Olango T, Tesfaye B, Catellani M, Pè M (2014) Indigenous knowledge, use and on-farm management of enset (Ensete ventricosum (Welw.) Cheesman) diversity in Wolaita, Southern Ethiopia. J Ethnobiol Ethnomed 10:41
Ovalle-Rivera O, Läderach P, Bunn C, Obersteiner M, Schroth G (2015) Projected shifts in *Coffea arabica* suitability among major global producing regions due to climate change. PLoS One 10(4):e0124155
Parry ML, Canziani OF, Palutikov JP, van der Linden PJ, Hanson CE (2007) Technical summary. In: Parry ML, Canziani OF, Palutikov JP, van der Linden PJ, Hanson CE (eds) Climate change 2007: impacts, adaptation and vulnerability. Contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change, Cambridge University Press, Cambridge, New York
Patton MQ (2005) Qualitative research. Jhon Wiley & Sons, London
Phillips S (1995) Poaceae (Gramineae). In: Hedberg I, Edwards S (eds) Flora of Ethiopia and Eritrea, vol 7. The National Herbarium, Addis Ababa University, Addis Ababa and Uppsala
Schmitt CB, Senbeta F, Denich M, Preisinger H, Boehmer HJ (2010) Wild coffee management and plant diversity in the montane rainforest of southwestern Ethiopia. Afr J Ecol 48(1):78–86
Smale M, Byerlee D, JayneT (2011) Maize revolutions in sub-Saharan Africa. World bank policy research paper 5659. The World Bank, Washington, DC
SNNPR (Southern Nations Nationalities and Peoples' Regional State) (2013) Kafa zone finance and economic department 2005 e.c. (2012) zonal statistical abstract
Stewart RB, Dagnachew Y (1967) Index of plant diseases in Ethiopia, vol 30. Alemaya University of Agriculture, Dire Dawa, Ethiopia, p 95
Stige LC, Stave J, Chan K, Ciannelli L, Pattorelli N, Glantz M, Herren H, Stenseth N (2006) The effect of climate variation on agro-pastoral production in Africa. Proc Nat Acad Sci 103:3049–3053
Tadesse M (2004) Asteraceae (Compositae). In: Hedberg I, Friis I, Edwards S (eds) Flora of Ethiopia and Eritrea, vol 4 (1). The National Herbarium, Addis Ababa University, Addis Ababa and Uppsala
Takele A (2001) Canopy temperatures and excised leaf water loss of tef (Eragrostis tef (Zucc) Trotter) cultivars under water deficit conditions at anthesis. Acta Agron Hung 49:109–117
Tefera A (2012) USDA—Ethiopia coffee annual report, global agricultural information network. United States Department of Agriculture
Wondimagegn T, Lemma S (2016) Climate change perception and choice of adaptation strategies: Empirical evidence from smallholder farmers in east Ethiopia. Int J Clim Chang Strat Manag 8(2):253–270
World Bank (2010) Ethiopia—economics of adaptation to climate change: main report (English). World Bank, Washington, DC
Yemataw Z, Mohamed H, Diro M, Addis T, Blomme G (2014) Enset (Ensete ventricosum) clone selection by farmers and their cultural practices in southern Ethiopia. Genet Resour Crop Evol 61:1091–1104

Chapter 24
Climate Information Services and Their Potential on Adaptation and Mitigation: Experiences from Flood Affected Regions in Bangladesh

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Abstract Climate services are the use of climate knowledge and information in climate-smart development. This study aims to explore the understanding and level of resilience at community level, including the potential of climate information services in promoting INDC, BCCSAP, LAPA. We also look at the adaptation and mitigation paradigm with smart mobile phones, along with an internet scheme via Short Message Service (SMS), Outbound Dial (OBD), Apps and Call Centre services on agriculture, agro meteorology, weather forecast and early warning system. The study was conducted in South Kharibari village of DimlaUpazila in the Nilphamari district in which a 100 climate vulnerable households are currently using a customized system for increasing resilience in households through climate information services. The study was conducted through explanatory methods, including contextual analyses, case studies, and best practice documentation, FGD, KII and PVA (Participatory Vulnerability Assessment). The study reveals that climate information plays a vital role in climate-resilient development at household level through increased women's participation in action research and formulation of LAPA. This fortifies their leadership role in food security and energy sectors which are the major

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focus area of INDC and BCCSAP. Its additionally helping climate-vulnerable women to adapt with changing environment through resilient crop farming, homestead gardening, fisheries, livestock, horticulture and poultry rearing. Thus helping them to develop resilient planning for alternative energy sources in cooking, lighting and other purposes which meets the mitigation needs at the household level.

Introduction

Bangladesh is one of the most climate-vulnerable countries in the world due to its geographical make up. It is a low-lying country within the tropics and is the largest delta in the world, formed by the Ganges, the Brahmaputra, and the Meghna. It has the Himalayan range to the north, the Bay of Bengal to the south which funnels towards the Meghna estuary and a vast stretch of Indian land to the west. These geographical features contribute significantly to the climate system of Bangladesh. Impacts of climate change in Bangladesh include excessive flooding, severe cyclone and storm surges, increased salinity and drought, declining of agricultural productivity, lack of drinking water and water logging due to the rise of sea level. Considering the area, it is a small country with a huge population and a predominantly agrarian economy. According to the Maple Croft study (2014), Bangladesh is the most climate-vulnerable country in the world. The Global Climate Risk Index (GCRI) 2010, covering the period 1990–2008, estimates that on an average, 8241 people die each year in Bangladesh. While the cost of damage was, at the time, around $1.2 billion USD per year and the loss of Gross Domestic Product (GDP) was 1.81% during the period. The CRI incorporated a number of events, total deaths, loss of property of each affected person, and loss of gross domestic product (GDP). In its report, Germanwatch estimated that 1993–2012 Bangladesh sustained $1.832 billion USD in damages, brought about by a variety of natural disasters. However, in 2017 the report estimated that between 1997 and 2016 Bangladesh sustained US$ (PPP) 2311.07 by various natural disasters induced by climate change (Germanwatch 2018).

The northern part of Bangladesh (Rajshahi and Rangpur divisions, the area lying west of Jamuna River and north of Padma River, and including the Barind tract.) is characterized by climate-induced drought and flood. The 1988 flood caused a reduction in agricultural production by 45%. Higher discharge and low drainage capacity, in combination with increased backwater effects, increase the frequency of devastating floods under climate change scenarios. Prolonged floods tend to delay Aman plantation, resulting in significant loss of potential Aman production, as observed during the floods of 1998. Loss of Boro rice crop from flash floods has become a regular phenomenon in the riverine areas over the years.

Living in the poverty cycle, the people of climate-vulnerable areas are trying to adapt to the impacts through community based adaptation and indigenous knowledge and skill. On the other hand, government and non-government organizations have intensified their efforts through adopting different policies and programs, introducing new technologies, and management practices to tackle the impacts. The regular and severe natural hazards that already batter the country include tropical cyclones, river erosion, floods, landslides, and drought. All of which are set to increase in intensity and frequency as a result of climate change (BCCAP 2009).

Climate Information Services

Climate information services involve the production, translation, transfer, and use of climate knowledge and information in climate-informed decision making and climate-smart policy and planning. Climate services ensure that the best available climate science is effectively communicated with agriculture, water, health, and other sectors, to develop and evaluate adaptation strategies. Easily accessible, well-timed, and decision-relevant scientific information can help society to cope with current climate variability and limit the economic and social damage caused by the climate-related disaster. Climate services also allow society to build resilience to future change, and take advantage of the opportunities provided by favorable conditions. Effective climate services require established technical capacities, active communication and exchange between information producers, translators, and user communities. Climate services are integral to minimizing climate change impacts and developing community resilience in different sectors. Services which include information and communication services, with special attention to database and information, is very much necessary.

BCCSAP, INDC & LAPA

There has been commendable progress in formulating policies and strategies to address climate change, disaster risk, and vulnerability. The government has prepared a National Adaptation Plan of Action (NAPA 2005), Bangladesh Climate Change Strategy and Adaptation Plan (BCCSAP 2009), National Disaster Management Policy and Plan (NDMP 2016–20); 7th Five-Year Plan (2016–20) of Bangladesh. The policies and plans have recognized the climate-induced problems like droughts, declining groundwater level, land degradation, flooding and river erosion. Programs that intend to tackle climate change issues are mostly focused on climatic concerns of southern and south-eastern coastal regions. Further, there are limited practical programs and actions for the vulnerable communities at the regional and local levels by the government and actors.

BCCSAP

On the adaptation to climate change and the future welfare of the people, the Government of Bangladesh has identified climate change as the ultimate threat to national development. In order to overcome this worsening situation, in 2005 the government formulated the National Adaptation Plan of Action (NAPA), Bangladesh Climate Change Strategy and Action Plan (BCCSAP) in 2009 and established Bangladesh Climate Change Trust Fund (BCCTF) in the 2010 to carry forward BCCSAP. Within the framework of BCCSAP, 2009, BCCTF has approved many projects for GOs and NGOs with a specific focus on the following thematic areas:

- Food security, social protection, and health
- Comprehensive disaster management
- Infrastructure
- Research and knowledge management
- Mitigation and low-carbon development, and
- Capacity building and institutional strengthening.

In order to implement 44 programs specified under the six thematic areas of BCCSAP 2009, Climate Change Trust Fund (CCTF) was created in the fiscal year of 2009–10. The Trust Fund was operated through a project titled' Strengthening Institutional Capacity of Climate Change' under the Ministry of Environment and Forests. Subsequently, Climate Change Trust Act, 2010 was enacted; and as per the direction of Climate Change Trust Act, 2010, Bangladesh Climate Change Trust (BCCT) was established on 24 January 2013 with effect from 13 October 2010.

NDC

Bangladesh committed to reducing GHG emissions by 5% below business-as-usual GHG emissions by 2030, using only domestic resources or 15% below business-as-usual GHG emissions by 2030, if sufficient and appropriate support is received from developed countries (MoEF 2015). Bangladesh also envisions reducing GHG emissions from domestic uses (such as through cooking), reducing uses of nitrogen fertilizers, and increasing renewable energy in lighting purposes in order to achieve the set target by its own initiative within 2030. To achieve the set target, BCCSAP also includes actions to improve energy efficiency in the domestic and commercial sectors, reduce emissions in the agriculture sector (through energy efficiency and water and fertilizer management), capture methane emissions from landfill sites, scale-up afforestation and reforestation and reduce emissions from transport through increased public transport and improved fuel efficiency of vehicles.

LAPA

In general, Local Adaptation Plans (LAP) refers to a plan developed by a local community; considering the key factors in addressing the vulnerabilities that specific region face due to climate change. These plans are developed so that the local vulnerability can be reduced effectively if the local plan is integrated within the sectoral or national plan or/and arranges finance for its implementation. The main features of this local adaptation planning are; bottom-up approach, participatory vulnerability mapping, prioritizing adaptation needs, designing immediate projects and action plans for implementation, linking with institutional policy process, resource mobilization at all level and peoples' monitoring (Doha and Bijoy 2015).

The Cancun Adaptation Framework (2010)[1] provides a opportunity for the Least Development Countries (LDCs)[2] to formulate and implement national adaptation plans (NAPs) as a means of identifying medium- and long-term adaptation needs and developing and implementing strategies and programmes (including the areas of water resources, health, agriculture and food security, infrastructure, socioeconomic activities, terrestrial, freshwater and marine ecosystems and coastal zones) to address those needs.

Bangladesh has experience in developing NAPAs (2005) and state-owned BCCSAPs (2009) which followed a top-down approach in assessing the adaptation needs, options and priorities. NAPA emphasized only immediate priorities and BCCSAP followed a specialist-driven process without any involvement of the most vulnerable communities affected by climate change. Moreover, in the absence of appropriate knowledge on local exposure and vulnerability, an efficient adaptation strategy cannot be developed and funding for Climate Change Adaptation (CCA) cannot be utilized effectively for the most vulnerable communities (NCC, B, 2018).

In the meanwhile, by scaling up the experience of NAPA, the UNFCCC initiated the National Adaptation Plan (NAP) formulation process, which was established under the Paris Agreement to strengthen climate resilience and deliver support for developing countries that are particularly vulnerable to climate change. Recently, the Bangladesh Government has received a financial commitment from the GCF for NAP formulation with the objective of long-term adaptation investment and enhancing national capacity for integration of CCA in planning, budgeting and financial tracking processes. It should be noted that the aim of the UN-NAP process is to identify medium- and long-term climate change adaptation needs, taking into consideration vulnerable groups, communities and ecosystems (Ref. https://goo.gl/kFqbce)[3] with an emphasis on planning at all levels. However, the current NAP

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[1]Cancun Adaptation Framework (FCCC/CP/2010/7/Add. (1) Decision 1/CP.16).

[2]The least developed countries (LDCs) are a group of countries that have been classified by the UN as "least developed" in terms of their low gross national income (GNI), their weak human assets and their high degree of economic vulnerability. At present (March, 2018) total 47 countries listed as "least developed", (http://unfccc.int/cooperation_and_support/ldc/items/3097.php).

[3]http://unfccc.int/files/adaptation/cancun_adaptation_framework/application/pdf/naptechguidelines_eng_high__res.pdf.

project in Bangladesh has considered both the ecosystem-based adaptation and local development planning as a strategy. Therefore, the UN-NAP process has offered an opportunity to incorporate local adaptation plans in addressing localized climate vulnerabilities. Thus bridging central planning and local priorities, connecting higher level mobilization of resources for adaptation and channeling these resources to the most vulnerable people. The Local Adaptation Plan for Action (LAPA) is also an opportunity to operationalize the policy objectives outlined in the National Adaptation Programmes of Action (NAPA) and Bangladesh Climate Change Strategy and Action Plan (BCCSAP) (IRB 2017).

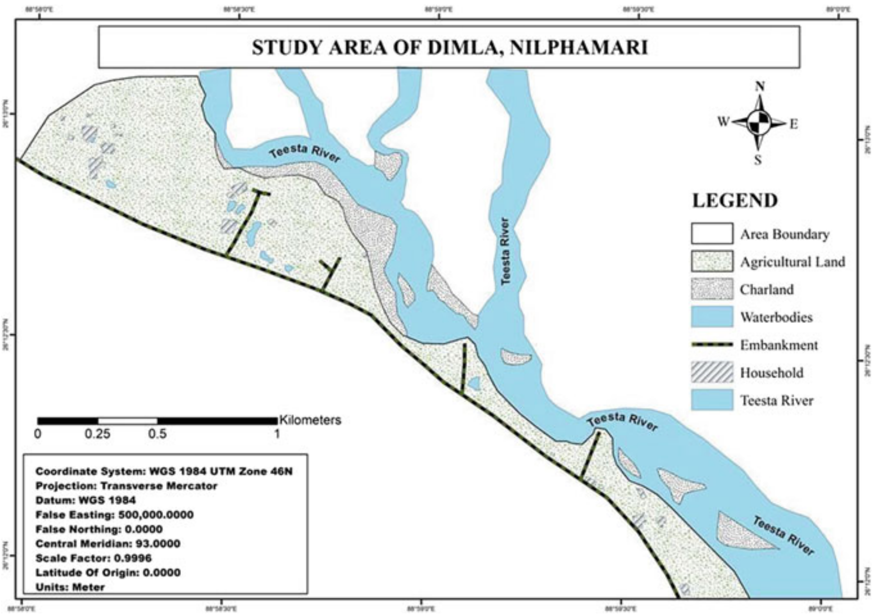
Research Methodology

This study was conducted by collecting primary data from field locations and analyzing them in order to draw the benchmark for working paper(s). Firstly, a review and analysis of national policies and strategies, such as Bangladesh Climate Change Strategy and Action Plan (BCCSAP), Roadmap of Intended Nationally Determined Contribution (INDC), and learning documents of Local Adaptation Plan of Actions (LAPA) took place. Secondly, primary data (especially qualitative and quantitative data) from the field locations through Household Questionnaire Survey (HHS), Focus Group Discussion (FGD), Key Informants Interview (KII), RS and GIS were accumulated. The study was conducted in Tepakharibari village under Dimla Upazila of Nilphamari district which is situated beside the Tista River (Map 1).

Results and Discussion

Climate Change Impact

The village is inhabited by 432 households who are affected by climate change-induced disasters including flood, flash flood, cold wave, wind storm, agricultural drought. Each year, flash flood hits the village while the rest of the country is free from flooding. For example, it was found during community consultation that where other areas of Bangladesh had not faced flood occurrence, South Tepakharibari village was flooded three times in 2018. Monsoon flooding, flash flooding and riverbank erosion in South Kharibari village (Map 2a, b and c) along the Tista River is a common climate-induced occurrence. According to BWDB, the water level in the Tista River rose by 49 cm during the period study period and it was flowing 78 cm above its danger level at the South kharibari point. It is also found that in every year South Kharibari village is flooded 7–9 times, even though the rest of the country does not face floods (BWDB 2018). Figure 24.1 shows that the South Tepakharibari village is highly vulnerable due to flood, flash flood, cold wave, heavy fog and riverbank



Map 24.1 Study area

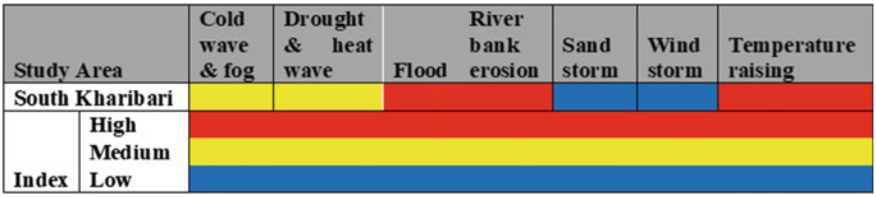
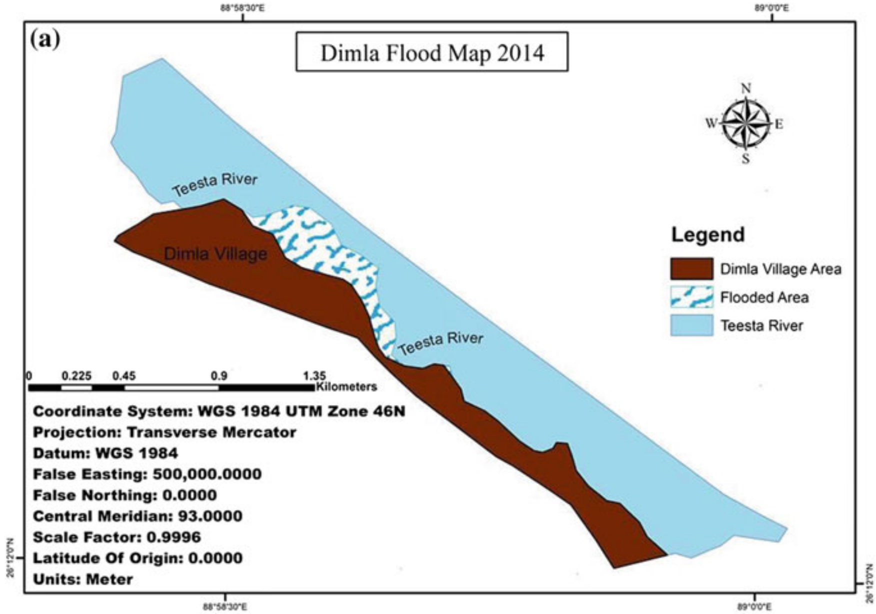


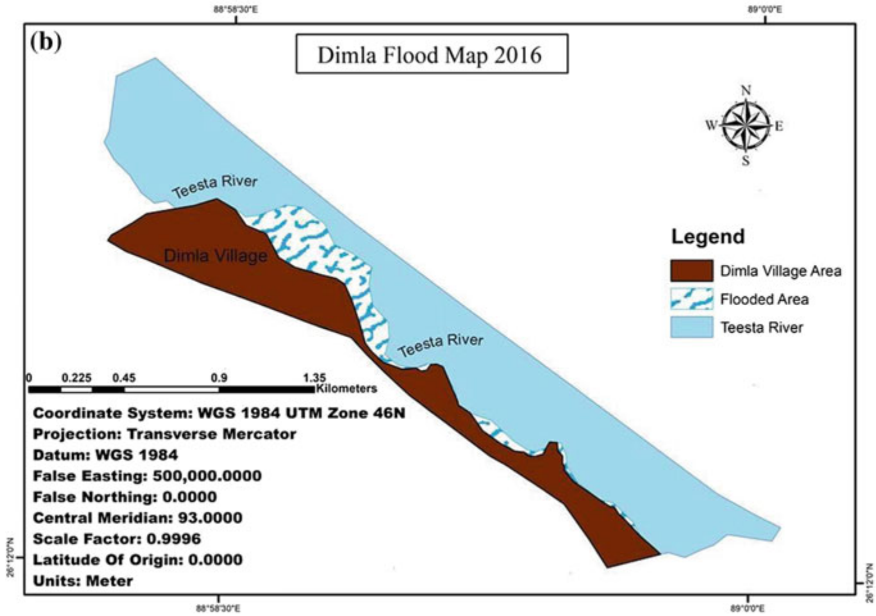
Fig. 24.1 Climate-induced disaster in the study area

erosion which were expressed by community people during the consultation and vulnerability mapping. Moreover, there are also two other types of climate-induced disasters observed in South Kharibari village which are not common in Bangladesh; wind and sand storms.

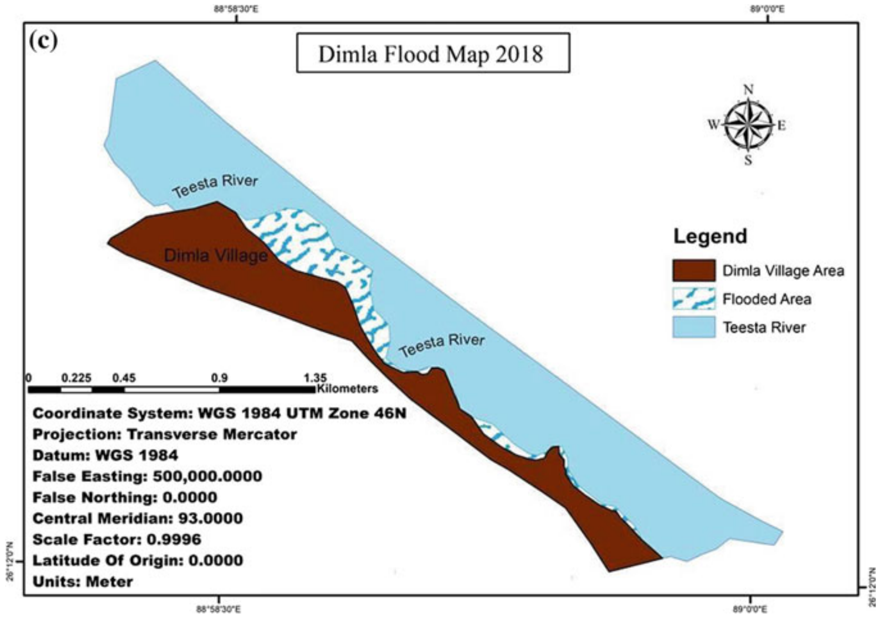
In 2016, continuous rainfall in north and northeastern Bangladesh, together with the rush of water from upstream, caused flash floods in low-lying and densely populated areas. More than 4,000,000 people were affected, including 775,000 displaced. The most affected districts include Nilphamari, as well as South Kharibari and nearby areas (ACAPS 2014; IFRC 2014).

It is also found that, in South Kharibari village of Dimla Upazila under the Nilphamari district, riverbank erosion is occurring at an alarming rate. Between 2016 and 2018 a total land lost 5 ha due to riverbank erosion of Tista River occurred. In 2016, there was 64 ha of land which stands at 59 ha in 2018 (Map 24.3a and b).





Map 24.2 **a** Flood map of South Kharibari in 2014; **b** Flood map of South Kharibari in 2016 and **c** Flood map of South Kharibari in 2018

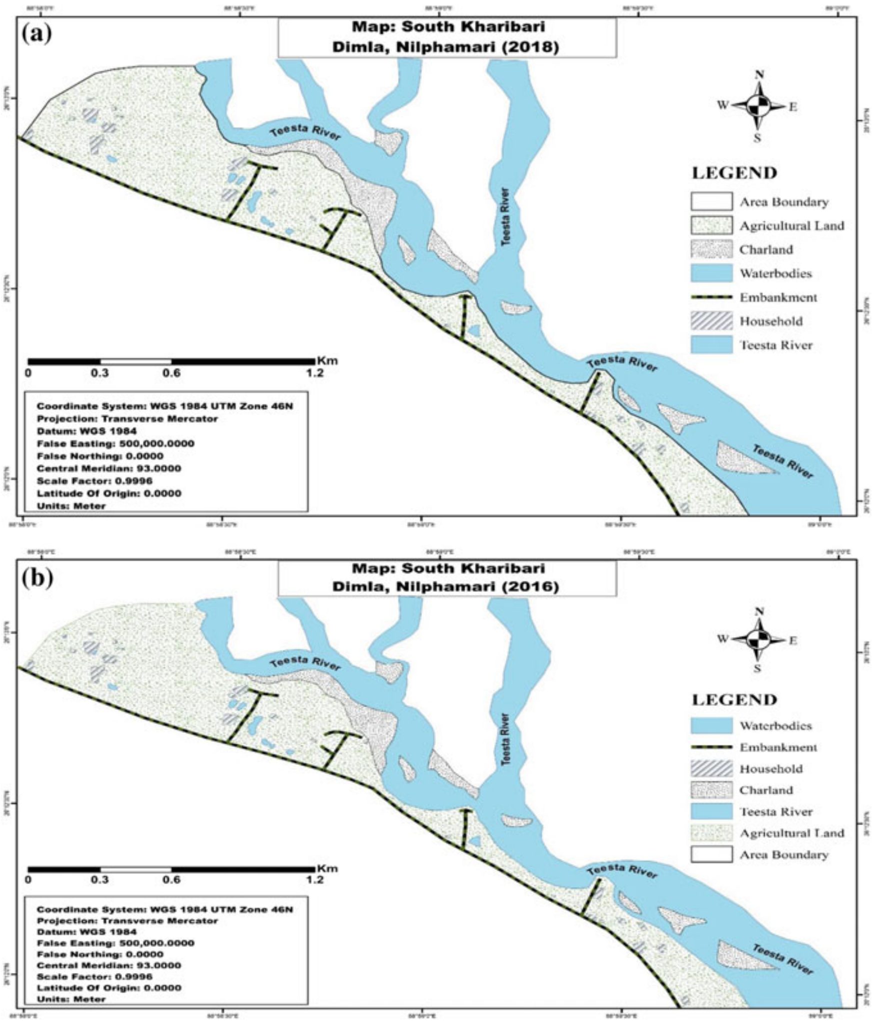


Map 24.2 (continued)

Climate Information Service: Information and Communication Methods in the Study Area

In recent years there has been remarkable progress in using Information Communication Technologies (ICTs) as a development instrument in marginalized communities. ICTs include the use of radios, televisions, computers, mobile phones, and alternative media sharing devices. For this study, we made an effort to extract the use of cellular phone-based information sharing and dissemination approach through texts, voice, OBD, SMS, photographs or images as climate-resilient means. With heightened access to communication resources, it is understandable that non-government organizations incorporates these tools into climate-resilient development in the study area, which is highly vulnerable to climate shocks.

Crop and location-specific agromet (agro meteorological information) advisory issues are disseminated to the climate-vulnerable communities in the project areas through SMS, OBD, voice message, hotline and Interactive Voice Response technology (IVR). Under the IVR system, the information from project areas for each village is collected and stored, then converted into voice form. Farmers can call to receive information. The National Climate Information Dissemination Hub is disseminating generated agromet advisories through SMS, OBD, and IVR. The ultimate aim is to disseminate advisories to the farmers in real-time, to help them save farm inputs, increase crop yield and ultimately increase economic benefits to the farming community.



Map 24.3 Riverbank erosion and land loss of South Kharbiari village under Dimpla Upazila of Nilphamari in 2018 and 2016

Customized information dissemination software was developed based on the information or data relevant to weather, crop calendar, soil health, soil quality management, suitable crops or plants, local agro-meteorology, soil and hydrological information and climate-resilient cropping pattern, climate-resilient crop varieties, location-specific best management practices, crop pathogen, irrigation scheduling, quality seed source etc. Every week, on the first and last day of the week, the information dissemination hub provides information packages through SMS. On the other hand, the end-users can reach the advisories through customer care calls, if needed. It is also found that the software is capable of providing fertilizer recommendations based on existing soil nutrient data, or soil test value for specific crops in the area. It is a dynamic model that contains crop land specific climatic information, land elevation, land use, hydro-meteorological information, agro-meteorological information, soil health, soil fertility, pest, and diseases, etc. The software analyzes all of the inbuilt information provided by field enumerators deployed from vulnerable women in the study area regularly. It is regularly updated based on the seasonal crop-related information. Skill development and training as well as appropriate support is provided to up-skill the target group of vulnerable women on the utilization of climate-resilient cropping pattern, and the utilization of climatic information.

Analyzing of Climate Information Services and BCCSAP

Food Security, Social Protection, and Health

Food security is defined as availability at all times of adequate world food supplies of basic foodstuffs to sustain a steady expansion of food consumption and to offset fluctuations in production and prices (UN 1975). Social protection is an integral component of poverty reduction strategies (Norton et al. 2001). Health security is defined as the ultimate health wellbeing of marginalized people. Information and Communication Technology helps to promote food security, social and health protection which is the topmost pillar of the Bangladesh Climate Change Strategy and Action Plan (BCCSAP). In terms of food security, positive feedback was received on the concept of food availability, food production and cost-minimizing for food buying. Based on investigation among ICT users and non-users, it was found that 21 women among 23 ICT users expressed their opinion on the improvement of food availability throughout the year. However, 11 non-users expressed that they have no improvement on food availability. On the other hand, 23 ICT users expressed that food consumption, especially vegetable consumption, increased in their households. They also reported that the cost of vegetable buying reduced before ICT were used, but the situation is almost identical among non-users. Among the ICT users, household income level increased. Based on the investigation, household monthly income increased to 2454.00 BDT in each household on average, but it did not increase in non-users women households. The ICT user women expressed that they are involved in climate-resilient vegetable farming, such as 3-D farming, conservation farming, hanging farming, duck and hen rearing with slatted houses, goat rearing with semi-scavenger housing, pot farming and homestead farming. By the end of 2018, over 90% of households had planted mixed vegetable varieties that were developed through mobile-based information services. Animators have been instrumental in advancing the scaling of these varieties to more households in neighboring villages. They have promoted the uptake of these varieties through village demonstrations, field days and multiplication of planting material. The ICT users also expressed that before utilization of ICT, during the rainy season, winter season and summer season they had to face duck and hen diseases and most of the time hen and ducks died during

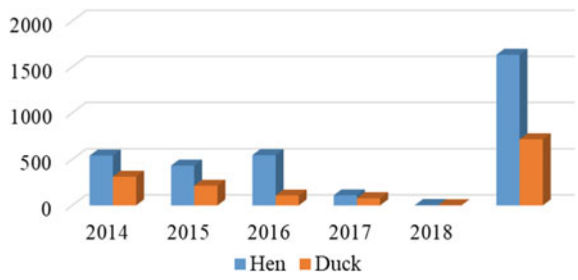


Fig. 24.2 Number of died hen and duck in 2014–2018 in the study area

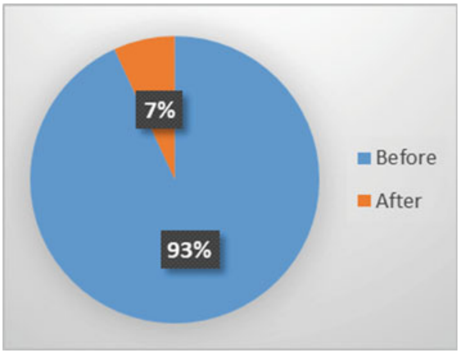


Fig. 24.3 Death of hen before and after climate information services

the extreme rain, cold, and extreme summer. Figure 24.2 illustrates the duck and hen death status in the last 5 years in the study area. It was also found that in the last five years (2014–2018), 93% of hens died before ICT utilization (2014–2016) and only 7% of hens died after ICT utilization (2017–2018). It was also shown that, in the last five years (2014–2018) more ducks also died before ICT utilization, which is illustrated in Fig. 24.3.

Among the ICT non-user women, duck and hen death rates were almost identical in the last five years. However, the ICT users are not facing such problems because they get information related to seasonal variation, climate-sensitive disease information, and information related to disease prevention through SMS, OBD, voice call, and apps. Using wheat and brinjal apps, mobile users also get information related to seedling time, fertilizer doses, harvesting time-related information and they also get a prediction of cold and heat waves, precipitation, watering, and harvesting. For this reason, their wheat and brinjal production increased twice after the ICT introduction. Vegetables are the main source of minerals and vitamins for marginalized people. Because this area is flood and drought-prone, vegetable productions were restricted in the study area before 2016 and vulnerable households were dependent on the village market for vegetables. But due to their low income, they were not able to buy essential vegetables. But now they can produce vegetables year round in their homestead and nearby homesteads based on vegetable agro met services. They are now not dependent on the village market and can consume sufficient vegetables

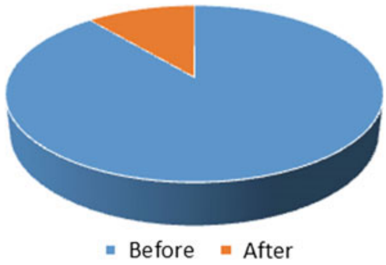


Fig. 24.4 Death of duck after and before climate information services

which provides them with essential minerals and vitamins. It is also found that crop pathogen and insecticide related information helps to increase the production of corn using corn apps. During the rainy season, the villagers obtain information related to flash flood which helps them to harvest rain-fed Aman rice before floods. It was also found that in 2017, farmers rescued their paddies from a flash flood; this shows the positive impact that timely information dissemination related to floods can have. Heavy fog is also a major threat for Rabi crops and is common in the study area. Agromet advisories provide information related to cold waves and heavy fog in advance which ICT user women use to secure their Rabi crops and seed beds; in 2017 they rescued their corn seed bed during the winter season from fog. These initiatives are good examples which highlight how information services and climate-smart practices increase farmers' climate resilience, and they also show how they can positively impact food security, social protection, and health (Fig. 24.4).

In terms of livestock protection, climate information services provide information related to heat-sensitive, cold-sensitive and water sensitive livestock diseases, and also protection measures. It was found that 250 ducks in a household which was not using ICT died in 2017. This was due to the fact that the women did not get information related to duck disease. With the intention to understand the food security status of the ICT users and non-users, a trial was conducted to examine the cash flow of the households; including sources of income and expenditure of the ICT users and non-users. Households in the study area typically gained access to cash from their own production in livestock and crops in 2018, this was not feasible in 2015 (it is noted that ICT was introduced in 2016). The sources of income among ICT users increased 3 times more than ICT non-users within this period (2016–2018). In the study area, villagers are extremely impoverished and they depend on agriculture, livestock and day labor for their main sources of income. In 2015, it was found that the target respondents crop production accounted for 21% of their household income, 5.2% from livestock production, and 63.3% from small businesses. However, the situation has changed, in 2018 50% of households from ICT users depended on income from crop production, 21.7% on livestock, 23.3% on small business and 5% on day labor (Figs. 24.5 and 24.6).

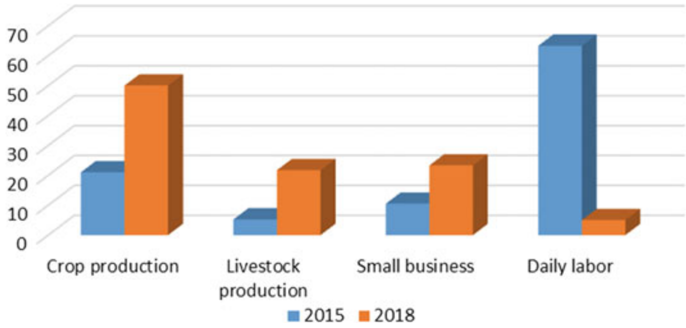


Fig. 24.5 Household income source in study area (2015–2018)

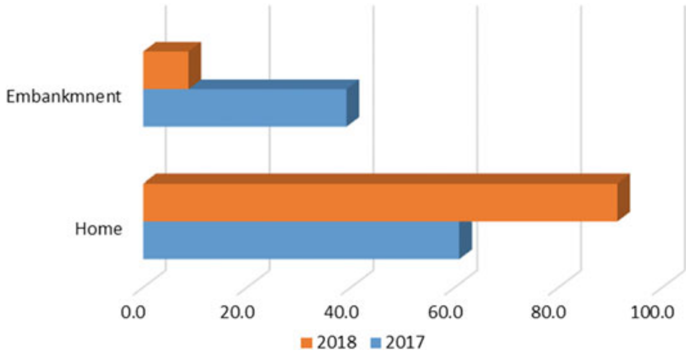
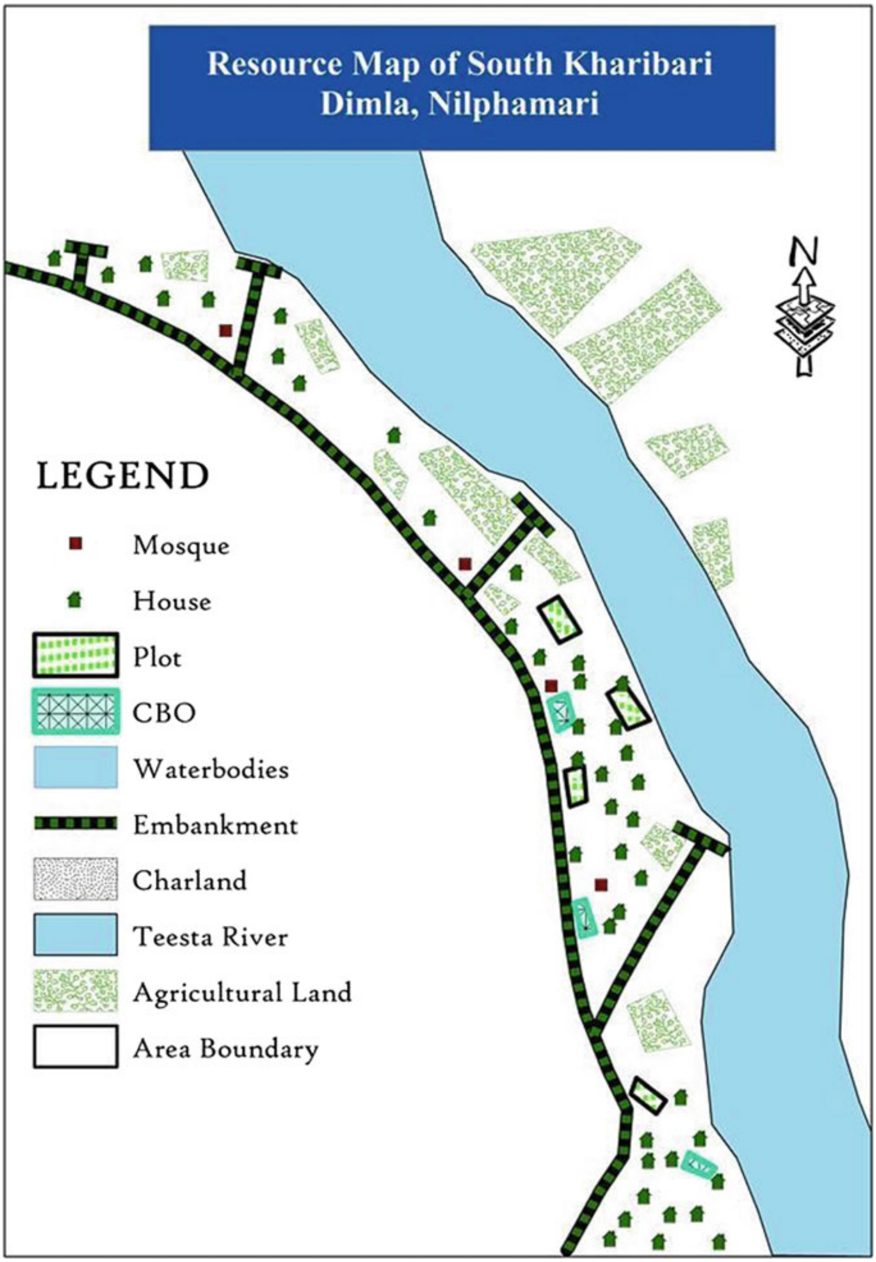


Fig. 24.6 Displacement during flood

Comprehensive Disaster Management

Comprehensive Disaster Management (CDM) is an integrated approach to disaster management which is an important pillar of BCCSAP. CDM refers to the management of all hazards through all phases of the disaster management cycle, as well as prevention and mitigation, preparedness, response, recovery, and rehabilitation. Agromet advisories not only provide agro-climatological information, but also provide disaster-related information regularly. Each Sunday and Thursday agromet advisories provide SMS containing information on precipitation, prediction of climatic extremities like a flood, flash flood, flood danger level, cold wave, heat wave, transboundary river flood level, upstream precipitation, etc. Each week, analyzing the national and local meteorological information, met advisories provide disaster forecasts which help communities prepare for a disaster. It was found that during 2017 almost 100% of respondents rescued livestock and crops from flash flood due to flood forecast. In contrast, in 2015 flood caused massive amounts of damage, which is illustrated in Table 24.1.



Map 24.4 Resource map of study area drawn by ICT user women

Table 24.1 Flood scenario in the study area during 2015 and 2017

Year	Flood period	Flood level (cm)	Flood-affected respondents	Economic loss (million BDT)
2015	July	53	23	1.3
2017	August	55	2	0.5

Infrastructure

Flood and flash flood is a common disaster in the study area. Each year, though the rest of the country does not flood, South Kharibari village often does face floods because the village is situated nearby the Gozoldoba barrage. It was found that in 2018, though the rest of Bangladesh was not flooded, South Kharibari village became flooded three times in July and once in August. ICT, as well as mobile users, do not get exact flood information but they get preparedness information for an upcoming flood. Prior to the introduction of ICT, most households in the study area become submerged in 1.5–2 feet of water each year. From 2016, the inhabitants of the study area learned to raise plinths in order to avoid the high water levels. In 2017 and 2018, ICT users were not flooded though ICT non-users were flooded similarly to 2016. On the other hand, ICT users have introduced 3-D and tower technology for farming in their homestead. By which they are able to produce vegetables during flood season. This is due to the fact that despite submerging homesteads and low land, 3-D and towers are flood resilient and do not become submerged. Every year villagers from the study areas were left homeless and landless due the increased incidence of floods caused by climate change; they often had to take shelter on the embankment. However, in 2017 and 2018, 60.9 and 91.3% of respondents had taken shelter in their house embankment prior to the flood. The number of villagers taking shelter on the embankment reduced consecutively because the respondents had raised their homestead plinths following information from the advisories. Due to climate information services, as well as flood information services, this forced displacement is markedly reduced.

Research and Knowledge Management

Community-based participatory research is the most effective means of community empowerment. It is conducted by people living in the community typically in collaboration or partnership with others who have research skills. This is beneficial as the people who live in the communities may not have the skills in research but are well aware of their local problems and solutions. During the field research, a trial was undertaken in order to understand the research skill-levels of the climate-vulnerable women who were utilizing ICT enabled mobile phones over the last two years. It was found that the ICT enabled women were capable of demarking the social resources in their locality, and produced a village resource map (which was overdrawn using

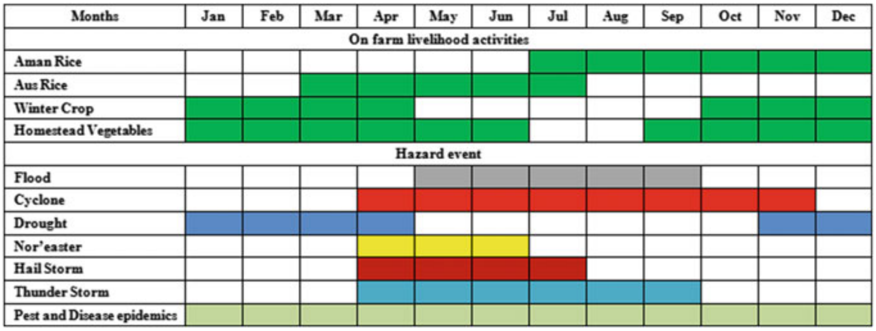


Fig. 24.7 Crop Calendar in South Kharibari, Dimla, and Nilphamari (drawn by climate-vulnerable women)

GIS) defining all-important resources. Another trial was undertaken to draw attention to the seasonal crop calendar in 2015 and 2018, as well as before enabling ICT and after ICT, including a hazard risk period. The women drew crop calendars which are currently being out into practice (Fig. 24.7). Both of these tasks illustrates the research and knowledge management skill of the women. It also illustrates that they are capable of mitigating climate-induced risk in their locality through the use of climate information services (Map 24.4).

Mitigation and Low-Carbon Development

Climate change mitigation is reducing the release of greenhouse gas emissions. Low carbon development means integrating and addressing climate change into development by cutting down on emissions. In rural areas, mitigation strategies include energy efficiency, adopting renewable energy sources like solar, promoting improved cook stoves, using bio fertilizers and improved crop varieties in farming, promoting agroforestry and promoting more sustainable uses of land and vegetation as well as forests. Mitigation and low carbon development can be promoted through direct or indirect interventions. Direct interventions include introducing renewable energy, improved cook stoves, waste management, zero waste development, etc. Indirect interventions include reducing fossil fuel use and reducing chemical fertilizers. In the study area, through ICT and climate information services, the priority was given to agriculture-based development and low carbon development in the agricultural sector. Utilization of bio fertilizers instead of chemical fertilizer is promoted to reduce GHG from chemical fertilizer. It was found that in 2018, 45% of ICT users were using bio fertilizer in their crop land, this is a great improvement of the 9% use in 2015. Also, 67% of ICT user women have introduced improved crop varieties to ensure water and energy efficiency in 2018, which was only 2% in 2015

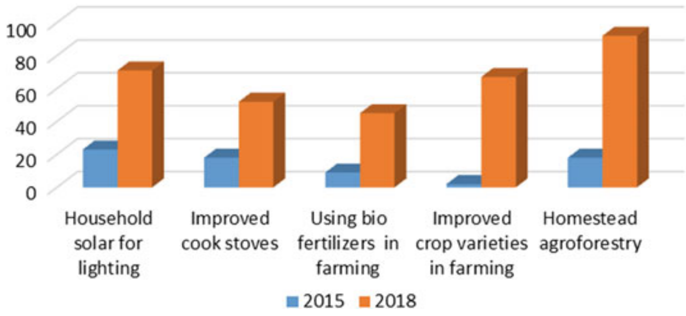


Fig. 24.8 Comparison of mitigation and low carbon development initiative in study area between 2015 and 2018

(Fig. 24.8). Improved cooking stoves, solar panel for household lighting and homestead agroforestry were also found in the study area, all of which were introduced via information obtained while using a cellular phone.

Capacity Building and Institutional Strengthening

Capacity building and institutional strengthening is an important pillar of BCCSAP, which is also promoted among ICT user women in the study area. ICT user women are organized into several climate-vulnerable groups; the groups were formed by themselves. In the study village, 100 ICT user women formed four community organizations containing 25 members in each group. They are capable of expressing their vulnerability, coping mechanisms, preparing changed crop calendars, preparing risk and hazard maps, undertaking disaster preparedness response and recovery initiatives, disseminating climate-induced disaster information and crop-livestock and fish related disease information to community as well as relatives far away. It is also found that the neighbors and relatives make phone calls and SMS to collect information related to climate information from the ICT user women.

Analyzing of Climate Information Services and INDC

Bangladesh committed to reducing GHG emissions by 5% by 2030, using only domestic resources, or by 15% by 2030 if sufficient and appropriate support is received from developed countries. Bangladesh also committed to reducing GHG emissions from domestic uses, which are mentioned in the Intended Nationally Determined Contributions (INDC). To achieve this target, the country has devised actions to improve energy efficiency in the domestic and commercial sectors, reduce emissions in the agriculture sector, and scale-up afforestation and reforestation Climate change mitigation and low carbon development is apriority in Bangladesh, and has been promoted throughout the last three years (2016–2018) through the delivery of climate information services to the climate-vulnerable women. This information promotes adopting renewable energy sources like solar, improved cooking stoves, using bio fertilizers and improved crop varieties in farming, agroforestry and promoting a more sustainable use of land, vegetation and forests. Utilization of bio fertilizer instead of chemical fertilizer is promoting in order to reduce GHG from chemical fertilizer. It was found in 2018 that 45% of ICT users were using bio fertilizer in their crop land, which is compared with only 9% in 2015. Also, 67% of ICT user women have introduced improved crop varieties in order to ensure water and energy efficiency in 2018, which was only 2% in 2015 (Fig. 24.8). Improved cooking stoves, solar panels for household lighting and homestead agroforestry were found in the study area, which was introduced obtaining information using a cellular phone.

Analyzing Climate Information Services and LAPA

Local Adaptation Plans for Action (LAPA), (a participatory, contextual and inclusive bottom-up planning process) need to be developed in order to operationalize the policy objectives outlined in the National Adaptation Programmes of Action (NAPA) and Bangladesh Climate Change Strategy and Action Plan (BCCSAP) (IRB 2017). The Bangladeshi government is committed to formulating LAPAs, and for this reason the government has taken some initiatives to help build the capacity of climate-vulnerable people at the community level.

Conclusions

Climate information services aim to increase women's participation, strengthen their leadership role, and to enhance their economic situation by developing customized information systems for agriculture; including crop farming, homestead gardening, fisheries, livestock, horticulture, and poultry. The ICT user women obtain climate information services through SMS, Outbound Dial (OBD), Apps and Call Centre services on agriculture, agro meteorology, weather forecast, and early warnings. Using climate information services through the ICT scheme, they are contributing to the Bangladesh Climate Change Strategy and Action Plan (BCCSAP) in terms of improving food security, disaster risk reduction, low carbon development (which is also align with Intended Nationally Determined Contribution (INDC)), capacity building and institutional development (which is also align with Local Adaptation Plan of Action (LAPA)). Though climate information services promotes BCCSAP, INDC, and LAPA it cannot be concluded that the information services are playing a role in ensuring climate-smart development or the promotion of BCCSAP, INDC, and LAPA. The information services should be dynamic, up to date and provide transboundary information related to weather forecasting. Hydrometeorology should also be incorporated in order to gain the highest result in the array of climate-resilient developments.

The rationality of the study

In Bangladesh, integrated study on ICT and climate-resilient development does not exist; we have tried to explore the role of ICT in promoting BCCSAP, NDC, and LAP. This is the first one study which has attempted to understand the contribution of ICT in promoting BCCSAP, NDC, and LAP as well as climate-smart development. Because of this, this study is a milestone in the scientific field of promoting climate change policy, strategy and action plans in Bangladesh.

Limitation of the study

Most of the resilience building initiatives in Bangladesh have emphasised adaptation practices, infrastructures and capacity building, compared to mitigation potentials at the local level. Therefore, resilience building initiatives should consider co-beneficial adaptation-mitigation practices. ICT has a great potential to deliver mitigation information at the community level, which could contribute to facilitating NDC targets on agriculture and energy sector. Therefore, the existing information delivery mechanism could be replicated in order to disseminate information on energy efficiency practices, promoting renewable energy, carbon management in agriculture, as well as contributing to achieving the low carbon development pathway. But, due to financial constraints, we could not explore how this could be done.

Acknowledgements We express our gratitude to OXFAM Bangladesh for funding this study under the research entitled "Developing working paper(s) on Climate Change Adaptation using Information and Communication Technology and Its Potential on National Actions (including Local Adaptation Plan of Action, Intended Nationally Determined Contributions and BCCSAP)".

References

Bangladesh Water Development Board (BWDB) (2018) Flood situation in Dimla, sub-district flood situation report, dimla. Nilphamari. Unpublished Report, Bangladesh Water Development Board (BWDB), Dhaka, Bangladesh

Denissen A (2012) Climate change & its impacts on Bangladesh. Retrieved from http://www.ncdo.nl/artikel/climate-change-its-impacts-bangladesh

Germanwatch (2018) Who suffers most from extreme weather events? weather-related Loss Events in 2016 and 1997 to 2016. Germanwatch Nord-Süd Initiative eV

Islamic Relief Bangladesh (IRB) (2017) Local adaptation plan for action: a tool for climate resilience. In: The Gobeshona conference for research on climate change in Bangladesh, Dhaka

Maplecroft (2014) World: climate change vulnerability index of 2014. Bath BA1 1JS, United Kingdom

Ministry of Environment and Forest (MoEF) (2015) Nationally determined contribution of Bangladesh-implementation roadmap. Ministry of environment and forest, government of the People's Republic of Bangladesh, Dhaka

Norton A, Conway T, Foster M (2001) Social protection concepts and approaches: implications for policy and practice in international development. Overseas Development Institute, London

Shamsuddoha M, Bijoy MR (2015) Step towards local adaptation planning: climate change vulnerability assessment of MonglaUpazilla. Network on climate change, Bangladesh (NCC, B), Dhaka

United Nations (1975) Report of the world food conference. Rome, New York

Chapter 25
Do Information and Citizens Characteristics Affect Public Acceptability of Landslide Protection Measures? A Latent Class Approach

Cristiano Franceschinis, Mara Thiene, Stefania Mattea and Riccardo Scarpa

Abstract The Italian Alps are increasingly vulnerable to landslides. Residents and visitors are exposed to serious socio-economic consequences from these natural events. Hence, risk mitigation is a major safety issue for local authorities. Publicly funded adaptation interventions are expensive to implement and cause the need to better understand acceptability of protection measures, and their economic efficiency. We investigate social demand for landslide protection in Boite Valley (North-Eastern Alps) by adopting a choice experiment survey approach. We specifically address the impact of information on preferences by eliciting them before and after providing respondents with visual simulations of possible catastrophic events. Choice data are used to estimate a Latent Class-Random Parameters model. This allows us to identify segments of the population with different preference profiles towards safety measures and their sensitivity to information treatments. Marginal willingness to pay (mWTP) values for protection measures are estimated and mapped to describe the spatial distribution of benefits from risk reduction. Overall, we found mWTP values to vary spatially and to be dependent on information and socio-economic characteristics.

Introduction

Over the last few decades the number of landslides events in the Dolomites (Italy) has increased. Among other factors, this is a consequence of more frequent extreme rainfalls and increased availability of debris material (Bernard et al. 2019; Gregoretti

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Climate Change Management, https://doi.org/10.1007/978-3-030-36875-3_25

et al. 2019). Hence, people living in such area are exposed to serious socio-economic consequences and there is high social demand for protection.

Due to the high hydrogeological risk level—which has been exacerbated by climate change—several landslides occurred in the Boite Valley (North-Eastern Alps, the study area) and caused deaths and damage to houses and other property. In 1814, a massive debris-flow destroyed two villages, killing 257 people. In 1925, a similar event caused 288 victims and 53 people went missing. In summer 2015 intense rainfalls over a short period triggered eight events, causing significant damage to public infrastructure and three victims among tourists. More recently one victim was caused in 2017 in Cortina and other landslides took place in 2018. Hence, risk mitigation is a major component of climate change adaptation and a safety issue for local authorities. Accounting for social preferences is crucial to inform fairly the ongoing public debate on this matter.

We report the results of an application of choice experiments (CE) in the Boite Valley aimed at estimating residents and tourists' willingness to pay (WTP) for different safety devices. Stated preference approaches have a broad record of use in the context of natural hazards, such as in floods (e.g. Brouwer and Schaafsma 2013; Ryffel et al. 2014; Arora et al. 2019), avalanches (e.g. Leiter and Pruckner 2009; Haegeli and Strong-Cvetich 2018), wildfires (e.g. Wibbenmeyer et al. 2013; Holmes et al. 2013) and landslides (Flügel et al. 2015; Thiene et al. 2017).

We also analyse the extent to which information (through simulations of possible events) affects respondents' stated preferences. Estimates of welfare measures have, in fact, been shown to be impacted by information provided to survey respondents (e.g. Aoki et al. 2019). Finally, we mapped average values of marginal WTP estimates at the individual level within each municipality. This approach roots on the increasing evidence that benefits from public goods are spatially heterogeneous (Campbell et al. 2008; De Valck et al. 2017; Sagebiel et al. 2017).

The remainder of this paper is organised in four sections. Section 2 describes data collection and Sect. 3 outlines the econometric approach adopted for the study. Section 4 reports the results. Finally, the conclusions are drawn in Sect. 5 along with the policy implications for landslide risk mitigation in the Boite Valley.

Survey Design and Data Collection

This section describes survey design and sampling procedure. More details can be found in Mattea et al. (2016).

The questionnaires used in the survey included seven sections: the first posed questions about subjective risk perception, attitudes toward risk activities and natural hazards, and personal experience with landslides. The second focused on recreational behaviour. The questionnaire was designed to include a CE in the third part and a "repeated" CE in the fifth. In-between (fourth section) two hydro-geological simulations of landslides were shown to respondents. The first simulation (Fig. 25.1) referred to three sites in the upper part of the valley and showed all debris-flow

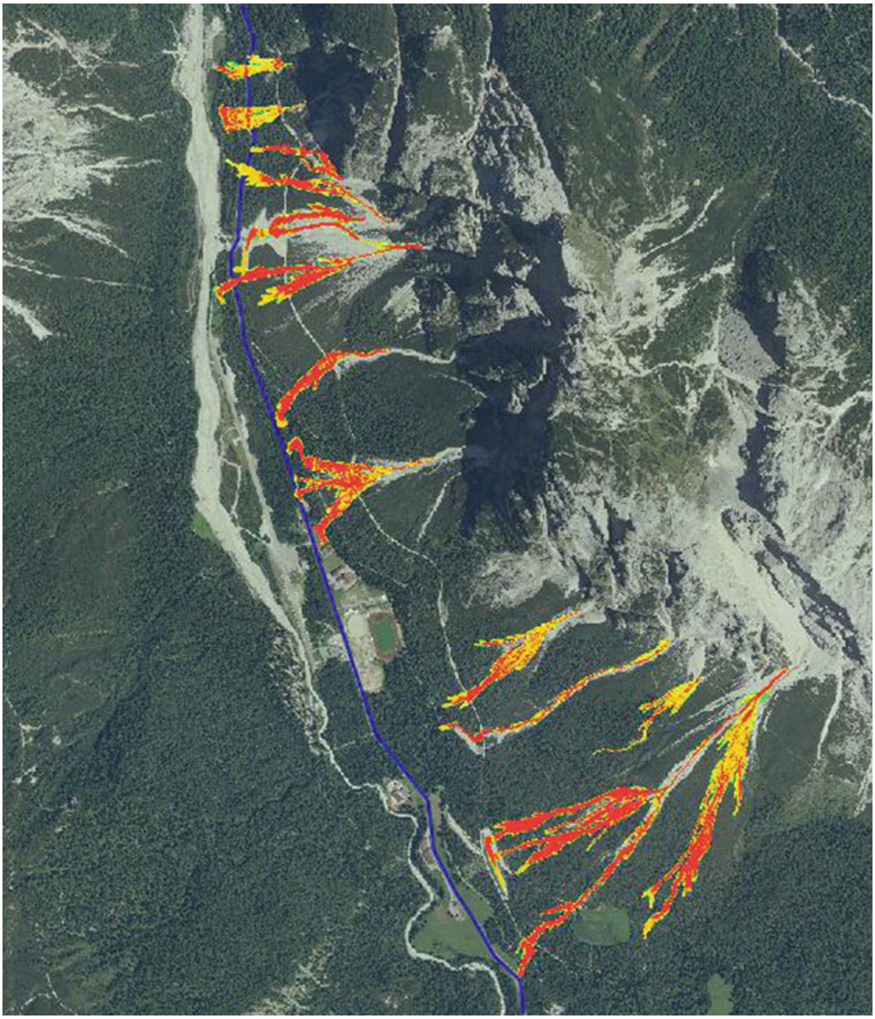

Fig. 25.1 Debris-flow simulation in the upper part of Boite Valley (Gregoretti 2014)

possible trajectories. The second simulation modelled debris-flow trajectories in a specific site with and without a channel (Fig. 25.3). The green lines show possible trajectories with a channel, while green and yellow lines are the trajectories without such safety device. The sixth section included follow-up questions, whereas the last one focused on socio-economic ones (Fig. 25.2).

The CE used five attributes to describe alternative scenarios (Table 25.1). Four attributes represented safety devices, namely diverging channel and retaining basin (passive devices) and video cameras and acoustic sensors (active devices). The fifth attribute is a hypothetical road toll to be paid by vehicles in transit across the valley.

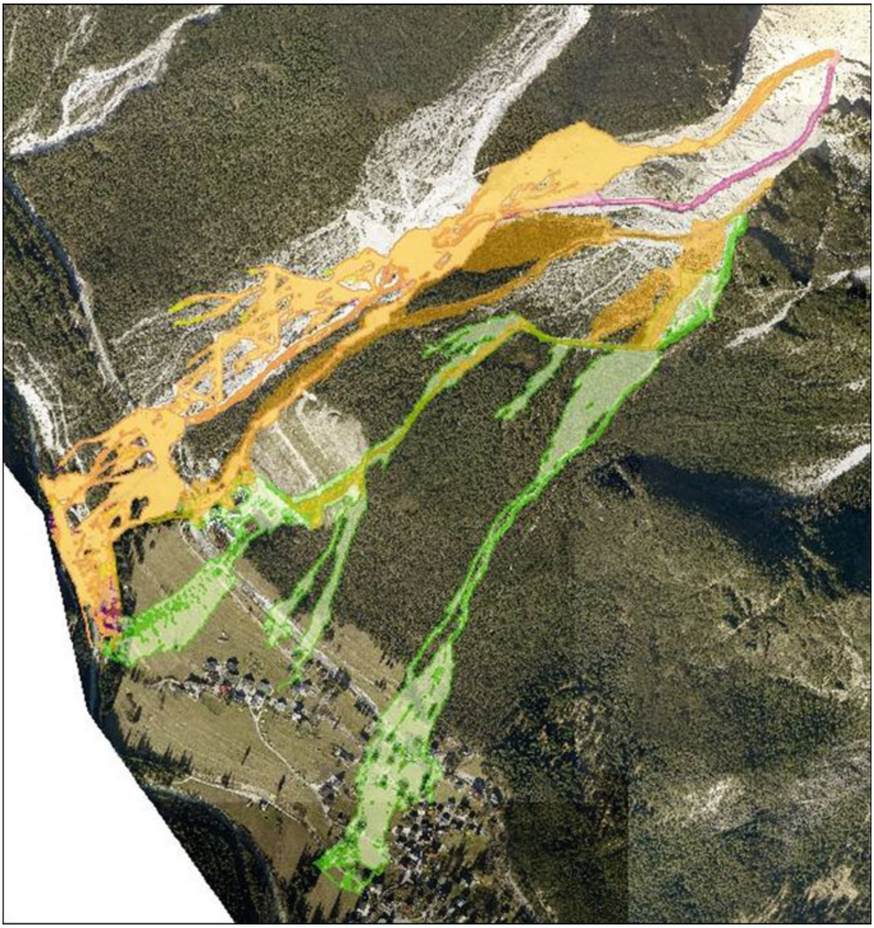

Fig. 25.2 Debris-flow simulation with (yellow area) and without (yellow and green areas) channel (Gregoretti 2014)

The toll was defined as a one-time payment valid for eight months to financially support the implementation of the mitigation programs. In the data all attribute levels are dummy-coded (presence of the safety device = 1, else = 0) with the exception of the monetary attribute that takes four numeric values. The experimental design used was an optimised orthogonal design (Ferrini and Scarpa 2007, Scarpa and Rose 2008) which generated 60 choice sets. The choice sets were blocked into 10 groups, so each respondent faced 6 scenarios.

Responses to the questionnaires were obtained during face-to-face interviews to a sample of 250 respondents, randomly sampled on-site among residents and visitors of the valley.

Table 25.1 CE attributes and levels

Attribute	Acronym	Description	Levels
Channel	CHAN	Diverging channel is a man-made channel built to redirect water. The water is carried off in a different way that the sediment and rocks mitigating the impact of the debris-flow	1 if present 0 otherwise
Basin	BAS	Retaining basin is a dam where the solid and liquid mass is collected prior to damage roads and villages	1 if present 0 otherwise
Video cameras	VIDEO	Video cameras monitor the debris-flow during the night and, in case of emergency, they will activate the alarm system and the traffic lights on the road	1 if present 0 otherwise
Acoustic sensors	SENS	Acoustic sensors detect soil movement in slopes prior to landslides. The sensors consist of pipes inserted vertically in the flank of a debris-flow slope. They provide with acoustic emissions used to give early warnings of landslide occurrence as well as activated the traffic lights	1 if present 0 otherwise
Road toll	TOLL	A road toll to pay for eight months (from April to November of a specific year) daily for transit in the valley by car for residents and tourists	€1 €2 €3 €4

Data Analysis

We modelled choice data by means of a Latent Class—Random Parameters (LC-RPL model) (Bujosa et al. 2010), which assumes that respondents' preferences vary discretely across C classes and continuously within each class.

To specify class membership probability, we use a logit formulation for the class allocation model (Bhat 1997). The probability (π_{nc}) that individual n belongs to segment C vector is given by

$$\pi_{nc} = \frac{\exp\left(\theta_c' Z_n\right)}{\sum_{c=1}^{c=C} \exp\left(\theta_c' Z_n\right)} \tag{25.1}$$

with Z_n being a vector of socioeconomic variables and θ_c a vector of estimated coefficients.

Respondents' preferences $\boldsymbol{\beta}_{nc}$ vary continuously within each class with class specific hyper-parameters (e.g. mean $\boldsymbol{\mu}_c$ and st. dev. $\boldsymbol{\sigma}_c$). Such parameters can be derived by estimating the conditional probability of individual n choosing alternative i out of a set of alternatives J:

$$\pi_{nti|c} = \int \prod_{t=1}^{t=T} \frac{\exp\left(\beta_{nc}' \mathbf{x}_{ti}\right)}{\sum_{j=1}^{j=J} \exp\left(\beta_{nc}' \mathbf{x}_{tj}\right)} f(\beta_{nc}) d\beta_{nc} \tag{25.2}$$

where random parameters follow a separate distributional law (Train 1999; McFadden and Train 2000). Finally, the LC-RPL unconditional probability that individual n chooses the t sequences of i in their choice task sequence can be derived from Eqs. (25.1) to (25.2):

$$\pi_{nti} = \sum_{c=1}^{c=C} \pi_{nc}\pi_{nti|c} \tag{25.3}$$

To investigate the role of information on preferences we estimated a pooled utility function and included an interaction variable between each attribute and a dummy variable I, which is defined as equal to 1 for data collected after the exposure to information. Finally, we created maps illustrating the spatial distribution of individual-specific mWTP values for each safety device.

Results

LC-RPL Estimates

The LC-RPL model has been estimated by simulated maximum likelihood using Pythonbiogeme software (Bierlaire 2003). The choice probabilities are simulated in the sample log-likelihood with 500 pseudo-random draws of the modified Latin hypercube sampling (MLHS) type. All the attributes' coefficients are assumed to have a normal distribution, except for the cost attribute that is fixed. Additionally, the model includes an alternative specific constants (ASCs) for the baseline option.

To identify the optimal number of classes, we estimated alternative specifications and compared them by using information criteria (Table 25.2). Based on these criteria and on the number of significant parameters in each class, we selected the specification with two classes.

To obtain a better profiling of the two classes we included several socio-demographic characteristics in the class membership function (Table 25.3). Many showed a significant effect and the signs suggest that women with higher education and income and larger families are more likely to belong to class 1. Class membership probabilities averaged across all individuals are nearly 55% for class 1 and the remaining 45% for class 2.

Table 25.2 Criteria for the selection of the number of classes

N = 250					
Number of classes	Parameters	lnL	AIC	BIC	AICc
2	43	−2425	4936	5087	4894
3	63	−2378	4882	5103	4820

Table 25.3 LC-RPL Estimates

	Class 1 (55%)			Class 2 (45%)		
Parameters	Value	|t|	mWTP	Value	|t|	mWTP
Mean parameters						
Basin	4.21	8.88	2.26	1.37	4.45	0.82
Channel	4.99	5.67	2.68	1.48	4.29	0.89
Sensor	3.12	6.98	1.68	0.95	2.66	0.57
Camera	3.48	8.81	1.87	0.71	2.30	0.43
Toll	−1.86	7.91		−1.67	14.69	
Status quo	−2.31	6.66	−1.24	−1.01	4.41	−0.60
Interaction parameters						
Info × basin	0.33	0.43	0.18	0.21	0.83	0.13
Info × channel	0.66	2.08	0.35	0.28	2.11	0.17
Info × sensor	0.38	0.32	0.20	0.12	0.01	0.07
Info × video	−0.06	0.34	−0.03	0.15	1.61	0.09
Info × toll	0.11	0.87	0.06	0.17	0.27	0.10
Info × *status quo*	−0.48	1.99	−0.26	−0.25	2.08	−0.15
Standard deviation parameters						
Basin	1.28	10.98		1.15	3.75	
Channel	2.01	11.21		0.24	5.40	
Sensor	1.41	9.87		0.27	3.35	
Camera	1.25	6.89		0.44	4.77	
Class membership parameters						
Constant				1.06	2.02	
Woman				−0.62	2.01	
Age				1.12	0.81	
Income				−0.42	2.01	
Degree				−0.36	2.81	
Number of family members				−0.41	2.36	

The estimates suggest a consistent preference for the improvement of the current scenario (negatives signs for status quo in both classes), as well as the existence of heterogeneity of preferences both among and within classes (significant standard deviation parameters). The coefficient of the cost attribute is negative and significant in both classes, as expected. In both classes the coefficients associated with safety devices are significant and positive, thus suggesting that citizens would generally benefit from the implementation of such measures.

The main difference among the two classes lies in the magnitude of WTP values. Specifically, such values are consistently higher in class 1 for all safety devices. This is consistent with the profile of the two classes emerged from the class membership function, and in particular with the higher income that members of class 1 are likely to have.

More in detail, the construction of a channel is associated with the highest WTP values in both classes (€2.68 and €0.89, respectively). The basin is the second preferred protection device in both cases (€2.26 and €0.82). In class 1 respondents slightly preferred video camera (€1.87) to acoustic sensor (€1.68), while in class 2 was the opposite (€0.57 vs. €0.43). It is also interesting to notice that members of class 1 are more averse to the status quo than those belonging to class 2, which seems to confirm that the former are willing to pay more to improve current safety programs.

Moving to the analysis of the information effect, it is interesting to notice that the interaction terms between treatment and safety devices are all insignificant, with the exception of the one for channel. Specifically, the positive sign in both classes suggests that the information treatment led to an increase in the perceived benefit from this safety device (and consequently in the WTP for its implementation). This result is consistent with the simulations being focused specifically on such device and seems to suggest that the provision of information only affects the interested attribute.

Mapping Results and Policy Implications

This section reports the mapping of the estimated individual-specific mWTP for each attribute and class within sampled municipalities. Individual class membership probabilities were computed, and each person was assigned to the class he/she has the highest probability to belong to.

Figure 25.3 reports the maps for channel and basin and Fig. 25.4 for sensor and camera. We considered only the municipalities in the Belluno province, given the low number of respondents from other provinces. The municipalities delimitated by the black line are those in the Boite Valley. By looking at the maps, a common pattern seems to emerge across all devices and classes: higher WTP values are in most cases retrieved in municipalities inside the valley boundaries or in its proximity. As expected, inhabitants of such municipalities are those more exposed to damages caused by catastrophic events in the valley. Hence, it is plausible that they may be generally willing to pay more to prevent (or at least limit) such damages, compared to individuals living at further distance.

Conclusions

We presented results of a choice experiment evaluating alternative protection policies in the context of landslide risk reduction. Results show evidence of preference heterogeneity for safety devices, by reflecting estimates of marginal WTP values which are well-differentiated across different segments of the population. We also

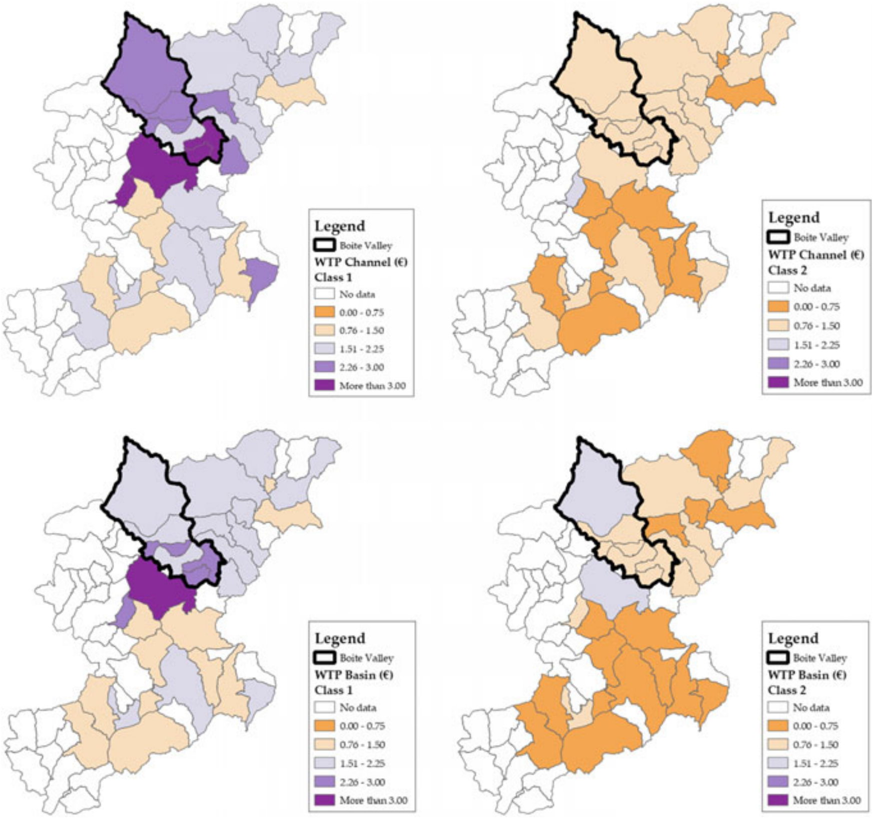

Fig. 25.3 Geographical distribution of mWTP values for channel and basin

find evidence of a treatment effect associated with the provision of visual information. While not clear-cut, the mapping of the estimated values seems to suggest that people living in the Boite Valley or in its proximity are generally willing to pay more for all devices than those living elsewhere.

With regards to policy implications, the estimates suggest that policymakers should focus on the implementation of plans which include the construction of passive devices, as residents and visitors of the valley are willing to contribute more to their realization. The analysis of information effect suggests that investment in information campaigns and educational activities could be a useful tool to increase financial support to public safety measures by the population. Specifically, it seems advisable to focus such activities on measures that policymakers are already planning to adopt, in order to increase their public acceptance. As a closing remark, it should be noted that our results do not account for the costs of implementing different safety devices. Future research should address this limitation and integrate our results with a cost-benefit analysis in order to inform more efficiently the public debate on protection plans.

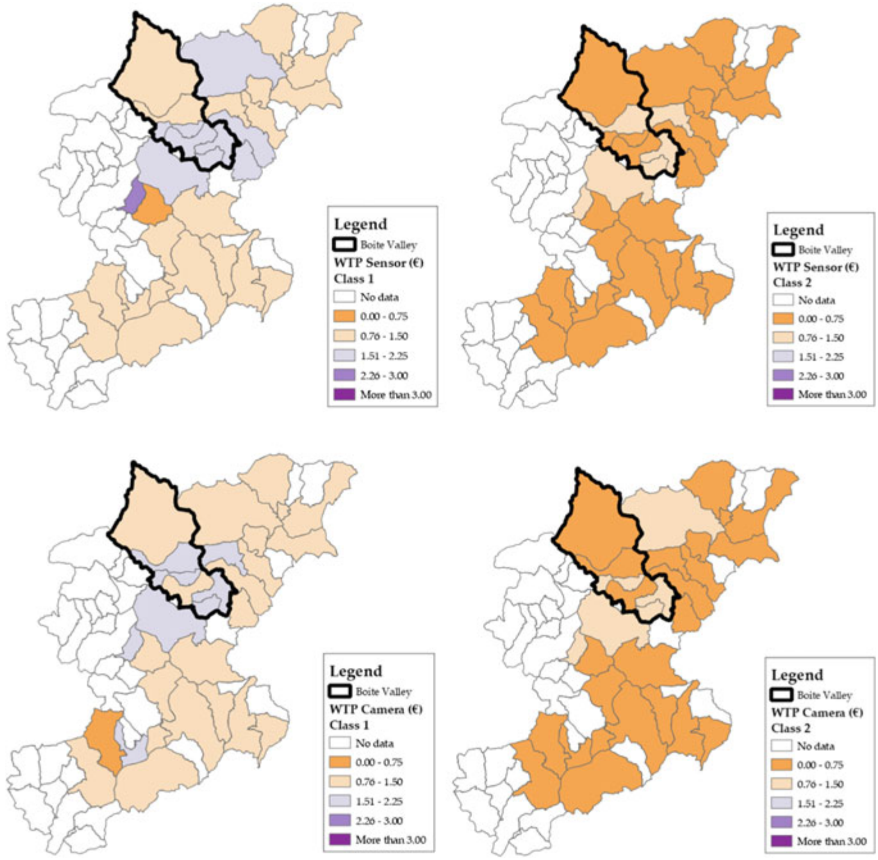

Fig. 25.4 Geographical distribution of mWTP values for acoustic sensor and video camera

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References

Aoki K, Akai K, Ujiie K, Shimmura T, Nishino N (2019) The impact of information on taste ranking and cultivation method on rice types that protect endangered birds in Japan: non-hypothetical choice experiment with tasting. Food Qual Prefer 75:28–38

Arora A, Sangeeta B, Ward PS (2019) Do farmers value rice varieties tolerant to droughts and floods? evidence from a discrete choice experiment in Odisha, India. Water Resour Econ 25:27–41

Bhat CR (1997) An endogenous segmentation mode choice model with an application to intercity travel. Transp Sci 31(1):34–48

Bernard M, Boreggio M, Degetto M, Gregoretti C (2019) Model-based approach for design and performance evaluation of works controlling stony debris flows with an application to a case study at Rovina di Cancia (Venetian Dolomites, Northeast Italy). Sci Total Environ 688:1373–1388
Bierlaire M (2003) BIOGEME: a free package for the estimation of discrete choice models. In: Chevroulet T, Sevestre A (eds) Proceedings 3rd Swiss Transportation Research Conference, Monte-Verita, Ascona, Switzerland
Brouwer R, Schaafsma M (2013) Modelling risk adaptation and mitigation behaviour under different climate change scenarios. Clim Change 117(1–2):11–29
Bujosa A, Riera A, Hicks RL (2010) Combining discrete and continuous representations of preference heterogeneity: a latent class approach. Environ Res Econ 47:477–493
Campbell D, Scarpa R, Hutchinson WG (2008) Assessing the spatial dependence of welfare estimates obtained from discrete choice experiments. Lett Spatial Resour Sci 1(2–3):117–126
De Valck J, Broekx S, Liekens I, Aertsens J, Vranken L (2017) Testing the influence of substitute sites in nature valuation by using spatial discounting factors. Environ Resour Econ 66(1):17–43
Ferrini S, Scarpa R (2007) Designs with a priori information for nonmarket valuation with choice-experiments: a Monte Carlo study. J Environ Econ Manag 53(3):342–363
Flügel S, Rizzi LI, Veisten K, Elvik R, De Dios Ortúzar J (2015) Car drivers' valuation of landslide risk reductions. Saf Sci 77:1–9
Gregoretti C (2014) Personal communication
Gregoretti C, Stancanelli LM, Bernard M, Boreggio M, Degetto M, Lanzoni S (2019) Relevance of erosion processes when modelling in-channel gravel debris flows for efficient hazard assessment. J Hydrol 568:575–591
Haegeli P, Strong-Cvetich LR (2018) Using discrete choice experiments to examine the stepwise nature of avalanche risk management decisions—an example from mountain snowmobiling. J Outdoor Recreat Tour. In press
Holmes TP, González-Cabán A, Loomis J, Sánchez J (2013) The effects of personal experience on choice-based preferences for wildfire protection programs. Int J Wildland Fire 22(2):234–245
Leiter A, Pruckner G (2009) Proportionality of willingness to pay to small changes in risk: the impact of attitudinal factors in scope tests. Environ Resour Econ 42:169–186
Mattea S, Franceschinis C, Scarpa R, Thiene M (2016) Valuing landslide risk reduction programs in the Italian Alps: The effect of visual information on preference stability. Land Use Policy 59:176–184
McFadden D, Train KE (2000) Mixed MNL models for discrete response. J Appl Econ 15(5):447–470
Ryffel AN, Rid W, Gret-Regamey A (2014) Land use trade-offs for flood protection: a choice experiment with visualizations. Ecosyst Serv 10:111–123
Sagebiel J, Glenk K, Meyerhoff J (2017) Spatially explicit demand for afforestation. For Policy Econ 78:190–199
Scarpa R, Rose JM (2008) Design efficiency for non-market valuation with choice modelling: how to measure it, what to report and why. Aust J Agric Resour Econ 52:253–282
Thiene M, Shaw WD, Scarpa R (2017) Perceived risks of mountain landslides in Italy: stated choices for subjective risk reductions. Landslides 14(3):1077–1089
Train KE (1999) Mixed logit models for recreation demand. In: Herriges JA, Kling CL (eds) Valuing recreation and the environment: revealed preference methods in theory and practice, new horizons in environmental economics. Edward, Cheltenham
Wibbenmeyer MJ, Hand MS, Calkin DE, Venn TJ, Thompson MP (2013) Risk preferences in strategic wildfire decision making: a choice experiment with US wildfire managers. Risk Anal 33(6):1021–1037

Chapter 26
Future Trends in Climate Services

Daniela Jacob

Abstract This concluding chapter offers an analysis of the presented findings, connects them to the history of climate services, and provides an overview of future perspectives. It considers current and future trends in climate science as well as the need to mitigate climate change, which is also impacting the development of climate services. The paper suggests that a major challenge by climate services is to identify the means and tools on how best to support adaptation to and mitigation of climate change.

During the last decade, the field of climate services has developed quite rapidly (cf. Brasseur and Gallardo 2016). Several initiatives have been implemented. For instance:

i. the international Climate Services Partnership (CSP; http://www.climate-services.org) founded in 2011, which is a network of climate services providers and users, NGOs, financing bodies and local stakeholder;
ii. the Global Framework for Climate Services (GFCS; https://gfcs.wmo.int) established in 2009 organized by the World Meteorological Organization, which is mainly focusing on the provision of hydro-meteorological information; or
iii. the Joint Programming Initiative "Connecting Climate Knowledge for Europe" (JPI Climate; http://www.jpi-climate.eu/home) also founded in 2011, which is a pan-European network of national funding bodies to jointly coordinate climate research.

The Paris Agreement, the Sendai Framework, the Sustainable Development Goals (SDGs) all UN frameworks established in 2015, the release of the IPCC special report on Global Warming of 1.5 °C (in 2018) among others, combined with the documentation and media attention to several extreme weather events all over the world, have boosted the public debate about climate change, thus raising awareness about the need for adequate measures for protection against climatic extremes, and for the mitigation of climate change.

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In 2015, the European Commission published the so-called European Research and Innovation Roadmap for Climate Services (cf. EU 2015) often referred to as 'the Roadmap', as a milestone to facilitate the development of the market for climate services. Climate services have matured to be part of the solutions to adapt to changing climates. This is also reflected in the ever increasing number of climate services providers in Europe, and elsewhere in the world. In the framework of the H2020 project Market Research for a Climate Services Observatory (MARCO), as many as 500 climate services providers have been identified across the 28 EU Member States (cf. Cortekar et al. 2019).

However, the market uptake of climate services is still rather weak. There are still some obstacles hindering market development (cf. Perrels et al. 2018). On the supply side, this includes (among others) the fact that climate services are not really packed as services but rather as Research and Development (R&D) project outputs. Also, the services are often perceived as being out of scope for the addressed user group, e.g. temporal and/or spatial scale mismatches. Important obstacles on the demand side include inherently short term-oriented decision-making ruling on climate change impacts in risk management, or the lack of a proper understanding of how climate services can be integrated in decision making. Matching supply and demand is also often difficult, due to "language" issues between providers and users in terms of terminology and conceptions.

There is now a broad agreement, worldwide, that adaptation to climate change is a necessary strategy in attempts to cope with a changing climate. In 2010, the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) established the National Adaptation Plan (NAP) process, which helps to empower the Least Developed Countries (LDCs) and other developing countries to identify potential vulnerabilities and address their adaptation planning. Four main elements of the NAP process have been identified:

(a) laying the groundwork and address gaps;
(b) preparatory elements;
(c) implementation strategies; and
(d) reporting monitoring and review (UNFCCC 2018).

Climate services can be useful in each of those elements, for example when developing user needs catalogues, climate projections, impact, risk and vulnerability assessments, adaptation modeling, and monitoring and evaluation of adaptation interventions. These services and products need to respond to the demand for sound information to guide adaptation and climate-related decisions.

Specific products and services, such as Climate Factsheets (which include climate projections), impacts, vulnerability or risks assessments are of special interest and useful for developing countries, especially for the least developed countries (LDCs) and small island development states (SIDS). Such countries are already facing many of the impacts of climate change, and have limited resources to invest in adaptation interventions. Therefore, the identification of sectors of their economies that should be prioritized due to their vulnerability to climate change, is a matter of outmost importance. In the same way, the identification of no-regret interventions which support their adaptation to the changing conditions, is a key element to be considered. This is reflected, e.g., in the information requested as part of funding proposals to the Green Climate Fund (GCF), which needs to be "based upon sound climate information", which at the same time remains limited for the national and local scales (GCF 2019).

Lately, the demand for integration of the three main agendas (climate, development and disaster risk reduction) when planning interventions or policies at the different levels, has increased. This integration also demands integrative services, which allow governments, UN agencies, multilateral banks, and practitioners to reduce the overlapping of efforts and take advantage of synergies.

The Development of Climate Services within the Next Decade

The articles presented in this book show very nicely the large variety of works in the field of climate services, from methodological frameworks and guidance, to data handling and case studies. Even though climate services have come a long way, further progress needs to be done. The advancements in the field of climate services will be fast. Big data and digitalization will stimulate the provision of data-based products. But the development and use of climate services and with this, the success of adaptation to climate change, heavily depends on solid science, transparency, knowledge sharing and the dialogue with local and sectoral stakeholders. To be more effective and relevant, and to close the temporal/spatial gaps mentioned earlier, the resolution of the underlying climate information needs to be increased, so as to allow for the provision of localized climate services. Currently, the new generation of regional climate models under development aims at a resolution of one to three kilometers. In addition, the integration of (regional) climate models with other physical and socio-economic impact models has the potential to significantly increase the relevance and effectiveness of climate services for decision making.

Developing relevant and effective climate services requires a variety of expertise along the value chain, from providing climate knowledge to the final climate service product (cf. EU 2015). Most of the climate services providers only cover parts of these needs (cf. Cortekar et al. 2019), which makes collaboration and good networking a key success factor to develop relevant climate services. This includes public and private providers of climate services equally, which, to some extent, requires the development of new business models (cf. Hoa et al. 2019; Larosa and Mysiak 2019). It makes climate services a labor-intensive business area, with the potential to create a large number of jobs in a sustainable, low-carbon society. For this, unfortunately, the educational background is still weak. Multi-disciplinary study programs at universities, or capacity development schemes outside of the academic arena and clear career opportunities, are still missing.

As mentioned above, the uptake of climate services needs to be improved. An important cornerstone—next to quality issues—is climate communication. This is not limited to communicating the latest advancements of climate science. Rather, it also includes communication on what is available where, how it can be applied. Quality control and quality assurance are still weak elements in the development of climate service products. Standards beyond good practices will have to be carefully developed, to guarantee that basic scientific findings and practices are underpinning climate change adaption. This is needed to avoid wrong and often expensive decisions. Even though it might be difficult to agree on binding quality criteria or standards, minimum requirements should entail transparency on the underlying datasets, and of the methods used.

Climate services are typically case specific, which implies that there are no one-size-fits-all solutions. Nevertheless, knowledge sharing of good-practices is a key to allow the transfer of proven concepts and methodologies to other regions and/or similar contexts, e.g. from Europe to Africa.

In the past decades, the priority sectors of climate services were mainly agriculture and forestry, water, energy and urban planning (cf. Cortekar et al. 2019). According to latest studies, new priority sectors will emerge during the next decade (cf. Howard et al. 2019), for which solutions will have to be developed and expertise needs to be built or connected.

Conclusions

The last decade can be labeled as the 'early years' of climate services, the exploration of a new field necessary in a changing world. The next decade will show how this field will mature, and how it can be mainstreamed in planning climate change adaptation and societal transformation towards a $+1.5°$ world. This requires a wise approach to address the various challenges that lie ahead. The "World Climate Research Program", the "World Adaptation Science Program" and "Future Earth" create important framework conditions for the further development of scientific principles (e.g. model resolution) and the integration of scientific communities. The new orientation of the forthcoming EU research framework program "Horizon Europe" will also strengthen the link between research and society. It will be crucial to make climate services more easily accessible to everyone, in an understandable way. Knowledge sharing and joint learning will be key to do so, for which books like this are a good example.

References

Brasseur GP, Gallardo L (2016) Climate services: lessons learned and future prospects. Earth Futur 4:79–89. https://doi.org/10.1002/2015EF000338

Cortekar J, Themessl M, Lamich L (2019) Systematic analysis of EU-based climate services providers. Clim Serv https://doi.org/10.1016/j.cliser.2019.100125

European Union (2015) A European research and innovation roadmap for climate services. European Union, Geneva

GCF (2019) Adaptation: accelerating action towards a climate resilient future. Available at https://www.greenclimate.fund/documents/20182/194568/gcf-wp1.pdf/9215ecb7–923a-9cfb-e4ae-d8f0be6e7b29

Hoa E, Lê T-T, Cortekar J (2019) MARCO Del. 2.7—recommendations. http://marco-h2020.eu/results/

Howard S, Howard S, Howard S (2019) Quantitative market analysis of the European climate services sector—the application of the kMatrix big data market analytical tool to provide robust market intelligence. Clim Serv. https://doi.org/10.1016/j.cliser.2019.100108

Larosa F, Mysiak J (2019) Business models for climare services: an analysis. Clim Serv. https://doi.org/10.1016/j.cliser.2019.100111

UNFCCC (2018) Progress, experience, best practices, lessons learned, gaps, needs and support provided in the process to formulate and implement national adaptation plans. UNFCC, Geneva

Perrels A, Harjanne A, Pilli-Sihvola K, Cortekar J, Lamich K, Hamaker-Taylor R, Stegmaier P, Damm A (2018) EU-MACS Del. 5.1—a structured analysis of obstacles to uptake of climate services and indentification of policies and measures to overcome obstacles so as to promote uptake. http://eu-macs.eu/outputs/. Accessed 21 Oct 2019

Websites

CSP. http://www.climate-services.org

GFCS. https://gfcs.wmo.int. Accessed 21 Oct 2019

JPI Climate. http://www.jpi-climate.eu/home. Accessed 21 Oct 2019