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Disaster Risk Reduction for Resilience

Disaster and Social Aspects

Springer

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Hazard has conditioned us to live in hazard. All our pleasures are dependant upon it. Even though I arrange for a pleasure; and look forward to it, my eventual enjoyment of it is still a matter of hazard. Wherever time passes, there is hazard. You may die before you turn the next page.

–John Fowles, Áristos

Preface

Disaster risk reduction (DRR) aims to prevent new and reduce existing disaster risk, strengthening the resilience of people, systems, and approaches. These disasters manly include climate change, displacement, urbanization, pandemics, protracted crises, and financial systems collapse.

The United Nations System Chief Executives Board for Coordination (CEB), at its 2011 Spring Session, committed to mainstreaming disaster risk reduction in the programs and operations of the UN system through the development of a common agenda, and to raise disaster risk reduction to the highest political support. UNISDR (United Nation Office for Disaster Risk Reduction) Strategic Framework 2016–2021 is guided by supporting countries and societies in its implementation, monitoring, and review of progress; the prevention of new and reduction of existing disaster risk and strengthening resilience through successful multi-hazard disaster risk management.

The Sendai Framework aims to achieve the substantial reduction of disaster risk and losses in lives, livelihoods, and health and in the economic, physical, social, cultural, and environmental assets of persons, businesses, communities, and countries by 2030.

The Sendai Framework includes seven targets and four priorities for action:

The Seven Global Targets could be summarized as follows:

a. Substantially reduce global disaster mortality by 2030.
b. Substantially reduce the number of affected people globally by 2030.
c. Reduce direct disaster economic loss in relation to GDP by 2030.
d. Substantially reduce disaster damage to critical infrastructure, among them health and educational facilities.
e. Substantially increase the number of countries with local disaster risk reduction strategies by 2020.
f. Substantially enhance international cooperation to developing countries through adequate and sustainable supports.
g. Substantially increase the availability of the access to multi-hazard early warning systems by 2030.

The four priorities for action for Sendai framework are as follows:
Priority 1. Understanding disaster risk
Priority 2. Strengthening disaster risk governance to manage disaster risk
Priority 3. Investing in disaster risk reduction for resilience
Priority 4. Enhancing disaster preparedness for effective response

The Book Series on "Handbook of Disaster Risk Reduction for Resilience (HD3R)" attempts to fill theory and practice gap in the Sendai Framework through publishing the six proposed books. There is a big hope that learning Primary and Secondary Audiences of HD3R helps to meet several Sendai targets and priorities for action; Book Series publications on HD3R could be continued beyond publishing these six books up to 2030.

For assisting the UN objectives in disaster risk reduction, 2022 Handbook Series of Disaster Risk Reduction for Resilience (HD3R-2022) have been contracted by Springer. The handbook volume titles are given below:

I-Disaster Risk Reduction for Resilience: New Frameworks for Building Resilience to Disasters

II-Disaster Risk Reduction for Resilience: Disaster Risk Management Strategies

III-Disaster Risk Reduction for Resilience: Disaster and Social Aspects

IV-Disaster Risk Reduction for Resilience: Disaster Economic Vulnerability and Recovery Programs

V-Disaster Risk Reduction for Resilience: Climate Change and Disaster Risk Adaptation

VI-Disaster Risk Reduction for Resilience: Disaster Hydrological Resilience and Sustainability

This book is part of a six-volume series on Disaster Risk Reduction and Resilience. The series aims to fill in gaps in theory and practice in the Sendai Framework and provides additional resources, methodologies, and communication strategies to enhance the plan for action and targets proposed by the Sendai Framework. The series will appeal to a broad range of researchers, academics, students, policy makers, and practitioners in engineering, environmental science and geography, geoscience, emergency management, finance, community adaptation, atmospheric science, and information technology.

The current handbook as the third book of these series on *Disaster and Social Aspects* includes 20 chapters as summarized below.

This book offers the resilience assessment at the state level using the Sendai Framework and further emphasizes on disaster recovery reform and resilience such that recovery, development programs, and place-based reconstruction policies are defined and a flexible framework and the instrumental role of insurance are presented.

Also addressed are the religious and cultural aspects of resilience in disasters. Socio-ecological resilience for flood-prone waterfront cities is designed and the key role of wetlands for building the socio-ecological resilience against drought is highlighted. Coastal wetland hydrologic resilience to climatic disturbances has been a big issue that is covered in this book volume.

Case studies including India, Nigeria, Sahel, Bangladesh, and Himalaya have been also conducted. Strengthening climate resilience and disaster risk reduction for an adaptive social protection are discussed to build socio-hydrological resilience. The effect of climate change on water availability and quality, establishing organizations and partnerships for climate change mitigation and disaster reduction have been conducted. The impact of climate change on poor women and local adaptation in a highly flood-prone area are analyzed. Climate change adaptation and resilience of small-scale farmers completely differs from the large-scale ones as demonstrated in this book.

Food resilient cities, coastal flood-prone communities and sustainability, and disaster risk reduction by detecting glacial lake outburst floods are the other topics covered in this volume. Flood risk instruction measures: adaptation from the school is discussed in another chapter. An assessment of socio-resilience is determined for different communities.

This book finally enables the reader to learn from the past to prepare for the future disaster to reduce its impacts. Development of a multi-hazard early warning system has been highly recommended.

Students in all three levels (and also short courses) and instructors, lecturers, and professors are the primary audiences.

The secondary audiences include Industry Members (Earthquake Industries, Pollution Control Industry, Chemical Factory, Construction Industry, Transportation Industry), Policy Makers, Consulting Engineers, Researchers (Civil Engineering, Geosciences, Natural Geography, Environmental Science and Engineering, Hydrologic Engineering, Atmospheric Sciences, Environmental Sanitation, Applied Sciences, Statistics, Information Technology), National Hazard Centers, National Weather Services, IPCC Members, Insurance Companies, International Bank for Reconstruction and Development, UNDRR, UNEP, Community Resilience Centers, Emergency Management Agencies, and Disaster Risk Managers.

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Part I
Disaster Recovery Reform and Cultural Aspects

Chapter 1
Resilience Assessment at the State Level Using the Sendai Framework

Melissa De Iuliis, Omar Kammouh, and Gian Paolo Cimellaro

Abstract The multitude of uncertainties of both natural and man-made disasters have prompted an increased attention in resilience engineering and disaster management. To overcome the effects of disastrous events, such as economic and social effects, modern communities need to be resilient. Natural disasters are unpredictable and unavoidable. While it is not possible to prevent them and protect individuals and societies against such disasters, modern communities should be prepared by incorporating both pre-event (preparedness and mitigation) and post-event (response and recovery) resilience activities to minimize the negative effects after a severe event. Resilience indicators may be fundamental to help the planners and decision-makers to develop strategies and action plans for making communities more resilient. This chapter presents a quantitative approach to estimate the resilience and resilience-based risk at the state level. In the proposed method, the resilience-based risk is a function of resilience, hazard, and exposure. To evaluate the resilience parameter, data provided by the Sendai Framework for Disaster Risk Reduction (SFDRR) are used. The framework is developed using resilience indicators with the primary goal of achieving disaster risk reduction. To use those indicators in the resilience assessment, it is necessary to define the impact and the contribution of each indicator towards resilience. To do that, two possible methods to combine and weight the different SFDRR indicators are presented: Dependence Tree Analysis (DTA) and Spider Plot Weighted Area Analysis (SPA). The proposed approach allows the decision-makers and governments to evaluate the resilience and the related resilience-based risk (*RBR*) of their countries using available information.

Keywords Resilience · Risk management · Recovery · Sendai framework · Disaster reduction

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1 Introduction

The emergence of stressors such as population growth, urbanization, natural and man-made disasters, and resource scarcity, has brought a remarkable attention to the concept of resilience in modern communities facing growing challenges from severe events. Over the years, the focus has shifted to managing and reducing disaster risk, as it is often impossible to predict. Disaster events can be managed through hazard emergency planning to make modern communities more resilient so that they can absorb the impacts and recover quickly after disasters and reduce the time of recovery (De Iuliis, Kammouh, Cimellaro, & Tesfamariam, 2019a, 2019b; Kammouh, Cardoni, Marasco, Cimellaro, & Mahin, 2018; Kammouh & Cimellaro, 2018; Kammouh, Cimellaro, & Mahin, 2018; Kammouh, Dervishaj, & Cimellaro, 2018; Kammouh, Silvestri, Palermo, & Cimellaro, 2018). The concept of resilience is multidimensional, and therefore involves the various subjects of different disciplines (Balbi, Kammouh, Pia Repetto, & Cimellaro, 2018; Bonstrom & Corotis, 2014; Chang, McDaniels, Fox, Dhariwal, & Longstaff, 2014; Cimellaro, Renschler, Reinhorn, & Arendt, 2016; Cimellaro, Zamani-Noori, Kammouh, Terzic, & Mahin, 2016), from psychology, sociology, and economics to engineering and environmental research. The term was first developed in the ecological field in 1973 by Holling, defined as "*a measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships among populations or state variables.*" In engineering, the concept of resilience is "the ability of social units (e.g., organizations, communities) to mitigate hazards, contain the effects of disasters when they occur, and conduct recovery activities in a way that minimizes social disruption and mitigates the effects of future earthquakes" (Bruneau et al., 2003; Cimellaro, Reinhorn, & Bruneau, 2010; Cimellaro, Renschler, et al., 2016; Cimellaro, Zamani-Noori, et al., 2016; Kammouh, Cardoni, et al., 2018; Kammouh & Cimellaro, 2018; Kammouh, Cimellaro, & Mahin, 2018; Kammouh, Dervishaj, & Cimellaro, 2018; Kammouh, Silvestri, et al., 2018; Zamani Noori, Marasco, Kammouh, Domaneschi, & Cimellaro, 2017). Wagner and Breil (2013) defined resilience as the ability to "withstand stress, survive, adapt, and recover from a crisis or disaster and move on quickly." In the engineering perspective, the resilience of a modern community is based on all the physical components of the system, including buildings and infrastructures, to absorb the damage caused by an external shock and restore their state before the shock (Bruneau et al., 2003; Kammouh, Cardoni, Kim, & Cimellaro, 2017; Kammouh, Dervishaj, & Cimellaro, 2017; Kammouh, Zamani Noori, Renschler, & Cimellaro, 2017; Kammouh, Zamani-Noori, Cimellaro, & Mahin, 2017; O'Rourke, 2007; Reed, Kapur, & Christie, 2009). Bruneau et al. (2003) state that resilience is based on its serviceability performance. A measurable function $Q(t)$, that depends on the variable of time, can describe the value of the community infrastructures. The performance of a system can range from 0% to 100%, where 100% means "no drop-in service" and 0% indicates "no service available" (see Fig. 1.1). The loss of resilience $Q(t)$ is the performance degradation of the system over the entire recovery period, which starts

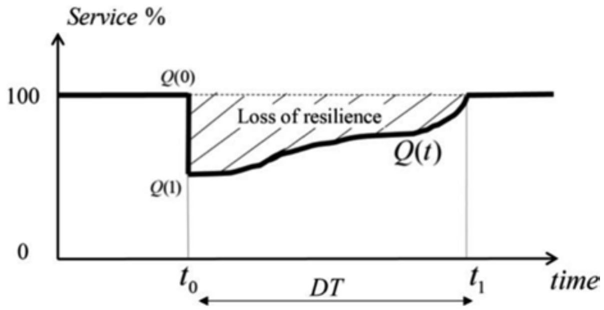

Fig. 1.1 Conceptual representation of engineering resilience

after the hazard event ends and when the functional capability returns to the initial state. Mathematically, the loss of resilience can be defined as follows:

$$\mathrm{LOR} = \int_{t_0}^{t_1} \left[100 - Q(t)\right] \mathrm{dt} \tag{1.1}$$

where *LOR* is the loss in resilience, t_0 is the time at which a disastrous event occurs, t_1 is the time at which the functionality of the system is 100%, $Q(t)$ is the functionality of the system at a given time t.

Nowadays, the concept of resilience is widely associated with disaster risk reduction. UNISDR (2005) defines resilience as "the ability of a system, community or society potentially exposed to hazards to adapt by resisting or changing in order to achieve and maintain an acceptable level of functioning and structure."

Several resilience frameworks available in the literature highlight the lack of standardization in defining resilience measurements due to the multidisciplinary context (Kammouh, Cardoni, et al., 2018; Kammouh & Cimellaro, 2018; Kammouh, Cimellaro, & Mahin, 2018; Kammouh, Dervishaj, & Cimellaro, 2018; Kammouh, Silvestri, et al., 2018; Marasco et al., 2018; Sarkis, Palermo, Kammouh, & Cimellaro, 2018). Available resilience frameworks are often based on the indicators that are important for assessing community resilience at different levels. Some address engineering resilience at the country level (Kammouh, Cardoni, et al., 2017; Kammouh, Cardoni, et al., 2018; Kammouh & Cimellaro, 2018; Kammouh, Cimellaro, & Mahin, 2018; Kammouh, Dervishaj, & Cimellaro, 2017; Kammouh, Dervishaj, & Cimellaro, 2018; Kammouh, Silvestri, et al., 2018; Kammouh, Zamani Noori, et al., 2017; Kammouh, Zamani-Noori, et al., 2017) and some at the local and community level (Kammouh, Cardoni, et al., 2017; Kammouh, Cardoni, et al., 2018; Kammouh & Cimellaro, 2018; Kammouh, Cimellaro, & Mahin, 2018; Kammouh, Dervishaj, & Cimellaro, 2017; Kammouh, Dervishaj, & Cimellaro, 2018; Kammouh, Gardoni, & Cimellaro, 2019; Kammouh, Silvestri, et al., 2018; Kammouh, Zamani Noori, et al., 2017; Kammouh, Zamani Noori, Cimellaro, & Mahin, 2019; Kammouh, Zamani-Noori, et al., 2017). Liu, Reed, and Girard (2017) proposed a framework that combines dynamic modeling with resilience analysis.

Two interconnected critical infrastructures were analyzed using the framework by performing numerical calculation of resilience conditions in terms of design, operation, and control of parameter values for specific failure scenarios. A quantitative method for assessing resilience at the state level was presented in Kammouh and Cimellaro (2018), Kammouh, Cardoni, et al. (2018), Kammouh, Cimellaro, and Mahin (2018), Kammouh, Dervishaj, and Cimellaro (2018), Kammouh, Silvestri, et al. (2018). In their approach, the data from the Hyogo Framework for Action (HFA) (ISDR, 2005), developed by the United Nations (UN), is used for the analysis. The methodology focuses on the implementation of the detailed measures at the government level through policies. Another quantitative framework for designing and measuring community resilience is the PEOPLES framework (Cimellaro, Renschler, et al., 2016; Cimellaro, Zamani-Noori, et al., 2016). PEOPLES is an extension of resilience research conducted at the Multidisciplinary Center of Earthquake Engineering Research (MCEER). The PEOPLES framework includes seven dimensions: Population, Environment, Organized government services, Physical infrastructures, Lifestyle, Economic, and Social capital (Renschler et al., 2010). Another measurement framework is the Baseline Resilience Indicator for Communities (BRIC) (Cutter, Ash, & Emrich, 2014). This is a quantitative tool that focuses on the pre-existing resilience of communities and, unlike the PEOPLES framework, is practically related to fieldwork. A qualitative framework that measures the ability to recover from seismic events is the San Francisco Planning and Urban Research Association framework (SPUR, 2009). The framework analyzes the recovery of buildings, infrastructure systems, and services.

Despite this robust literature, there is still considerable disagreement about the indicators that define resilience and the frameworks that are most useful for measuring it. As a result, approaches to assessing community disaster resilience are poorly integrated. The modeling approaches (e.g., PEOPLES framework) described above require accurate data to feed into the models to be functional, but access to this data is limited and often the accuracy is insufficient. Moreover, when unexpected events occur and not enough information is available or the previously prepared plan is not adequate, the decisions made are subjective and based on experience. The difficulties in collecting data and indicators, as well as in defining the interactions between them makes the resilience assessment so complex that it cannot be used by decision-makers and industry (Bonstrom & Corotis, 2014; Chang et al., 2014; Cimellaro, Renschler, et al., 2016; Cimellaro, Zamani-Noori, et al., 2016). The Hyogo 10-year Plan gave rise to a new framework, the Sendai Framework, developed by the United Nations (UN). The Sendai Framework is a new quantitative framework for building the resilience of nations and communities based on the implementation of the Hyogo Framework (UNISDR, 2015a, 2015b). The methodology adopted by the Sendai Framework aims to reduce disaster risk and loss of life, livelihoods, and health in the economic, physical, social, cultural and environmental assets of individuals, businesses, communities, and countries. The objective is to assist countries in implementing the framework into their laws. The main objective of this chapter is to propose a quantitative method for quantifying the resilience and resilience-based risk of countries using the results of the Sendai Framework. It is believed that the proposed methodology will enable decision-makers to learn about the state of their communities in the face of a specific event and to identify the key aspects on which the greatest effort should be placed to improve the resilience of their communities.

The remainder of the chapter is organized as follows. Section 2 describes the resilience-based risk analysis as a function of resilience, exposure, and hazard. Section 3 introduces the Sendai Framework for Disaster Risk Reduction with its global targets. Section 4 illustrates the Sendai Framework indicators and the corresponding calculation. Section 5 proposes the quantitative methodology to assess the resilience of communities. Finally, conclusions are drawn in Sect. 6 together with the proposed future work.

2 Resilience-Based Risk Analysis

The concept of resilience is associated with vulnerability in several disciplines (Klein, Smit, Goosen, & Hulsbergen, 1998). Several approaches to vulnerability measurement defined in the literature link vulnerability to the concept of risk assessment (Papadopoulos, 2016). For instance, an engineering-based damage assessment model was developed to define the vulnerability of low-rise buildings to tornadoes. The output of the model is a damage index percentage and the overall damage ratio of the building (Peng, Roueche, Prevatt, & Gurley, 2016). An important vulnerability and risk assessment tool is *Hazus*, a standardized risk assessment software developed by the U.S. Federal Emergency Management Agency (FEMA, Hazus) to estimate losses following natural hazards (Nastev & Todorov, 2013). It consists of four main models: (1) the *Hazus* earthquake model, (2) the *Hazus* hurricane wind model, (3) the *Hazus* flood model, and (4) the *Hazus* tsunami model.

While some works in the literature provide the same definitions for resilience and vulnerability (Klein, Nicholls, & Thomalla, 2003), others present different views for the two concepts (Cutter, 2016). A comparison between vulnerability and resilience on different scales is presented in Table 1.1.

Table 1.1 Comparison between vulnerability and resilience at different scale (adapted from Cimellaro, 2016)

Vulnerability	Resilience
Resistance	Recovery
Force bound	Time-bound
Safety	Bounce back
Mitigation	Adaptation
Institutional	Community-based
System	Network
Engineering	Culture
Risk assessment	Vulnerability and capacity analysis
Outcome	Process
Standards	Institution

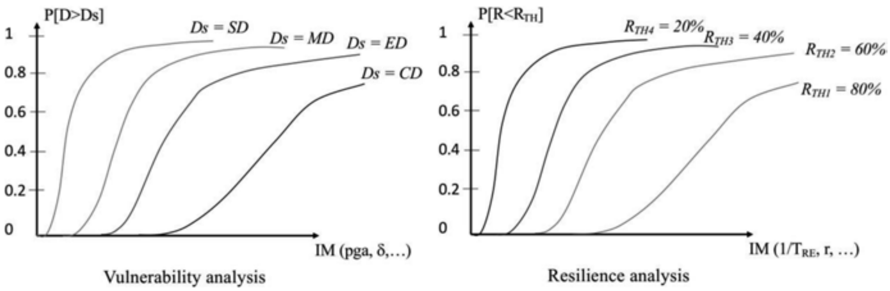

Fig. 1.2 Comparison between the vulnerability and the resilience analysis

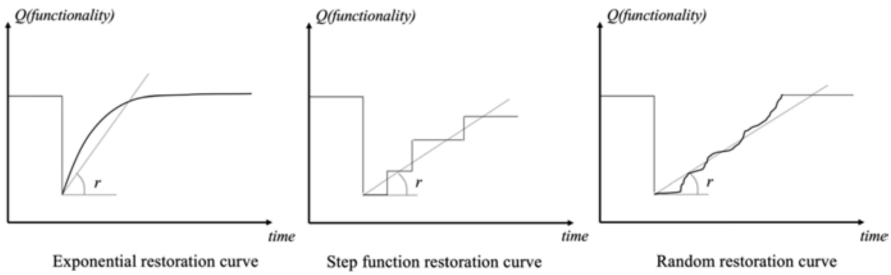

Fig. 1.3 Typical restoration curves

The differences between vulnerability and resilience at different levels suggest that resilience is more concerned with the human ability to recover from a severe event within a short period of time, while vulnerability is concerned with the capacity to withstand stress caused by natural hazards (Kammouh & Cimellaro, 2018). Since the process of resilience assessment is subject to several uncertainties, a probabilistic approach can be defined similarly to the classical vulnerability analysis. That is, in vulnerability analysis, the vulnerability of a system is determined by designing fragility curves that represent the probability of exceeding a certain damage state under different hazards. In resilience assessment, on the other hand, the fragility curves describe the probability that a system will exceed a resilience level at a given intensity. In resilience estimation, both recovery time and recovery speed *r* should be considered. The speed of recovery depends on several factors, such as human resources, recovery plan, and financial resources (see Fig. 1.2).

Figure 1.3 illustrates three different types of restoration curves: exponential function, step function, and random function. The rapidity of recovery *r* is considered as the slope of the best-fitting line obtained by applying linear regression to the restoration curve (Kammouh, Cardoni, et al., 2018; Kammouh & Cimellaro, 2018; Kammouh, Cimellaro, & Mahin, 2018; Kammouh, Dervishaj, & Cimellaro, 2018; Kammouh, Silvestri, et al., 2018).

The aim of this chapter is to provide an index that allows countries to be compared in terms of their resilience and corresponding risk. The probability of not achieving a certain level of resilience is defined as resilience-based risk (*RBR*). While in the classical risk assessment method, risk is the combination of vulnerability, hazard, and exposure, in the proposed work, resilience-based risk is influenced

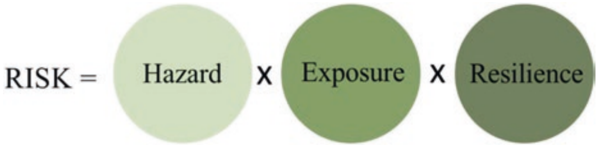

Fig. 1.4 Resilience-based risk analysis

by both the internal characteristics of a system (resilience) and the external factors (exposure and hazard). As Fig. 1.4 shows, resilience-based risk is a function of Resilience (*R*), Hazard (*H*), and Exposure (*E*). The mathematical formulation of *RBR* is given by:

$$\text{RBR} = (1 - R) \times E \times H \tag{1.2}$$

A hazard is a dangerous event that can cause the loss of a line, an impact on society or health, loss of property, livelihood, and services. In this chapter, the impact of hazards is neglected due to the lack of necessary hazard maps. Exposure is the number of people affected in a hazardous area and it is taken from the World Risk Report (WRR), a study by the United Nations University for Environment and Human Security 104 (UNU-EHS). The third parameter, resilience, is determined using data from the Sendai Framework. The Sendai Framework indicators are equally weighted for ranking and scoring countries. However, in assessing resilience, these indicators need to be weighted according to their impact on resilience. Two weighted methods are used in the proposed work. The first method is based on dependency tree analysis (DTA) (Kammouh, Cardoni, et al., 2017; Kammouh, Cardoni, et al., 2018; Kammouh & Cimellaro, 2018; Kammouh, Cimellaro, & Mahin, 2018; Kammouh, Dervishaj, & Cimellaro, 2017; Kammouh, Dervishaj, & Cimellaro, 2018; Kammouh, Silvestri, et al., 2018; Kammouh, Zamani Noori, et al., 2017; Kammouh, Zamani-Noori, et al., 2017). DTA is a method that determines the correlation between components and their subcomponents (i.e., between resilience and its indicators) by assigning different weights to the subcomponents. Another method used to assign the appropriate weights to the indicators of the Sendai Framework is spider plot analysis (SPA). In this method, the spider plots are designed to define a geometric combination of the indicators. The weights of each indicator are plotted on one of the axes of the spider plot. Resilience is then computed as the area between the linked angles normalized by the total area of the shape. The resilience results obtained by each of the two methods are then used to obtain the RBR by combining them the exposure and risk hazard.

2.1 *World Risk Report (WRR)*

The World Risk Report is a study prepared by the United Nations University for Environment and Human Security (UNU-EHS). This report aims to rank countries around the world according to their vulnerability, exposure, and risk level by taking

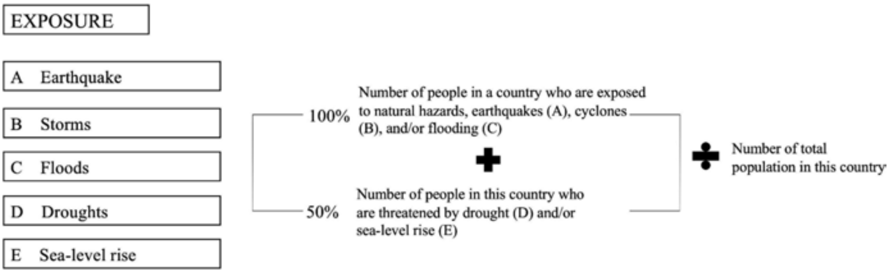

Fig. 1.5 Exposure analysis in the world risk report

various measures. In the work, the WRR is implemented to assess the exposure of the countries, and consequently, used for the resilience-based risk evaluation. Figure 1.5 shows the strategy adopted by WRR to determine the exposure of countries. The exposure is computed as a combination of the number of people exposed to the hazards of the different countries, divided by the total population of the country.

3 Sendai Framework for Disaster Risk Reduction

The Sendai Framework for Disaster Risk Reduction 2015–2030 was adopted on March 18, 2015, at the Third UN World Conference in Sendai, Japan. The Sendai Framework is the successor tool to the Hyogo Framework for Action (HFA) 2005–2015. Although the HFA was an important tool for raising awareness on disaster risk reduction, a relevant loss has occurred in the 10 years of its implementation. That is, despite the efforts, there was a high number of fatalities (about 770,000) and 1.5 billion people were affected by disaster events.

Consequently, the framework was developed to reduce the damage and loss of life, livelihoods, and health, hazard exposure and vulnerability to disasters, and increase preparedness for response and recovery from 2015 to 2030. An important aspect to consider is the data on loss and damage at different scales and levels (local, national, and regional) in the context of event-specific hazard, exposure, and vulnerability (UNISDR, 2015b).

The Sendai Framework, which is a multi-level development, emphasizes risk management instead of disaster management, which was the focus of the HFA. It also defines a list of activities that nations should follow to prevent new risks, and is based on four specific priorities for action (UNISDR, 2015a, 2015b):

- Priority 1: Understanding disaster risk, vulnerability, and exposure to hazards.
- Priority 2: Strengthening disaster risk governance, with clear institutions and budgets for managing disaster risk.
- Priority 3: Participating in DRR funding to strengthen resilience (including public and private investments that help prevent disasters).
- Priority 4: Highlighting the importance of disaster preparedness and building back better in recovery, rehabilitation, and reconstruction.

In addition, the framework sets out seven different global disaster risk reduction targets to help assess global progress towards this goal (UNISDR, 2015a, 2015b). The global targets are:

a. Substantially reduce global disaster mortality by 2030, with a target of reducing the average mortality rate per 100,000 people in the decade 2020–2030 compared to the period 2005–2015.
b. Significantly reduce the number of affected people globally by 2030, with the aim of reducing the average number per 100,000 in the decade 2020–2030 compared to the period 2005–2015.
c. Reduce direct economic loss from disasters in terms of global gross domestic product (GDP) by 2030.
d. Substantially reduce disaster-related damage to critical infrastructure and disruption of essential services, including health and education facilities, including by developing their resilience by 2030.
e. Significantly increase the number of countries with national and local disaster risk reduction strategies by 2020.
f. Significantly strengthen international cooperation in developing countries through adequate and sustained support to complement their national actions to implement this framework by 2030.
g. By 2030, significantly improve the availability of and access to multi-hazard early warning systems and disaster risk information and assessments for the population.

The targets described allow for global improvements in data collection procedures to facilitate their definition. Beyond the seven global targets, the Open-Ended Intergovernmental Working Group (OEIWG) on indicators and terminology related to disaster risk reduction has developed a list of indicators that depend on each of the seven targets and allow monitoring of progress on the targets and global implementation of the Sendai Framework. More details on the indicators for monitoring the global targets of the framework can be found in the next section.

3.1 Sendai Framework Indicators

The Sendai framework can be applied by conceptualizing its seven main targets to create a common method for measuring and assessing resilience. The creation of indicators is essential to report on progress at regional, national, and local levels and to achieve the expected outcomes of the framework and its global targets.

Following the structure of Arup's City Resilience Framework, supported by the Rockefeller Foundation, it is possible to subdivide the framework. The Arup framework is divided into four dimensions: health and well-being, economy and society, infrastructure and environment, and leadership and strategy. It can be divided into 12 goals and 52 indicators.

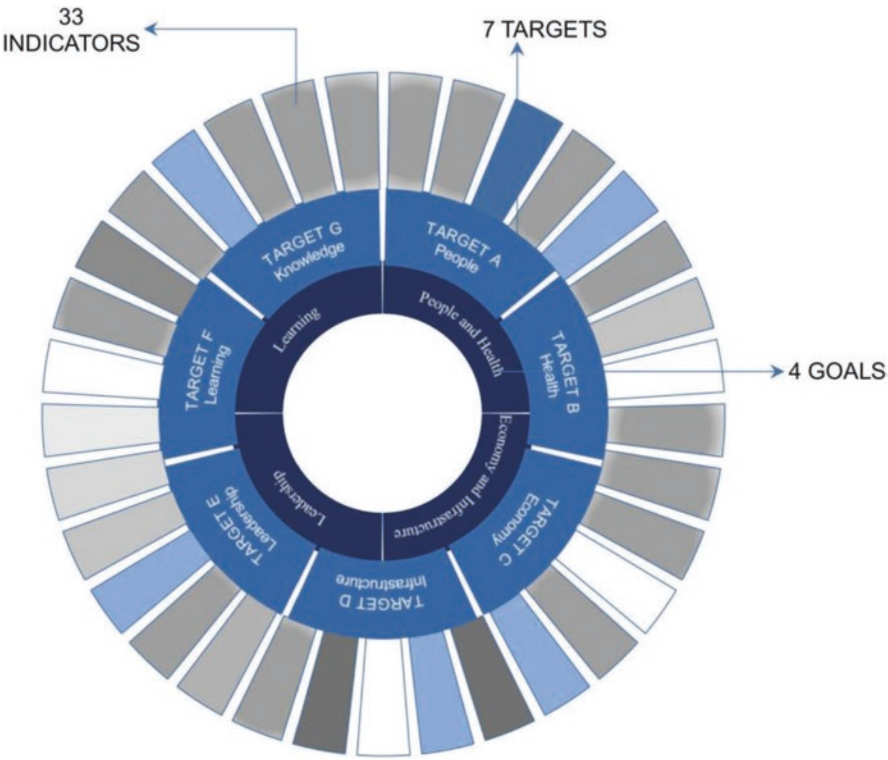

Fig. 1.6 Synthetized Sendai framework structure (adopted to ARUP, 2014)

As illustrated in Fig. 1.6, the targets of the Sendai Framework are merged with the following goals:

a. People
b. Health
c. Economy and housing
d. Infrastructure and city services
e. Leadership and strategy actions
f. Learning
g. Knowledge

The different goals are then divided into 33 indicators that are used to assess resilience at different scales, i.e., from buildings and structures to cities and countries.

4 Sendai Framework Indicators Calculation

Since damage and loss are the most important aspects of the framework, only the first four global targets (A–D) are considered. While the first two targets focus on mortality and the degree of affectedness, target C is based on capturing direct economic losses due to disasters. Finally, the target D focuses on disaster damage to infrastructure.

To calculate the losses and damages from target A to D, it is first important to determine the time dimension. That is, the disaster may change depending on the analyzed period (e.g., people heal after a certain period, reducing the number of injuries). UNIDR recommends a period of 42 days after the occurrence of a hazard event. Moreover, the resilience assessment must consider certain minimum requirements by collecting data relevant to a specific group, country, hazard, and residence. Below, is a further description for each target.

4.1 Target A: People

Target A estimates the mortality index due to a disaster, considering the number of missing and presumed dead in a 100,000 population area. Some specific minimum requirements are set for the calculation of Target A indicators. Poverty level is defined by the international poverty line of $1.90 US dollars set by the World Bank; gender is divided into female and male; age is categorized in children, adults, and elderly. Disability is categorized into with or without disability, and finally, geographic location is reduced to the municipality level.

Target A is divided into three indicators:

- A_1: Number of deaths and missing people/presumed dead people due to hazardous events per 100,000.
- A_2: Number of deaths due to hazardous events.
- A_3: Number of missing people/presumed dead people due to hazardous events.

Indicator A_1 strongly depends on the indicators A_2 and A_3 as follows:

$$A_1 = \frac{\left(A_2 + A_3\right)}{\text{populations}} \times 100{,}000 \tag{1.3}$$

where A_1 is a compound indicator, and A_2 and A_3 are directly calculated from a physical survey on the direct count of either dead people or missing people for the considered event.

4.2 Target B: Health

The Sendai Framework established the target B, which estimates the number of people affected by a disaster and their health index, considering population growth and the rise in the number of affected people.

Target B necessitates the same minimum requirements as target A, as it is concerned with people. Target B is broken down into seven indicators:

- B_1: Number of affected people by hazardous events.
- B_2: Number of injured or ill people due to the hazardous events, number of people suffering from physical injuries, trauma or cases of disease requiring the immediate medical assistance.
- B_3: Number of evacuate/relocated people after a disaster.
- B_4: Number of people whose houses were damaged by a catastrophic event.
- B_5: Number of people whose houses were destroyed by a catastrophic event.
- B_6: Number of people who received aid including food and nonfood aid.
- B_7: Number of people whose livelihoods were disrupted, destroyed, or lost.

Some of the indicators of target B may cause problems with their measurements. For instance, the number of homeless people is not always easy to define, and the number of people receiving food and medical aid is challenging to count because different ONGs, private and public entities may provide then.

B_1, like A_1, is a compound indicator obtained by adding indicators B_2 to B_6 as follows:

$$B_1 = \frac{B_2 + B_3 + B_4 + B_5 + B_6}{\text{population}} \times 100{,}000 \tag{1.4}$$

It is important to note that indicators B_2, B_3, and B_6 are derived from the hazard dates, whereas indicators B_4 and B_5 are calculated by multiplying the number of an average number of occupants per house of each country (AOH):

$$B_4 = n\,\text{houses} \times \text{AOH} \tag{1.5}$$

4.3 Target C: Economy and housing

Target C is concerned with the economic losses incurred because of the disaster. That is, disaster losses and damages are not always caused by humans, they also impose an economic burden that must be accounted for. It assesses whether the city/country economic resources are sufficient to deal with the disaster. Domestic, agricultural, and infrastructural services are all considered to estimate the damages they have suffered and the amount of the damages.

Target C can be classified as:

- C_1: Direct economic loss about the global gross domestic product.
- C_2: Direct agricultural loss due to hazardous events.
- C_3: Direct economic loss.
- C_4: Direct economic loss due to commercial facilities damaged or destroyed.
- C_5: Direct economic loss caused by damaged houses.

- C_6: Direct economic loss caused by destroyed houses.
- C_7: Direct economic loss caused by damages to critical infrastructures.
- C_8: Direct economic loss as a consequence of a degraded environment.
- C_9: Total insured direct losses caused by hazardous events.

Indicator C_1 is a compound indicator consisting of the summation of the number of economic losses from various sectors, starting from agricultural loss (indicator C_2) up to economic losses due to environmental degradation (indicator C_8). C_1 is then divided by the GDP, which is a measure of economic resources. The formula for obtaining indicator C_1 is shown in Eq. (1.6).

$$C_1 = \frac{C_2 + C_3 + C_4 + C_5 + C_6 + C_7 + C_8}{\text{GDP}} \tag{1.6}$$

where indicators are calculated by considering the size of the facility (e.g., small, medium, and large evaluated by national ranges), cost per unit (e.g., per square meter, per kilometer, per hectare), the number of damages to the unit, and the number of infrastructures.

4.4 Target D: Infrastructures and City Services

Target D is responsible for repairing damaged infrastructure and restoring essential services that have been disrupted because of a major event. Target D is characterized by different indicators based on the infrastructure and service under consideration. Target D indicators are:

- D_1: Damage to critical infrastructures.
- D_2: Number of health facilities destroyed or damaged by hazards.
- D_3: Number of educational facilities destroyed or damaged by hazards.
- D_4: Number of transportation units and infrastructures destroyed or damaged by hazardous events.
- D_5: Number of damaged or destroyed bridges.
- D_6: Number of damaged or destroyed airports.
- D_7: Number of damaged ports.
- D_8: Number of damaged electricity plants or transmission lines.
- D_9: Number of time basic services disrupted by hazards.

Indicator D_1, as well as the previous targets' first indicators, is a compound indicator. It needs data from the other indicators and the number of times interruption of damage occurs. It is calculated as follows:

$$D_1 = \frac{\left(D_2 + D_3 + D_4 + D_5 + D_6 + D_7 + D_8 + D_9\right)}{\text{population}} \times 100{,}000 \tag{1.7}$$

4.5 Target E: Leadership and Strategy Actions

To calculate Target E, some basic data from different nations must be collected. Nations should have (*a*) a clear legislative and regulatory policy in all sectors, public and private, defining each responsibility; (*b*) precise time and roles of the administrator to deal with disaster risk situation; (*c*) precise measurements and objects to prevent a risk; (*d*) a clear technical and financial management to cope with the disaster; and (*e*) periodic assessments to report the progress on developing a strategy.

Target E considers:

- E_1: Number of countries that adopt and implement the national DRR strategies in line with the Sendai Framework for Disaster Risk Reduction 2015/2030.
- E_2: Percentage of local governments that adopt and implement the local DRR strategies in line with the Sendai Framework for Disaster Risk Reduction 2015/2030.

Indicator E_1 can be obtained by weighting the data described above to determine the impact each data presents on E_1. That is, indicator *a* shows a 40% influence on E_1, indicator *b* for 20%, indicator *c* has 10% impact, indicator *d* of 20%, and finally, the weight of indicator *e* is about 10%.

Therefore, E_1 is equal to:

$$E_1 = 0.4 \times a + 0.2 \times b + 0.1 \times c + 0.2 \times d + 0.1 \times e \quad (1.8)$$

Indicator E_2 measures the number of local governments that adopt a disaster risk reduction strategy by counting the total number from a survey.

4.6 Target F: Learning

Target F refers to the calculation of the number of international cooperation to sustain and implement the framework. Target F is divided into four indicators (Eslamian & Eslamian, 2021):

- F_1: Number of countries that support the implementation of the framework.
- F_2: Number of international institutions that support financially the implementation of the framework.
- F_3: Number of international institutions and regional multi-stakeholder partnerships established to build a disaster risk reduction.
- F_4: Number of countries with international and regional initiatives for the exchange of technology and innovation in disaster risk reduction.

The compound indicator F_1 is used to determine the cooperation from different sectors: financial and economic resilience (F_2), building resilience (F_3), and science and innovation resilience (F_4). In this case, the indicator F_1 is the sum of:

$$F_1 = F_2 + F_3 + F_4 \quad (1.9)$$

4.7 Target G: Knowledge

Target G can be classified as:

- G_1: Number of countries that have the multi-hazard early warning system.
- G_2: Number of countries that have the multi-hazard monitoring and forecasting system.
- G_3: Number of people who are covered by and have access to multi-hazard early warning system per 100,000.
- G_4: Number of local governments having a preparedness plan (including EWS) or evacuation plan with standard operating procedures.
- G_5: Number of countries that have multi-hazard national risk assessment with results in an accessible, understandable and usable format for stakeholders and people.
- G_6: Number of local governments that have a multi-hazard risk assessment or risk information, with results in an accessible, understandable, and usable format for stakeholders and missing people.

Indicator G_1 is a compound indicator, and it is calculated using equally weighted indicators from MHEWS.

Indicators are defined through a detailed survey that includes a series of questions necessary to obtain information on the resilience progress of each country. Table 1.2 lists the types of questions and the answers, which can be Yes/No or description text, that were presented in the survey for indicator A_2. After each country's authorities have completed the questionnaire, it is returned to the UN. Each country tracks its progress on a five-point scale for each indicator, with one point indicating slow progress, and five points indicating rapid progress in that area.

Table 1.2 Questions asked by UN to assess the indicator A_2

Question	Answer type
Do you collect the number of deaths attributed to disasters?	Yes/No
Do you collect the number of deaths attributed to disasters disaggregated by the event?	Yes/No
Do you collect the number of deaths attributed to disasters associated with a hazard type?	Yes/No
Do you collect the number of deaths attributed to disasters disaggregated by location?	Yes/No
Do you collect the number of deaths attributed to disasters disaggregated by age?	Yes/No
Do you collect the number of deaths attributed to disasters disaggregated by sex?	Yes/No
Do you collect the number of deaths attributed to disasters disaggregated by disability?	Yes/No

5 Resilience-Based Risk Assessment

As previously stated, indicators in the Sendai Framework have the same weights, implying that they have the same level of importance. However, because the importance of the indicators varies, they must be weighted before being used in the resilience evaluation. To do that, two different weighting methods are applied to the Sendai Framework indicators, and the corresponding resilience results are compared. In the following, the two weighting methods are described in detail.

5.1 Dependence Tree Analysis (DTA)

The dependence tree analysis method subdivides the components into subcomponents by capturing their correlation. The DTA is implemented to combine the Sendai framework indicators based on their contribution to the resilience assessment.

The DTA method starts with the identification of all potential components that influence the main output. The most common method for identifying these components is to brainstorm or refer to lessons learned (Kammouh, Cardoni, et al., 2018; Kammouh & Cimellaro, 2018; Kammouh, Cimellaro, & Mahin, 2018; Kammouh, Dervishaj, & Cimellaro, 2018; Kammouh, Silvestri, et al., 2018).

The components, which are classified into main components, intermediate components, and basic components, are presented in the dependence tree according to the way in which they are logically related to one another. The main component is known as the task required to get out of a system and it is located at the top of the dependence tree. The intermediate components are those required to achieve the main component. Finally, the basic components are those that cannot be divided into subcomponents. Furthermore, depending on the importance of the component, it may appear multiple times in the dependence tree.

Figure 1.7 depicts the arrangement of the components in the dependence tree. In the resilience assessment, the main component is referred to as resilience, the intermediate components are the targets, and the basic components that cannot be divided into any further subcomponents are the SFDRR's indicators.

The analysis starts with the identification of the indicators and their relationships. The Sendai Framework assigns a numerical score to each indicator with a maximum value of 5 ($I_{max} = 5$). Equation (1.10) is then used to normalize the indicators' scores for their maximum value. Finally, resilience is computed using the DTA by combining the scores of indicators in such a way that the indicators in series are multiplied, while the indicators in parallel are weighted averaged (Kammouh, Cardoni, et al., 2018; Kammouh & Cimellaro, 2018; Kammouh, Cimellaro, & Mahin, 2018; Kammouh, Dervishaj, & Cimellaro, 2018; Kammouh, Silvestri, et al., 2018). As a result, the DTA method's main output is a normalized resilience that ranges between 0 and 1.

$$I_{i,N} = \frac{I_i}{I_{i,\max}} \tag{1.10}$$

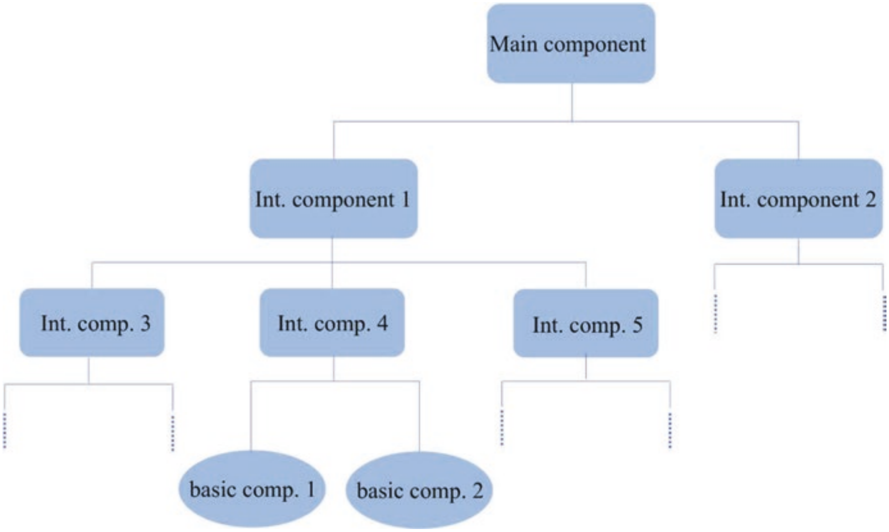

Fig. 1.7 Dependence tree diagram and different types of components

where $I_{i,N}$ is the normalized score of indicator i $(0 \leq I_{i,N} \leq)$, I_i is the total indicator score obtained from Sendai framework $(0 \leq I_i \leq 5)$, and $I_{i,\max}$ is the maximum score that can be reached by an indicator I $(I_{i,\max} = 5)$.

There are two limitations to the proposed method: (1) the DTA results are dependent on the tree structure, which defines the links between the different indicators; (2) only numerical indicators can be combined (e.g., Boolean indicators cannot be implemented in this method).

5.2 *Spider Plot Weighted Area Analysis (SPA)*

Another option for weighting the Sendai Framework indicators is the Spider Plot Weighted Area, which represents the indicators with a spider plot. Resilience is simply the enclosed area obtained by connecting the indicators and then normalized to the total area of the polygon (Fig. 1.8). Resilience is mathematically calculated as:

$$R = \frac{A}{A_{\max}} \tag{1.11}$$

where R is the resilience, A is the total area of the polygon, and $A_{\max}$ is the maximum area that can be reached if all indicators are equal to 5.

Different indicator arrangements were attempted, and the area of each arrangement was computed using MATLAB to show that the value of the area inside the enclosed shape is not very sensitive to the indicators' arrangement order (Kammouh,

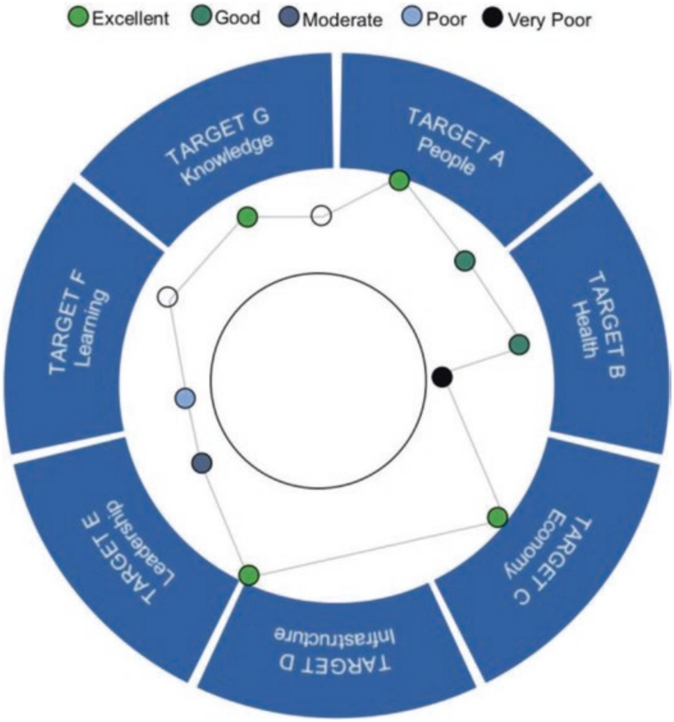

Fig. 1.8 Spider plot representation of the Sendai indicators

Cardoni, et al., 2018; Kammouh & Cimellaro, 2018; Kammouh, Cimellaro, & Mahin, 2018; Kammouh, Dervishaj, & Cimellaro, 2018; Kammouh, Silvestri, et al., 2018; MathWorks, 2005).

6 Conclusion

This chapter introduces a new analytical method for quantifying the resilience and resilience-based risk of countries. The resilience-based risk is defined as the probability of being below a certain resilience level and is calculated by combining resilience, exposure, and hazard. In this chapter, the resilience index is evaluated by using the results of Sendai Framework for Disaster Risk Reduction (SFDRR), which ranks the countries based on 33 indicators. Despite the Hyogo Framework for Action is a widely accepted method in evaluating the community risk reduction, the Sendai Framework presents a higher level of complexity due to its multiple layers structure.

Like in the HFA, not all the indicators contribute in the same way towards the resilience output. Therefore, the indicators of SFDRR are weighted and combined using two different methods to determine the resilience index, the Dependence Tree

Analysis (DTA) and the Spider Plot Analysis (SPA). The DTA method identifies the correlation between resilience and its indicators in a quantitative way. The SPA, on the other hand, is a geometrical method in which the indicators are plotted on the spider chart's axes. The resilience is evaluated as a normalized value of the area obtained by connecting the adjacent indicators' score. The weights for targets E and G in the Sendai framework don't need to be computed since they are already weighted in the Sendai Framework result. The developed framework has not been applied to any case study since data from the countries are currently being collected by the UN and they are not yet available.

In conclusion, following the methodology described above, each country would be able to quantify its resilience-based risk to be prepared for future disasters and to mitigate their impact. This can be done by analyzing the hazards from the hazard map, the exposure from the WWR, and the resilience parameter through the Sendai Framework.

The quantitative approach introduced in this chapter allows to have a proper estimation of how long it would take a system or a community to restore its functionality to its original state. However, the proposed approach is general. Future work will be oriented towards the application of the presented methodology using reliable data as soon as they are available to determine the resilience index of communities.

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Chapter 2
Disaster Recovery Reform and Resilience

Adriana Galderisi, Scira Menoni, Giulia Setti, and Alisia Tognon

Abstract This contribution discusses the need for a substantial reform of recovery, intended as the disaster phase stretching between the end of the emergency and the beginning of reconstruction. First, the main features and emerging needs of this phase have been explored on the base of both literature review and reports on extensively investigated recent disasters, such as the recovery after Katrina in New Orleans or the Christchurch earthquake in 2010–2011. Then, two recovery case studies have been in-depth analyzed: the ongoing recovery after the Central Italy seismic swarm 2016–2017, and the past successful recovery following the Gujarat earthquake in India in 2001. Finally, a set of recommendations—aimed at improving practices and tools that should be prepared and dedicated to this rather neglected, albeit crucial, disaster phase—has been outlined. An innovative governance model oriented towards a more participatory approach, capable of involving all stakeholders that should have a say on the recovery and reconstruction pathways, is proposed. Pre-disaster planning is then recommended as a set of tools that should oversee the entire process, allowing a rapid and smooth shift into reconstruction. Such tools should include guidance and rules for building back better and for rehabilitating cultural heritage that can be saved or at least partially restored; urban and spatial planning that are essential for example to identify the most suitable sheltering solutions so that they will be coherent and aligned with visions for the future development of the hit areas. Last but not least, post-disaster damage and loss assessment is proposed as a key activity that permits not only to establish priorities for immediate recovery, but also to learn lessons about vulnerabilities, both physical and systemic, that should be reduced for a resilient recovery.

Keywords Recovery planning · Disaster phases · Risk governance · Build back better · Disaster resilience

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1 Introduction

The term recovery has been often considered a synonym of rehabilitation or reconstruction. While Quarantelli (1999) indicated recovery as “the post-impact stage at some point after the crisis time,” it is generally used to roughly indicate the wider post-disaster response.

The boundaries between response, recovery, and reconstruction are often blurred even in the most recent glossary on DRR. As remarked by the United Nations (UN) (2016), indeed, “some response actions, such as the supply of temporary housing and water supplies, may extend well into the recovery stage,” while recovery activities, aimed at “restoring or improving of livelihoods and health, as well as economic, physical, social, cultural and environmental assets, systems and activities, of a disaster-affected community or society (…)” (United Nations (UN), 2016), partially overlap with activities that are typical of the reconstruction phase.

Rather early though in disaster studies it has been acknowledged that the time needed for full reconstruction can be long, in the range of decades, especially in cases where the event has caused massive destruction of assets and artifacts. Kates, Colten, Laska, and Leatherman (2016), grounding on several studies on post-disaster reconstruction processes, noticed that very often recovery and first reconstruction—mostly addressed to physical rebuilding—last approximately 10 times the time interval of the preceding period. For example, in the case of the Katrina event, in respect to an emergency period of about six weeks, they estimated a time of about 50 weeks for recovery and 500 weeks for the first reconstruction.

It is unlikely that such a long duration be characterized by homogenous and smooth processes leading from a state of disruption to a new configuration of the built environment that according to Kates (1977) requires large investments of financial resources, and human and social capital to be committed.

Skewed between emergency and reconstruction, recovery has gained little attention in research and practice, despite being a crucial phase when key decisions regarding the future of the affected area are made and the shift from extraordinary measures typical of the first intervention to ordinary rules and legislation is never smooth nor easy. It is not by chance therefore that in the design of this book a chapter is devoted to proposing new tools and methods to address recovery in an innovative and more effective way.

In the following, Sect. 2 will outline an operational definition of recovery linking it to the concept of resilience based on selected bibliography; Sect. 3 outlines the critical aspects to be considered for improved disaster risk governance; Sect. 4 will be devoted to the illustration of two case studies shedding light on how decisions made during the recovery phase have impacted the subsequent reconstruction process and outcome; Sect. 5 will provide the key pillars and tools for a disaster resilient recovery process.

2 Disaster Recovery: An Evolving Concept

2.1 Towards an Operational Definition of Recovery

Given the lack of a univocal, largely agreed upon definition of recovery, an operational one will be proposed that will guide us in the analysis of two examples of post-earthquake recovery and in the development of guidelines resulting from in-depth analyses of the weakness and the opportunities identified both in literature and in the case studies. The proposed definition builds on both a temporal and a functional perspective as shown in Fig. 2.1. According to a functional perspective, the activities that need to be performed to transit the territorial systems from emergency to reconstruction are listed in light and dark blue. Envisioning strategies and planning recovery for a more resilient outcome, lifelines rehabilitation, securing cultural heritage, collection and analysis of damage data, are among the activities that will be analyzed in depth in the case studies discussed in Sect. 4.

According to a temporal perspective, recovery is considered as the window that follows the immediate relief and crisis management and precedes the reconstruction, intended as the phase in which rebuilding and comprehensive restoration of damaged areas is largely on the way. Features and needs emerging in the recovery phase largely depend on the type and duration of the hazardous event at stake. Even though often intended as a short-medium term phase, recovery may extend over much longer time periods in case of prolonged or repeated impacts, such as those provoked by the seismic swarms or volcanic unrest.

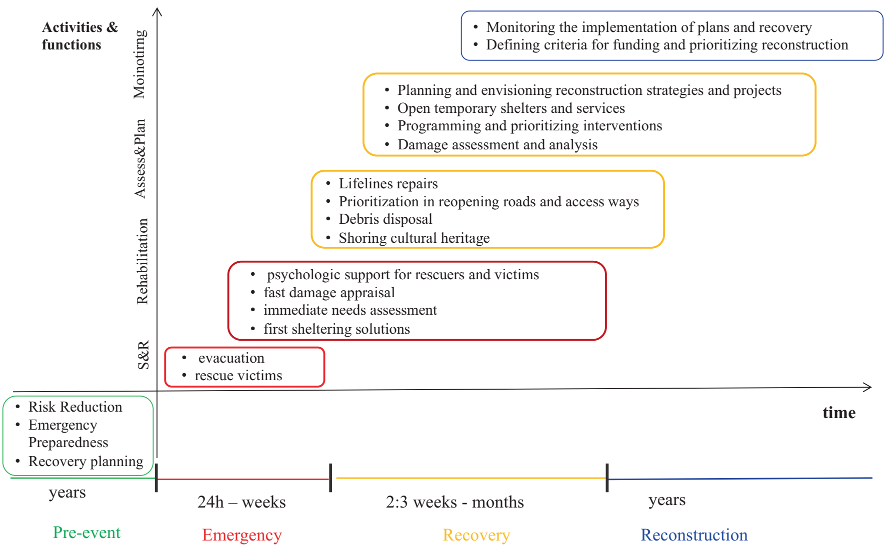

Fig. 2.1 Temporal and functional differences among the post-disaster phases

As for the first case, the seismic swarm affecting the Canterbury region in New Zealand in the period between September 2010 and February 2011 can be considered. The starting event, the main Darfield earthquake, was followed by several shocks, many of which affected Christchurch City, imposing a significant change of pace and new directions to the reconstruction that had already started after the first shock. The following shakes not only increased the degree and extent of damage but significantly overwhelmed the response capacity of the affected communities. In addition, the area suffered flood events attributed "to the changed ground levels from ground tilting and subsidence as a result of liquefaction" (Saunders & Becker, 2015). The protracted recovery phase required to shift from an idea of "engineering" resilience—aimed to rapidly bounce back from the event, by rebuilding damaged areas as they were and recovering as soon as possible to the previous, normal state—towards a bounce-forward perspective, aimed at guiding the reconstruction process towards long-term sustainability, also through relevant relocations of people and assets.

As for the second case, related to volcanic eruptions, it is worth reminding that the latter may induce a range of different hazards over long time intervals, often requiring mass evacuation that may last from months to years. Numerous cases of long-term relocation of population have been recorded along the last two centuries during volcanic crisis (Wilson et al., 2012). For example, the Merapi eruptions in 2006 and 2010 in Indonesia involved thousands of people and lasted for months, pointing at the need to overcome the traditional notion of recovery, enlarging the spatial scale to be considered. Although far from the directly threatened area of the Merapi volcano, the evacuated communities were asking for specific recovery activities, aimed at providing basic services and facilities allowing them to perform their daily activities over long time intervals.

2.2 *The Contribution of Resilience Thinking to Recovery*

In the last decade, meanings and roles of the recovery phase have significantly changed, proceeding hand in hand with the emergence and the evolution of the resilience concept. Since the late 1990s, the transition from an "engineering" to an "ecological" approach to resilience (Holling, 1996) led resilience studies to progressively move from the idea of improving elements and systems' capacity to bounce back—by recovering the previous equilibrium state after a crisis and maintaining in so doing their stability—towards an idea of improving elements and systems' capacity to "bounce forward," by shifting from one state to another following a crisis (Galderisi, 2018; Manyena, O'Brien, O'Keefe, & Rose, 2011). Such a transition had relevant implications in the disaster field, and namely in the recovery phase that has been, for long, based on a bounce-back perspective, addressed to "restore" the essential basic structures and functions of the hit system in a "timely and efficient manner". The "restorative" approach has been seriously challenged, in the last years, by a number of disasters: Hurricane Katrina, which destroyed the physical fabric of New Orleans in 2005, revealed for example situations to which it was not desirable to return, pushing several scholars to point out the need for a "new normality" in social, economic, and political terms (Committee on Homeland Security and Governmental Affairs, 2006; Kammerbauer, 2013). This transition is also the basis of the "Building Back Better" principle introduced in 2015 by the Sendai Framework for Disaster Risk Reduction that clearly emphasizes the need of preparing recovery and reconstruction before the hazardous event, exploiting the "critical opportunity" to improve the pre-existing state of the hit area and to enhance its resilience in the face of future events (United Nations (UN), 2015).

Starting from the late 1990s, the spread of a social oriented understanding of resilience favored an interpretation of this concept as a dynamic process, based on "continual learning" (Cutter et al., 2008), and allowing socio-ecological systems to learn from experience and constantly adapt themselves in the face of perturbances. The relevance attributed to the capacity of learning along the whole disaster cycle, by combining experience and knowledge, has also led to consider post-disaster damage assessment in a different light. Besides its obvious use for administrative purposes and for compensation, damage assessment is understood, indeed, as a crucial and long-term activity aimed to better understand root causes and drivers transforming hazardous events into disasters (Keating, Venkateswaran, Szoenyi, MacClune, & Mechler, 2016) and to support evidence-based decisions on the future configuration of affected systems. Interestingly, the new branch of resilience engineering, to be distinguished from the traditional "engineering perspective" mentioned above (Hollnagel et al., 2006), focuses on the adaptive learning capacity of complex systems. The resilience engineering approach fully acknowledge the relevance of blending cognitive, cultural, informational aspects across the disaster cycle in order to improve both the resistance of individual physical components of complex systems and their capacity to fail but avoiding catastrophic cascading effects (Linkov et al., 2013).

The emergence of an evolutionary approach to resilience, rooted in ecological resilience and intended "as a continually changing process" (Davoudi, Shaw, Haider, et al., 2012), has led to emphasize "the ability of complex social-ecological system to change, adapt, and more importantly, transform, instead of 'back-to-normality'" (Wang and Yamashita, 2015). Moreover, the widespread recognition of the resilience building process as a social construct, led to better focus on governance issues. The resilience building process should foster active participation of governments, citizens, scientists, private sectors, etc. (Borquez, Aldunce, & Adler, 2016; Rivera & Miller, 2011). Besides the exchange and sharing of information, such approach aims at strengthening and creating networks of stakeholders that collaborate and deliberate together. Thanks to the engagement of a wide panel of stakeholders, such process permits to co-produce knowledge and ideas to figure out the possible post-event development scenarios (Mulligan, 2017).

Operationalizing the theoretical aspects that have been shortly discussed above in the planning and redesign of affected cities, an important dichotomy often emerges between those who wish to modernize and develop futuristic places and those willing to bounce back to the original ambience. These diverging views are even more difficult to tackle in the presence of a large and rich ancient built heritage that does not only represent a cultural and economic resource but is also a fundamental pillar of the identity of affected community (Dandoulaki & De Jong, 2017). Without entering into a debate that has been ongoing for decades among experts in preservation, it must be acknowledged that the resilience of cultural heritage requires a tense and subtle equilibrium between intervention that can guarantee its resistance to extremes and changes that are likely to alter its features beyond acceptable levels. Meaning that on the one hand such heritage has been always subject to changes and intervention, without which it would have not survived, so also in the present days retrofitting should be regarded as a normal activity, aiming at preservation. On the other, special provisions and care in restoration and retrofitting are needed if the aim is to preserve the compound of cultural, historic, and human characters that are embedded in its bricks or stone blocks (Donatelli, 2016).

3 Critical Aspects of Resilient Recovery Governance

While emergency preparedness and planning is universally considered a key part of any disaster risk reduction policy, it is not so for instruments supporting and guiding decision makers and administrators in the recovery phase. For the latter there is a general lack of tools and even reflection on past cases aimed at eliciting what worked well and what didn't.

In fact, what public administrators, service providers, and citizens often criticize and indicate as the worst aspect of a poor recovery is the lack of clarity regarding responsibilities, immediate actions to be taken, resources to be committed to restore community life and to restart economic activities. Delays are an obvious consequence of such deficiencies, as it takes too much time to start defining the path to reconstruction and its intermediate steps.

In some countries, the duration of the emergency phase is defined by law, setting a definite deadline by which first responders should give the floor to ordinary agencies in charge of starting reconstruction activities. However, in the shift between emergency and ordinary administrations, uncertainty about who should intervene, how, with what powers and means is often recalled as a significant obstacle to smooth recovery, because many challenges persist, and many operations cannot be fully accomplished according to standardized rules. A first problem relates to the delivery of data and information: too often, during this shift, data are lost or not fully provided to the organization/agency taking the lead. A second issue relates to the identification of the organizations and the agencies that need to take the lead in recovery. There is often a lack of a well-defined governance structure for recovery and a clear identification of what organizations must be appointed to do what. It is one area in which the largest variety of solutions can be found and where even in the same country solutions change from one disaster to another. In most cases, special committees are created to oversee and coordinate recovery activities. The dramatic shift between an emergency approach, where ad hoc solutions and specific legislation to deal with extraordinary circumstances exist, and the normalization of practices and procedures that suddenly need to obey to ordinary rules in a situation that is not normal yet often overwhelms ad hoc governance arrangements. In the latter case, ordinary tools, rules and regulations create an overburden, making appointed organizations unable to fulfill their task with the rapidity that is required and asked by affected citizens. As the concept of recovery is absent in most existing legislations and governmental arrangements, the general expectation is that, after the emergency, routine practices can be reestablished quickly and effectively. However, ordinary tools, that function when there is a normal flux of requests to handle, are too demanding when the number of lifelines, houses, and firms to be restored or replaced is extremely large and complex. Even the hiring of temporary officials to complement and help administrations is not enough or not done in a sufficiently prompt and suitable way to respond to the suddenly rocketing number of practices to be fulfilled.

3.1 The Need for Enhanced Forms of Communities' Participation to Recovery Decisions

Communities' participation to decision-making processes, especially in the sphere of land use and urban planning, is recognized as essential and significant efforts have been so far invested in developing methods and formats to implement it. Despite the issue has been on the floor for long time and participatory planning is not new, still it is more debated than actually practiced. In the specific case of recovery and reconstruction planning, a limited number of studies focusing on the value of community led activities for improving post-disaster response (Cretney, 2015) as well on the role of participation in the quality of pre-disaster recovery plans has been published (Horney, Nguyen, Salvesen, Tomasco, & Berke, 2016).

Even though participatory decision-making is a key aspect of the build back better principle, the multiplicity of involved actors as well as the pressure to restart activities and services overshadow the relevance to take the time to discuss with affected communities about their same future. In fact, without a clear format and organization such participation does not take place or occurs only in a formal, not substantial way. Some studies and reports following disasters clearly show the persisting ineffectiveness of communities' engagement in recovery planning (Pyles, Svistova, Ahn, & Birkland, 2018). In particular, a report on community participation in the aftermath of the Haiti earthquake in 2010 (Pyles, Svistova, & Andrè, 2015) highlighted some of the main weaknesses related to this issue:

- the gap between the capacity building rhetoric of participation emphasized by the media and the effective engagement of citizens
- the different relevance attributed to urban population compared to rural one

- the key role of international organizations (e.g., the World Bank) in post-disaster recovery planning, leading to focus more on macro-economic renewal of Haiti than on human capital building

3.2 The Need for Pre-disaster Recovery Planning

The need to consider the aspects related to the functioning of public administration under the pressure and the difficulties that characterize the recovery phase, the request of a wider participation of the affected communities to crucial decisions impacting on their future lives should not result in the underestimation of the physical component of any planning effort. Actually, urban planning, urban and landscape design should be integrated as a fundamental part of recovery management as discussed by Allan and Bryant (2011). By comparing the two cities of San Francisco (USA) and Concepciòn in Chile after the earthquakes suffered in 1906 by the former and in 2010 by the latter, the two authors showed rather convincingly how the urban morphology, the city layout, the relationship between open public or private spaces with built lots influenced how temporary shelters and service were disposed. They also suggest how urban and landscape planners and designers should provide solutions taking into consideration the specificities of the context in which they operate in the aftermath of a disaster.

In fact, decisions that are taken during recovery often restrict the variety of options that can be considered for reconstruction and in some cases even create further damage. On the one hand, the decisions to relocate the population in far areas may trigger abandonment mechanisms or initiate a process of impoverishment of the population taken away from its sources of sustenance.

On the other hand, shelters implemented in place configure new urbanized areas that are usually not envisaged in urban master plans. In the absence of planning, and under the pressure to provide a fast response to the needs of homeless, decisions regarding the areas where to relocate the latter are often made without fully considering long-term effects and outside a strategic vision for the city.

For example, in the aftermath of the severe earthquake that in 2009 hit the city of L'Aquila, in Italy, it was decided to develop 19 temporary settlements (New Towns) of relatively good quality dwellings, at a rather high cost of over 800 million Euros. The new neighborhoods, scattered over a vast territory, poorly connected to each other and with the city center, with limited public facilities, designed without thinking about their future reuse, have undermined the environmental sustainability of the whole area. Ten years after the earthquake, such neighborhoods, which have been progressively abandoned, have induced an impressive amount of soil consumption, about 500 hectares, and have significantly changed the shape of the city lacking any organic design. They have become part of a vast and disconnected suburb that represents a difficult challenge for the newly drafted master plan.

4 Limits and Innovation in Recovery Processes: Case Studies

In this paragraph, two case studies will be more in-depth investigated in order to better understand limits and innovation that characterize different recovery processes. In particular, the case study of Central Italy and the Gujarat recovery processes have been selected as authors have direct access to firsthand documents and materials and have experienced the places. Moreover, they are less reported cases with respect to available literature and relate to areas comprising small to medium towns with a marginal position in the main economic and trade global trajectories and, therefore, less in the spotlight.

4.1 The Central Italy Recovery Process: An Ongoing Case

In the years 2016 and 2017 until today four regions of Central Italy, namely Umbria, Marche, Abruzzo, and Lazio have been affected by a prolonged seismic swarm with epicenters moving from North to South and back North, along a system of active faults in the Apennines. Thousands of seismic shocks have been recorded in the area; however, the highest peaks occurred in the period comprised between the 24 August 2016, when the first 5.9 shake hit a mountain area between the Marche and the Lazio Regions with epicenter very close to the town of Amatrice. Other two very strong earthquakes occurred on the 25, 26, and 30 October 2016, reaching a maximal level of 6.5 on the Richter scale in the last shake of this sequence. A series of 4 events occurred on the 18 of January 2017, the strongest of which reached a level of 5.5 on the Richter scale with an epicenter close to the town of Campotosto in the Abruzzo Region. The shakes provoked widespread damage across a rather wide region, mostly mountainous, thus triggering also a very large number of landslides and some avalanches, especially in January 2017. Central Italy had already been the scene of a number of recent seismic events, including the Val Nerina earthquake in 1979, the 1997 earthquake at the border between the Umbria and the Marche Regions, and L'Aquila earthquake in 2009. Seismologists are actually debating if this sequence can be considered similar to the one that affected the same regions along the entire eighteenth century. As for the Umbria case, the first two events are of relevance regarding the lessons learnt and the actual response of traditional buildings that were seismically retrofitted.

The prolonged seismic swarm created a long-lasting emergency that made it difficult to shift towards recovery and reconstruction. Each time civil protection authorities and interveners were ready to gradually leave the area, another strong shock was bringing back communities to the fears and the problems typical of a crisis. A similar situation occurred between the September 1997 and March 1998 seismic events. However, the seismic swarm between 2016 and 2017 affected a much larger area and with shakes of higher intensities. This condition has certainly hampered attempts to develop a vision and a comprehensive plan for reconstruction, as agencies were continuously faced with urgent needs in the residential, agricultural and infrastructure sector calling for immediate intervention, temporary sheltering solutions, reopening of vital roads. After more than two years, even though it can be said that first steps towards reconstruction have been made, communities are still in the recovery phase. The authors, thanks to projects in collaboration with public administrations in Central Italy, are witnessing the recovery from a privileged perspective and count on firsthand experience of issues and problems in their unfolding and making.

4.1.1 Post-disaster Needs Assessment

In the last years, post-disaster damage assessment has gained prominence in Italy, also as a consequence of the financial crisis that affected Europe since 2008. As insurance against natural hazards has very limited penetration in the country, the main source of compensation is by large the State. Justification and detailed description of damage and transparent declaration of amounts for repairs is now required by the National Department of Civil Protection that manage the funding that is allocated by the Ministry for Economic Affairs in the annual financial law. However, such obligations are not organized in a structured way but rather requested each time in ad hoc ordinances or in annexes to decrees. Italy has a long tradition of post-earthquake habitability assessment carried out using predefined rather complete forms that are filled by experts including public officials, professionals, and academics. Usability forms though were mostly developed for residential buildings. In the last years an effort has been made to develop damage assessment tools also for productive buildings and infrastructures.

A further innovation was triggered by the introduction of the European Solidarity Fund, granted by the DG-Regio responsible for territorial cohesion policies. In order to apply the Fund, countries must provide an all-sectors loss assessment, distinguishing between affected private and public assets, as only the latter are eligible for funding. Italy has applied for the Solidarity Fund on the occasion of the Central Italy earthquake. Figures 2.2 and 2.3 show the difference in the distribution of damage among sectors after the August and the October shakes. The latter estimate totals 16 billion Euros, with a rough 50% for residential buildings, 15% for critical infrastructures, and 15% for cultural heritage. While the assessment is rather complete and results from the coordination a large campaign of data collection at the municipal level, priorities are defined politically and have initially privileged the housing and the infrastructural sectors. It has become evident soon, though, that without an effort to boost an already marginal economy, the future of those areas could be a further decline, especially demographically. Some care has been devoted to the few factories located in the area, to agricultural activities and to commerce, even though the provision of temporary barns, for example, has been delayed by the lack of pre-event established procedures.

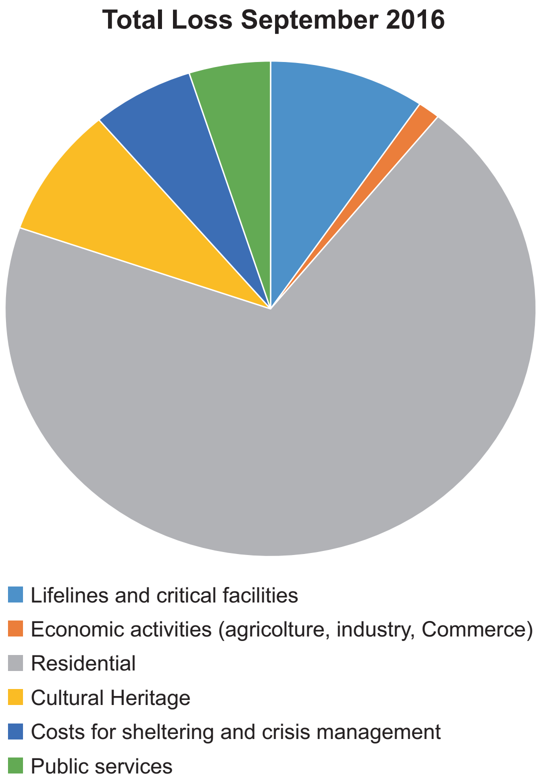

Fig. 2.2 Total loss figures after the August shake

4.1.2 Problems Arising in a Multi-hazard Environment and in a Prolonged Emergency Consequent to a Long Duration Event

As many as 540 working sites for the repair and the remaking of roads have been established since August 2016 and progressively increased following the subsequent shakes. This very large amount, which refers to the numbers provided by the public agency in charge of the main road system (excluding therefore local level roads that are managed by provincial and municipal offices), is only partially due to structural damage to bridges and mostly (over 65%) to the very large number of landslides that were triggered by the seismic events. Damage due to the shaking combined with damage provoked by the large variety of hydrogeologic phenomena that are typical of a mountain environment, including avalanches, rockfalls, landslides, as the one that destroyed the hamlet of Pescara del Tronto. The combination of chained or independent co-occurring hazards (like the snowstorm lasting over a week in January 2017 (Menoni & Boni, 2020) and a system of small towns scattered over a relatively large area with a high level of systemic vulnerability, made the Central Italy earthquake a complex event, particularly challenging for rescuers, but also for administering recovery.

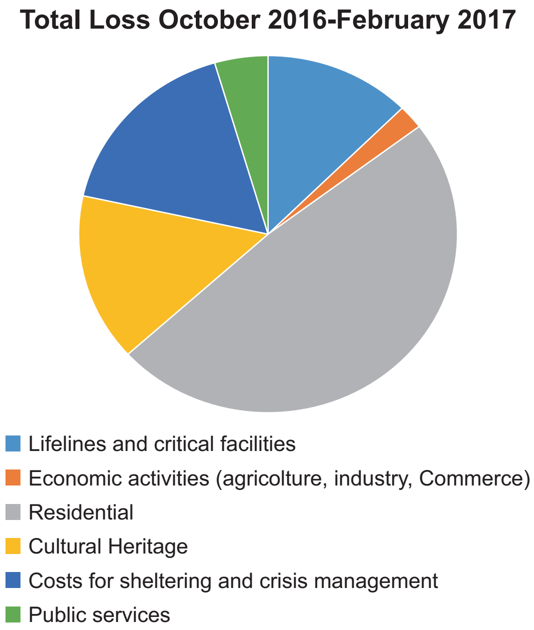

Fig. 2.3 Total loss after the October shakes

4.1.3 The Lack of Established Protocols and Procedures for Post-earthquake Recovery

On the 17 October 2016, a special governance structure was created by law appointing a Commissioner for Reconstruction who should have coordinated the efforts of the four involved regions. Since its establishment, three commissioners have succeeded in the role, partly because of political problems, partly because the task changed and became increasingly complex overtime. In fact, it should be reminded that, when established, the Commissioner was responsible for a total of 17 municipalities that suddenly, in the last 4 days of October, became 140, as shown in Fig. 2.4.

The first Commissioner established also a technical panel of professors and researchers with different expertise to support him in the decision-making process. A certain number of ordinances covering all aspects of recovery were issued, related for example to the relocation of economic activities, to the establishment of temporary sheltering areas, to the guidance for planning the reconstruction. The Commissioner holds in his hands the funds that are allocated by the government for the disaster and is in charge of redistributing them according to needs, priorities, and projects following a common framework.

One emerging critical issue relates to the lack of established frameworks and protocols to deal with recovery and reconstruction, leaving the commissioner to "invent" somehow new rules and practices, without being able to rely on lessons learnt and experiences from past events, that, though, have been rather numerous in Italy. As a consequence of the lack of shared and pre-existing rules and protocols,

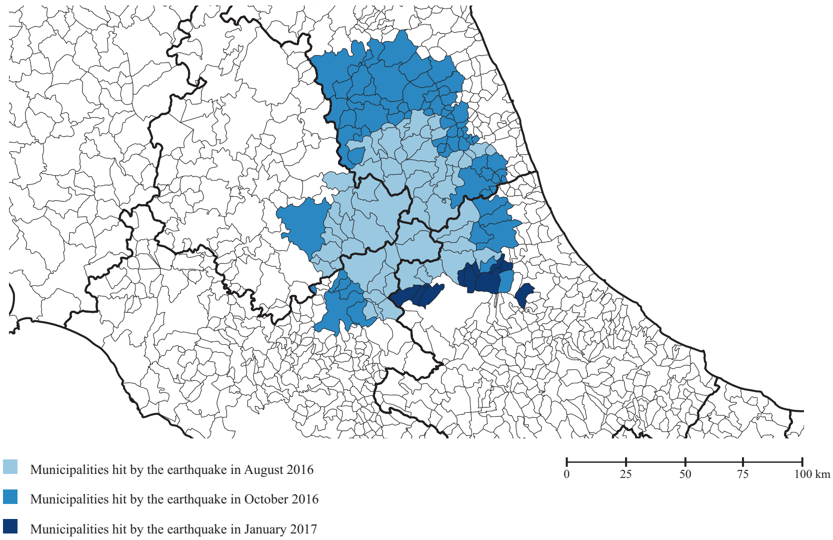

Fig. 2.4 The progressive increase of the affected municipalities (Guido Minucci from Politecnico di Milano is acknowledged for this map)

ordinances had to be issued each time a new problem arise outside a comprehensive framework. Such ordinances sometime end up contradicting each other, creating new uncertainties regarding timing, responsibilities, and priorities. This became a particularly critical point for three aspects that will be briefly commented in the next sub-section: delays in temporary housing provision; problems in dealing with the enormous amount of debris and waste; criticalities emerging from an already declining and marginal economy.

4.1.4 Dynamics of Decisions, Debris Management, and Economic Recovery

As correctly put by Olshansky and Chang (2009), it is very difficult to make decisions under the pressure of the urgency created by the disaster and the need to reestablish at least some basic vital services for a community. The case of Central Italy certainly fits this remark, considering that the area is already subject to demographic decline and to the general reduction of economic and social vitality. Figures 2.5 and 2.6 provide a snapshot into the reality of the area that has been affected: mountain zones, with an aging and decreasing population with few or even very few job opportunities.

In this regard, the decisions that were taken right after the event were to support economically also the reconstruction of secondary houses, considered as an important asset of the fragile tourism economy relying on those who visit in the summer and during holidays the area and eventually families there. It is certainly a very

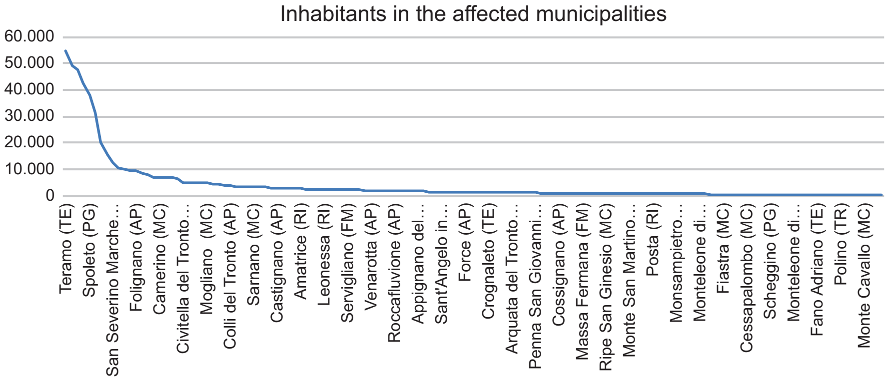

Fig. 2.5 Inhabitants in a sample of the affected municipalities

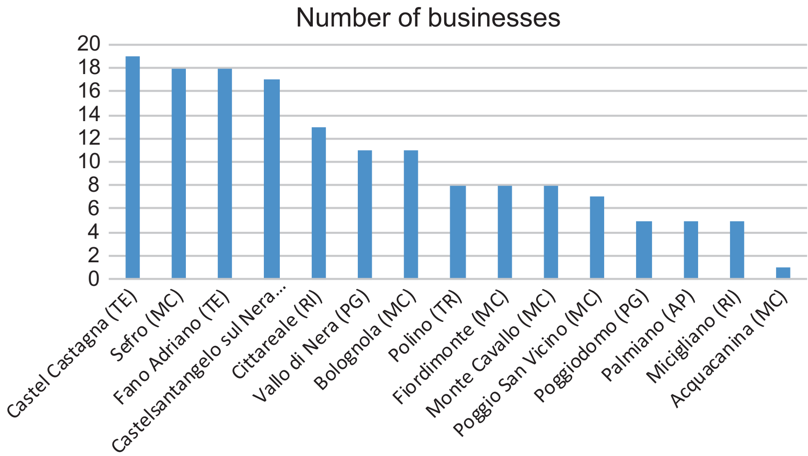

Fig. 2.6 Number of businesses in the affected municipalities of the Abruzzo Region

beautiful landscape, hosting some important cultural heritage spots and it is not by chance that two national parks, the Gran Sasso and Laga Mountains and the Mounts Sibillini, are located here.

A key problem that has hampered and is still delaying reconstruction relates to the management of debris and disaster waste. Where to locate debris and what to do with it has been always an issue, however, since the introduction of constraining legislation at the EU level and consequently at the national one, the management of large quantities of waste and debris have encountered major obstacles. According to the 2008/98/EC Directive, the concept of disposal has been substituted by a much more comprehensive approach that aims at diminishing dramatically what has to be dumped in favor of recycling and reuse, throughout a very refined classification and selection of waste aimed at grouping materials by type, content in pollutant, etc. This requires a double effort: firstly, to bring the waste to a safe site where materials can be classified and grouped; secondly, the identification of final solutions for disposing what cannot be reused. Quantity is also an issue. Literature and scientific research have not investigated enough this field. Empirical equations to assess the quantity of debris a disaster can provoke are available (Brown, Milke, & Seville, 2011), but would require further validation and real case applications. In the case of Central Italy, the method and the equation that were used after the L'Aquila earthquake were adopted; however, in some cases they led to an underestimation of the real amount, totaling 2 million tons of debris, the majority of which in the Lazio and the Marche regions.

In the case of cultural heritage, the treatment is even more challenging as according to the Italian law, which is very careful regarding the restoration and repair of monuments and historic sites, every piece of a column, window, stair pertaining to a palace or to a church needs to be classified and numbered so that it can be reused in the same structure.

4.1.5 Recovery Options for a Large Widespread Cultural Heritage: Technical and Social Challenges

Central Italy hosts a diffused albeit very rich cultural heritage, made of elements of relatively minor relevance to very important pieces such as the Church of San Benedetto in Norcia, that collapsed completely apart from the façade and a part of the lateral wall.

Management of cultural heritage in Italy is at a very advanced stage, as it results from a long-term experience in restoration, preservation, and retrofitting that is very careful to maintain, as much as possible, the features of the artifacts, considered as a testimony of the past layering of changes and transformations that occurred over the centuries. The artifact is considered as a legacy of history and therefore its peculiarity and unicity should be preserved without opting for one specific period. Current management of cultural heritage after disasters is also the result of an unfortunate long series of devastating earthquakes and other hazards that have affected historic monuments and hamlets in the last decades. A set of techniques for shoring historic buildings, for preserving them from external disrupting forces while waiting for restoration and repair have been established and now codified in norms and regulations governed by the Ministry for Cultural Heritage and its regional and local branches. Personnel of the Ministry are always intervening together with civil protection and firemen in case cultural heritage is at stake. A significant difference in treatment is made between mobile and unmovable goods. The former are saved and temporarily recovered until the building hosting them (a church, a museum, a palace) is not reestablished and safe; the latter are protected as much as possible from atmospheric aggression and theft until rehabilitated. In the case of Central Italy, a very relevant aspect of the protection of movable heritage (paintings, documents, statues, pieces of monuments) was played by a special shelter that had been built at the time of the 1997 earthquake that hit the Umbria and the Marche regions and that was meant to be used in case of disaster. The shelter is a very large structure, where the different objects are kept in a controlled environment as for humidity and light, and where a sort of emergency intervention is made to prepare them for final restoration and repair. It works like a sort of “triage” for cultural heritage goods, diagnosing the level of damage, identifying immediate measures to halt further disruption and prepare them for final interventions that will be probably carried out in other laboratories. It is a unique structure in Italy, but certainly a very advanced and pioneering one that proved though to be insufficient to store the large number of objects that were located in the many churches, museums, and palaces affected by the Central Italy earthquake. The 1979 and 1997 post-earthquake recovery played an important role also in determining the level and severity of damage to cultural heritage. In fact, an important distinction needs to be made between traditional housing that underwent significant seismic amelioration and churches for which the norms for restauration issued at the time by preservation bureaus actually forbad invasive intervention. This resulted in a significantly diversified damage pattern: traditional buildings resisted the two strong shakes in October, while most churches collapsed or suffered severe damage.

4.2 The Gujarat Earthquake: An Innovative Approach to Recovery

On January 26, 2001, an earthquake of 6.9 Richter magnitude hit the Gujarat area. The epicenter was located in the district of Kachchh, at latitude 23.40N and longitude 70.28E, 65 km east of Bhuj town. It was around 8:45 am when the ground shook for 30 s causing massive destructions. The final death toll reached the very high number of 20,000 people killed under the rubbles; not a single settlement in villages and towns of Kachchh remained unaffected (Wisner, 2001). This earthquake has been stronger than the previous one in the same area, occurred in 1819, and affected almost all civic facilities, especially the infrastructure system, including water supply, electricity, and telecommunications. About 38 million people in the State of Gujarat were affected (UNDP, 2001). Nearly one million homes were damaged leaving two million people homeless. Thanks to a collaboration between the Polytechnic of Milan (Italy) and the CEPT University (Ahmedabad, India), authors were able to get primary data, consult documents, and visit the reconstructed areas.

4.2.1 Post-disaster Needs Assessment

The Gujarat earthquake raises some important issues about the recovery and reconstruction processes. Given the catastrophic consequences of this event and the conditions of the Indian context, the Government acted at different levels, supporting a rehabilitation of social and commercial activities and, moreover, a new plan for the recovery of the buildings.

Immediately after the earthquake, the State Government finalized a comprehensive program called Gujarat Earthquake Rehabilitation and Reconstruction Program Policy[1] and created the Gujarat State Disaster Management Authority (GSDMA).[2] The program was meant to deeply support the process of rehabilitation and reconstruction, addressing different issues at various stages of the recovery process. In particular, the policy started from the immediate support to the population, the economic rehabilitation and livelihood restoration, till a long-term program aimed at preventing future disasters (World Bank/Asian Development, 2001).

Two overarching objectives were set: in a short-term, to promote the sustainable recovery in the disaster-affected areas (from the social, economic and urban point of view) and in a long-term perspective, to lay the foundation of a sustainable disaster management capacity in Gujarat. Specifically, the main outcomes foreseen by the government were:

- Sustainable rehabilitation and reconstruction
- Reduce vulnerability in order to set up the future preservation of life and property
- Increase community risk awareness and preparedness for natural hazards
- Enhance preparedness and response capability of emergency responders

Since the day after January 26, many short-term courses, workshops, and conferences related to earthquake resistant design and practices were organized. Moreover, the media produced a number of programs to highlight the role of communities in recovering from the earthquake disaster. Consequently, long-term initiatives have been planned: the government departments and the agencies recognized the importance of improving seismic design practice and knowledge to prevent possible future damages.

The *Gujarat Earthquake Rehabilitation and Reconstruction Program Policy* focused on different layers, especially on the identity of the villages and local communities in order to support their rehabilitation. In this sense, the overall strategy shows an innovative perspective: preserving the local communities was considered crucial to strengthen the economy of Kachchh area, given the tight relationship between the local communities and the entire State economy. The program provided support to revive agriculture, industries, small business, and handicrafts and at the same time took a series of actions to develop social infrastructures, providing health support for the population and to repair transportation system (Gujarat State Disaster Management Authority – GSDMA, 2001).

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[1] http://gsdma.org/uploads/Assets/iec/earthquakerr06172017024901390.pdf.

[2] The Government established the GSDMA (www.gsdma.org), an independent state agency, to coordinate response and recovery efforts and to guide the state in developing its disaster management capacity. Modeled after the Orissa State Disaster Mitigation Authority (after the 1999 cyclone), the main goal of GSDMA was to provide the needed autonomy to develop policies and guidelines for the various facets of recovery.

Due to the massive disaster, funding for the recovery program came from different promoters all over the world. Funds were provided by the Government of Gujarat (GoG), Government of India, European Commission, Netherlands and various NGOs and other donors. The World Bank and the Asian Development Bank have also provided more than 1,000 million US dollars to finance the reconstruction program (EERI, 2005).

4.2.2 Plans, Visions, and Projects

After the earthquake in a letter to the Chief Minister of the Government, Kirtee Shah (2001) said: “Vision, not only administration, is the requirement for a good reconstruction,” opening up the debate around the strong, and essential, condition that could support the reconstruction: “the need of a common vision.” The topic is to operate in a long-term process, addressing meanwhile the primary needs of the population after the disaster. Moreover, it has also strong implication in the design process and in the definition of a strategy for the new rehabilitation projects.

The recovery program was designed to address various needs in the following sectors: housing renovation, livelihood rehabilitation, infrastructure, urban and social facilities and also to promote community participation and disaster management capacity building. The governmental staff played a central role managing the recovery effort at the village level working in close contact with affected citizens. In order to achieve such collaboration, a rather innovative organizational model was established, named “SETU,” which means “bridge” in Guajarati language. SETU is a research mobilization center for a cluster of about 25 villages, staffed with 7 to 8 people, who worked for facilitating and creating information linkages between the GoG and the local communities. The SETU played in this situation a valuable role as facilitators, particularly giving to the citizens adequate information to take advantage of government plans. They also strengthened local initiatives and helped to incorporate citizen participation in the community’s decision-making. In addition, more than 260 NGOs worked through the SETU model and other initiatives for promoting community involvement in the decision-making process. This model also ensured that proposed solutions, designed by professional agencies and consultants, were adequately debated and, in the meantime, permitted to professionalize local technical knowledge and promote visits and meetings with international experts in the seismic domain.

The reconstruction acted at different scales and touched upon various design topics. The first decision to be made in rebuilding rural villages was whether the latter should be relocated or rebuilt in situ. Rather fast consensus was reached regarding the unfeasibility of relocation and the need therefore to lay out development plans for each of the towns before rebuilding. In general, interviewees believed that the entire process (relief, rehabilitation, reconstruction) was a great learning experience for all the involved actors. In this context, a careful back analysis of the damage suffered by each building constituted the necessary step to propose solutions adaptable to different situations, starting from the debris removal and providing aids according to differential damage degree. Many discussions regarded the design of the temporary shelters, in order to define the best solutions in terms of material (e.g., tin sheets, cement, fiber glass surfaces, bamboo matting) and durability. However, many solutions were discarded given the local environmental conditions and all the effort was put on fast rebuilding, and the priority given to prompt releasing of the necessary funds. The earthquake hit a huge area, affected also by conditions of extreme poverty: hence, the reconstruction has worked mostly giving priority to achievable actions able to preserve the local identity of villages; most of the villages, not all the ones involved, have been restored, avoiding process of relocation but the overall process has stressed the need to plan carefully what was necessary to rehabilitate. In terms of cultural and environmental sensitivity, the main reconstruction materials used were bricks, stones, and wood, and many people managed to recycle material salvaged from their former homes. People were familiar with the main reconstruction materials, and the use of vernacular designs and spatial arrangements ensured that villages reconstructed with government financial assistance maintained their traditional character. Most housing followed vernacular designs and spatial arrangements, although there was also space for some innovation. Individuals were also able to adapt their homes to suit their livelihood activities, such as cottage industries, farming, and animal husbandry.

In parallel, the program addressed the recovery of the infrastructural system, devoted to the transportation (roads and bridges), but also the restoration of the facilities network, like power and water supply. It is noteworthy that the opportunity to address long-term-issues in physical infrastructure development was positively exploited. In fact, many bridges distressed before the earthquake were repaired under the program. Contemporary, a separate strategy was developed to rebuild infrastructure in heavily damaged urban areas. The Asian Development Bank granted funds to repair the distribution network, as well as to strengthen 3286 km of transmission line. Within 4 days after the earthquake, pipes and tube wells started to be repaired. The government, with the funds of Asian Development Bank, developed new water supply plans for 40 towns and 1610 villages, with a long-term view of the next 30 years. Another high priority was to repair the dams that provide drinking water in this drought prone area, both to capture water in the next monsoon season and to make sure that the dams would not fail when the reservoirs would be full. Following the recommendations of a panel of experts, the government created the "Dam Safety Review Panel" to guide the reparation and strengthening of the dams.

People of this district have a reputation for being hardworking, determined for pulling together in the face of hardship. Communities participation had been the driver of the entire reconstruction process since early recovery, facilitating the connection of viable solutions to the cultural identity of the area. Community participation was promoted through information and education campaigns, self-help networks, empowerment of women, creating workshop to highlight gender issues in the rebuilding, and strengthening of "Gram Sabhas," a term that indicates the entire voting population of a village. This term was used by the elected members of the villages (panchayats) as a way to discuss the rehabilitation choices and the importance of disaster resistant constructions compatible with villages' construction tradition.

4.2.3 20 Years After the Event: Considerations

The reconstruction effort in post-earthquake Gujarat was broadly successful (Gujarat State Disaster Management Authority – GSDMA, 2005). Today it represents an interesting case study because it allows seeing the effects of a recovery and reconstruction program with a critical distance from the disaster. It has been also an extensive program, almost unique, since it has been applied on a large geographic area and it has developed an innovative approach towards the rehabilitation after a catastrophic event. In fact, according to the GSDMA, by December 2005 the government had supported repairs to more than 900,000 homes damaged in the earthquake, and had fully rebuilt 197,000 destroyed homes, out of a total of more than 222,000 (Duyne Barenstei, 2006). Even with the NGO's helps, over 70% of repair and reconstruction work was completed by the beginning of 2003, only 2 years after the earthquake.

The government's housing restoration effort mainly concentrated on the reconstruction of destroyed homes. Much less attention was given to the repair and retrofitting of damaged buildings. In general, the highest level of satisfaction was achieved in most cases and, in the villages, everyone felt that their housing situation was better than before the earthquake. However, there are some cases where the dissatisfaction with the reconstruction process was very high, especially in terms of quality of materials and construction. Beneficiaries also complained that the new houses and settlements did not conform to their rural lifestyle, there was no privacy for women, and there was no space for cattle, fodder, agricultural implements, and people's furniture. Even the disparity between castes is visible in some areas, where the interests of the local elite were the most influential key factor in the decisions.

In closing, a possible lesson that could be taken, from the Gujarat earthquake, concerns a long-term institutional change, trying to support an urban planning approach focused not only on the immediate issues but able to build a vision for the future. Overall, the Gujarat reconstruction could be taken as a positive way to address the complex issues related to post-disaster conditions, especially due to a clear vision of the actors involved in the program and due to the concept of "coproduction in action." The common vision, provided by the Institution but shared and built with local population, has been able to drive the funds got from different sources and to plan interventions providing a support in the immediate necessity, but also planning improvement of the quality of the main infrastructural elements (e.g., dams, bridges).

5 Guidelines for a Resilient Disaster Recovery Process

With reference to an evolutionary approach to resilience, which emphasizes the ability of socio-ecological systems to transform themselves "instead of 'back-to-normality'" (Wang & Yamashita, 2015), and on the basis of what can be learnt from past experiences, some recommendations addressed to improve current disaster

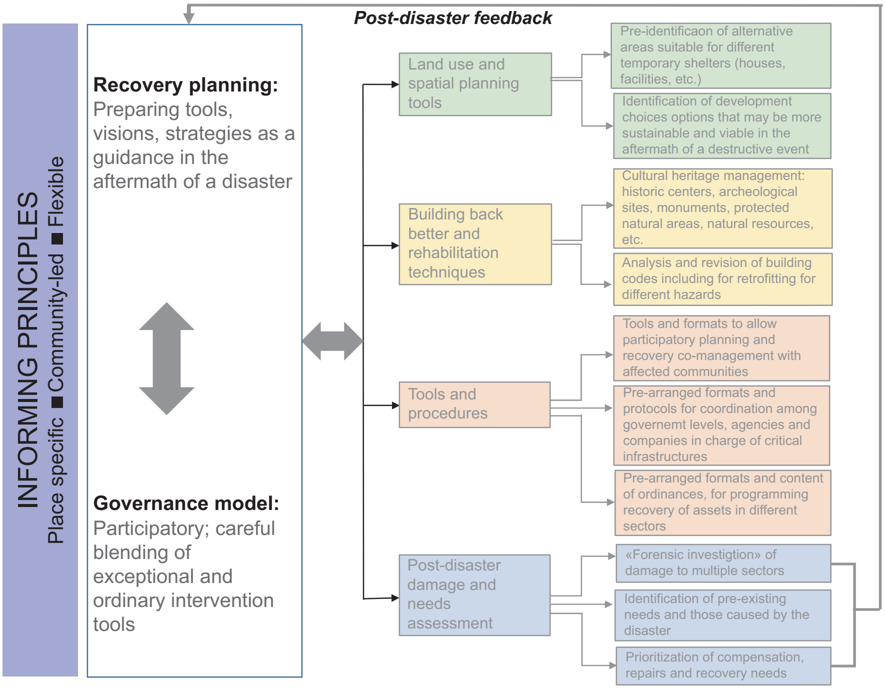

Fig. 2.7 The reformed disaster recovery process: basic principles, pillars, and tools

recovery practices are proposed. First of all, the recovery phase has to be intended as a process in which actors, role, responsibilities, plans, and tools are defined and planned in advance (Smith, 2011) and reviewed, in the aftermath of a disaster, according to a detailed and cross-sectoral analysis of the damage and losses that have occurred. The reformed process is structured in three main parts: informing principles; key pillars, which include planning and governance; tools and techniques capable of substantiating and supporting the two pillars of the recovery process, which can be grouped under four categories: "tools and procedures," "sustainable land use and spatial planning," "build back better and rehabilitation techniques," and "post-disaster damage assessment" (Fig. 2.7).

5.1 *Basic Principles*

In respect to the key principles that should inform a disaster resilient recovery, it has to be firstly highlighted that recovery activities should be based on both occurred and expected hazardous events. Moreover, they should take into account the likely interactions among different hazard factors as well as the features of affected communities and territorial contexts, since each disaster and the consequent recovery needs are highly *place specific*.

Moreover, since recovery activities are addressed not only to merely restore the physical, social, and economic fabric but, above all, to improve the pre-existing features of the affected area, by enhancing its resilience in the face of future events, it is essential to ensure that recovery activities actually reflect a shared vision of the future (Eslamian, Parvizi, & Behnassi, 2021). To this aim, the whole process should be *led by local communities*, even when technical assistance of external organizations is required.

Furthermore, since according to March and Kornakova (2017) "unforeseen situations occur in almost every large disaster event," also due to the uncertain duration of the recovery phase, another key principle that should inform strategies is *flexibility* that allows a constant review of goals and strategies, according both to the changing needs of the communities over this critical post-disaster phase period and to the challenges posed by unexpected situations and events that could occur also some time after the initial stressful event.

5.2 Key Pillars and Tools

The two pillars of an enhanced disaster recovery process, recovery planning and governance model, are tightly connected to each other. As for the governance model, a series of formats facilitating participatory planning can be proposed, as well as a set of pre-arranged protocols, draft of ordinances and coordination tools that are known to speed the recovery process and that address the need of victims to make their voice heard, ensuring a correct uptake of their needs by decision makers and legislators. Strategies and tools for recovery must be planned in advance and overseen in the light of an accurate, cross-sectoral post-disaster damage assessment. Each of the aspects above will be further detailed in the following.

5.2.1 Recovery Planning and Governance Model

The potential added value of *pre-disaster recovery planning* to better tackle the many problems related to sheltering, evacuation, relocation, funding decisions, and programming has been largely emphasized in scientific literature (Berke, Cooper, Aminto, Grabich, & Horney, 2014; Smith & Wenger, 2007). Moreover, the Federal Emergency Management Agency (FEMA) has recently issued a series of Pre-disaster recovery planning guides addressed to different governmental levels (State, Local, Tribal).[3] These guides embrace a bounce-forward perspective to recovery planning, interpreting a successful recovery as "broader than simply restoring the infrastructure, services, economy and tax base, housing, and physical environment," since it should be also addressed to "re-establishing civic and social leadership,

[3] https://www.fema.gov/emergency-managers/national-preparedness/plan#pre-disaster.

providing a continuum of care to meet the needs of affected community members, reestablishing the social fabric, and positioning the community to meet the needs of the future" (FEMA, 2017).

Pre-disaster recovery plans should guide post-disaster decisions and investments in close relationships with other existing planning tools, including urban master plans, housing plans, climate adaptation plans, economic development strategies, etc., fostering and facilitating the adoption of a vision for the towns and settlements to be reconstructed following a disaster, shortening the time required to layout a fully new development or re-development plan under the pressure of urgent needs.

The difficulty to coordinate the multiple actors involved in recovery as well as to develop and maintain a single vision for all involved stakeholders, requires a *governance model* capable of identifying in advance leading and involved actors as well as their tasks and responsibilities. While government arrangements are those that formally address both planning and recovery decision-making, governance is here intended as the set of collective decisions made to guide, coordinate, and oversee the recovery process. The first is focused on institutions and public administrations, the second also considers the role of associations, informal organizations, individual citizens, and private stakeholders that have a say on the future of the affected regions. The two spheres are clearly interconnected at many levels. All successful cases, as the Gujarat one, are the result of a highly participatory process, in which citizens and affected communities have become a very active part of recovery, orienting the external aid and the solutions designed by external experts to the local culture(s) and prioritizing on the basis of their own necessities in terms of livelihood. The interaction between official governmental organization, formal laws and regulations, and local social arrangements requires ad hoc solutions that must be tailored to the characteristics of the areas where recovery must take place.

The governance model must be adapted to the guiding principles of recovery plans and vice versa. In the FEMA Guidelines, pre-disaster recovery plans are interpreted as flexible and constantly updated outcomes of a local community-driven process, fully engaging the whole community, taking into account needs and resources of all its members including minority or under-represented groups: thus, a participatory pre-disaster recovery planning also contribute to improve learning and awareness about risk features of the areas where communities live.

5.2.2 Tools and Techniques for Recovery Planning

As mentioned above, pre-disaster recovery plans should guide post-disaster decisions in close relationships with other planning tools already in place and, above all, with land use and spatial planning tools. As clearly demonstrated in the Christchurch recovery, an effective *interaction between land use planning and pre-disaster recovery planning* may contribute to increase the future sustainability of the hit area (Saunders & Becker, 2015). This is particularly relevant when suitable sheltering solution has to be identified. Sheltering policies leave, indeed, an important legacy on the future of communities, despite being too often taken outside a strategic vision for the sustainable future development of the hit area. Decisions regarding one option or a mix of options depend on the level of destruction and also on other considerations related, for example, to the need to be close to markets or production sites, to maintain local communities in place so that the areas will not be completely abandoned and forever, etc. Those dilemmas are very typical of more rural and marginal areas, such as those that characterize Central Italy. When the decision to build temporary dwellings is preferred, a number of issues arise that need to be carefully addressed. Firstly, the provision should occur fast enough not to leave victims in precarious conditions for too long. Secondly, the fact that architectural solutions and amenity are important even though structures are not designed to last forever, as there may be well a generation of children that will grow up and become adults in the temporary housing. Thirdly, when thinking about the future of such structures, when full reconstruction will be accomplished, also the future of the infrastructures and services created for the temporary shelters must be considered. In this regard, areas to be devoted for temporary shelters matter. They may prefigure large irreversible urban development, sometimes with negative environmental consequences as in the case of L'Aquila, or be interlaced with the existing city, exploiting unused and underutilized urban areas and empty buildings and facilities. Additionally, in the most recent events it has become clear that not only dwellings must be provided but also community services, even hospitals, schools, as well as buildings for productive activities, such as factories and barns. The development of such temporary shelters to host a variety of functions must occur in areas that are safe, not exposed to hazards, served by lifelines and provided with transportation. The extent and the type of solutions to be found must be tailored to the needs of the population, to the economic, cultural, and morphological features of the cities and regions that have been affected and must not compromise the environmental quality of the affected area.

Particularly relevant in recovery planning are the *tools, norms, and techniques for Building Back Better* as well as for rehabilitating the hit building stock, with a particular attention to cultural heritage. Building codes are often revised in the aftermath of a severe disaster, especially when modern structures that should have resisted the stress have failed. The essence of the Build Back Better principle is clearly to learn from the event and reduce the vulnerability of individual structures, but also reconsidering certain techniques that proved to be unsafe. Recent earthquakes, such as that in Christchurch, New Zealand, 2010 or Nepal in 2015 required to address not only the vulnerability of modern buildings, but also the problems connected with large, vulnerable, historic assets. Providing specific and tailored tools for the diagnosis of damage, for primary shoring solutions to stabilize what has not collapsed, for safeguarding movable objects against theft and atmospheric aggression is key. A number of tools and solutions have been proposed as good practices, as for example damage survey forms, designed to address the specificities of cultural heritage, advanced shoring techniques, and modality of intervention. In both respect, tools that have been developed in Italy can be mentioned, such as the Stop manual for firemen for immediate post-earthquake relief using wooden structures; and the forms that have been developed and adopted by the Ministry for cultural heritage for churches and palaces. Such solutions need then to be tailored to the cultural environment of the affected country and to the priorities identified by the affected communities. Dilemmas regarding the trade-offs between restoration, retrofitting, and safety, on the one hand, and between careful rehabilitation and partial reconstruction of heritage artifacts and the delays that are entailed in such process, on the other, must be solved through a participatory approach and considering the function and role of heritage in the identity of affected communities (Dandoulaki & De Jong, 2017).

5.2.3 Tools Supporting an Effective Governance of the Recovery Process

Since the 1990s, urban and spatial planners, landscape designers and architects have developed a variety of *tools and formats to foster a participatory approach* to project development, ranging from charrettes (Roggema, 2014) to the use of enhanced visualization tools, the latter much improved since the introduction of computer-aided design systems. In this context, co-mapping of areas has been quite extensively used in cities in need of renovation of problematic clusters of poverty and criminality or areas requiring extensive transformation due to relocation of industries. Social sciences have been using questionnaires, surveys, semi-structured and structured interviews, and focus groups as means to collect data and information about people's preferences on a given choice, their knowledge and perception for example regarding hazards and risks in their city or working place. Computer scientists have introduced a wide range of instruments, including simulation techniques based on virtual reality, in order to facilitate the uptake of digital technologies by people who never used them before and to enhance "smart" public participation in decision-making at city level. Living labs are an eminent example. Such tools can be easily adopted to co-design, together with affected communities, plans and projects that meet the expectations and the hopes for recovery and reconstruction, considering in the meantime constraints of funding and addressing environmental sustainability concerns.

Also crucial for an effective governance of the recovery process is the availability of *standard formats for ordinances* as well as of *protocols for improving cooperation among private and public stakeholders*. Ordinances are typical tools used in the emergency; however, they are extensively used also to address the many problems arising during recovery, ranging from the identification of suitable sheltering areas to fast provisions for victims and affected businesses, to relief them from taxes for a certain period, to establishing priorities for inspection of damaged buildings. Such ordinances are known to be required very often, hence, it makes sense to provide pre-arranged forms that can be filled and adapted to the various circumstances, shortening the time needed to write them. Similarly, coordination among private and public stakeholders is often required for the repair of critical infrastructures that involve several companies and agencies in the same place; pre-signed protocols for speeding intervention, without going through long procedures of authorization can be prepared as well. They require that in peace time companies managing lifelines and critical services meet with civil protection organizations so that such arrangements are studied with the sufficient level of care regarding delicate legal issues.

5.2.4 Post-disaster Needs and Damage Assessment

The identification and analysis of damage and losses that have occurred are fundamental components of the recovery process that allow to review, in the aftermath of a disaster, the outlined pre-disaster recovery plan. A comprehensive, sufficiently detailed and cross-sectoral damage assessment is key to both prioritize funding for recovery and learn lessons regarding why damage has occurred and what can be done to reduce its potential in the future. In this respect, post-disaster damage and needs assessment should inform all tools and steps of the recovery planning process and may have important repercussions in terms of decisions to be made and the type of regulations and ordinances to be issued to guide reconstruction.

In 2008, the Post Disaster Needs Assessments (PDNA) was launched as a joint initiative between the UN, the World Bank, and the European Union "to develop and use common assessment and recovery planning approaches in post-crisis settings" (European Commission, UNDP, The World Bank, 2013). The PDNA is made of two parts: the DALA (damage and loss assessment) and the Needs Assessment that are derived from the damage but may be also the evidence of pre-existing lack of services and vulnerabilities of the built environment, both physical and systemic. The former is aimed at providing a comprehensive and cross-sectoral reporting of a disaster, considering the impact on all relevant sectors. The PDNA initiative is important in that it has become a sort of standard applied insofar to a significant number of events with a relatively common structure and methodology. The PDNA must be considered as a key factor of the reformed recovery process in that decisions and plans taken in advance must be reviewed according to the full understanding of the needs that have arisen following the event and on the wish to establish plans for the future that minimize the vulnerabilities that the damage has unveiled.

6 Summary and Conclusions

This contribution has been focused on the recovery phase, a crucial step of the whole disaster management cycle, even though it has so far been fairly neglected, being stretched between the emergency and the reconstruction phases.

In particular, meaning and role of the recovery phase as well as its relationships with the other phases of the disaster cycle, namely with emergency and reconstruction, have been clarified, also highlighting how recent approaches to recovery have significantly changed thanks to the emergence and evolution of the resilience concept. Then, limits and drawbacks but also innovative aspects of past recovery practices have been investigated based both on literature and reports on well-known recovery experiences and on two case studies that authors have directly experienced. Finally, building on lessons learnt from past event and according to the most advanced interpretations of the resilience concept, some recommendations for reforming and improving current disaster recovery practices have been provided. These recommendations, although the proposed case studies mostly refer to seismic events, may be easily used to drive the recovery activities following different typologies of rapid-onset events (e.g., seismic, flooding, volcanic eruptions, etc.).

The reformed recovery phase has been here interpreted as a continuous process, along which involved actors, role, responsibilities, plans, and tools have to be outlined in advance and reviewed in the aftermath of a disaster according to a detailed and cross-sectoral analysis of damage and losses that have occurred. Basic principles, pillars, and specific tools aimed at supporting both the governance of the whole process and the outlining of the recovery plans have been outlined and discussed.

Particular emphasis has been placed on the need for closer interactions among land use and spatial planning tools and recovery plans, in order to better frame sheltering solutions in strategic visions and plans for the future development of the hit areas and guide reconstruction towards an improvement of pre-event conditions, by reducing vulnerabilities and promoting the social and economic development. The principle of Building Back Better, although informing the whole process, has been specifically declined in respect to the need for extensive rehabilitation of both modern buildings and cultural heritage. Finally, tools, norms, and procedures capable of shortening the recovery time, ensuring meanwhile a wide engagement of local community and an effective cooperation of the numerous stakeholders involved in the recovery phase, have been discussed.

Summing up, despite the intrinsic difficulties related to the recovery phase in which conflictual needs and goals, ranging from the understandable aspiration of local communities to return as soon as possible to a new normality to the time-consuming need for a careful assessment of occurred losses and damage, crucial to support reconstruction strategies and actions have to be reconciled, the proposed reform of the disaster recovery process may contribute to overcome some of the main problems and limits that arise from current recovery practices. The setting up in advance of pre-disaster recovery plans, including procedures and tools to better guide recovery activities, and the prior identification of leading and involved actors as well as their tasks and responsibilities might allow not starting from scratch following an event, provided that the specificities of any disaster are accounted for and solutions are carefully tailored to the context at stake. Hence, the provided recommendations represent a guide to be sized on the peculiarities of different places and events.

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Chapter 3
Recovery, Development Programs, and Place-Based Reconstruction Policy: A Flexible Framework

Federico Fantechi and Marco Modica

Abstract Hazards, territories, and communities are not all the same and the relation between these objects might result in post-event fuzzy scenarios that will increase the complexity of reconstruction activities in the aftermath of extreme events. Thus, risk might be dependent to territories according to their socio-economic exposure, vulnerability, and resilience turning into a scattered socio-natural disasters scenario. It results that serious considerations need to be devoted to the "optimal" reconstruction policies to be implemented in order to recover quickly since several shortcomings in the management of reconstruction activities are still unsolved. This chapter proposes a flexible framework to operationalize the steps for recovery in the aftermath of extreme events and in different contexts and to prompt for reconstruction and development policies. Indeed, granted that fitting actions and policies are put into action during the recovery phase, the aftermath of a natural disaster might represent a small window of opportunity for a turning point in the development path of the affected communities. Aiming at empowering and supporting communities affected by natural disasters, this chapter presents and discusses a Context-Bound Framework for Resilience not only as a "framework for research" but also as a "framework for action." Providing policy and investment information ex-ante such framework allows policy makers to immediately outline strategies to improve the ability of community resilience of the territories, affecting both the reconstruction process and their development path.

Keywords Resilience · Place-based · Socio-natural disasters · Reconstruction · Development programs · Recovery

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1 Introduction

Disasters triggered by natural phenomena are one of the biggest problems that a society needs to address, today and in the near future. Only in the last decade, an average of 354 disastrous events were registered around the globe, affecting more than 2 billion people and causing the death of almost 78,000 (Below & Wallemacq, 2018). A wide range of natural phenomena such as tsunami, landslides, floods, hurricanes, fires, and droughts occur almost daily in different parts of the globe. This is particularly worrying in the light several studies assessing the impact of climate change on the specific types of climate events (e.g., droughts, rainfall, cyclones). Such studies have shown a positive correlation between climate change and the magnitude and probability of these events (NAP, 2016; Stott, 2016). Nonetheless, the occurrence of such events alone does not make a disaster. Natural events become disasters when they affect man-made territories and the communities living in those areas (Mela, Mugnano, & Olori, 2017)—that is when a destructive force (nature) meets the built environment with its social and economic structure (society).

Since the turn of the century and the publication of the Hyogo Framework for Action[1] the topic of reconstruction and development has risen the public attention, much has already been done in order to reduce damages and to improve the effectiveness of the recovery process caused by natural hazards with the complicity of society.

In fact, it is very well-known that socio-natural disasters affect both the built environment and the social and economic structure, causing—in addition to the human losses and damages to infrastructure and buildings—also huge economic losses.[2] However, despite an enormous loss, for some territories and communities—especially those locked-in to an underdevelopment path (Belmonte, Bove, D'Inverno, & Modica, 2019; Martin & Sunley, 2006; Wilson, 2014)—socio-natural disasters can also be thought as the trigger for positive opportunities that allow to contrast negative trends and eventually revert a dependency path. Indeed, disastrous events generate a temporary window of opportunity by "suspending the everyday life" and disrupting the economic and social structure of communities (Berger & Luckmann, 1966; Modica, Faggian, & Aloisio, 2019). Granted that fitting actions and policies are put into action during the recovery phase, this temporary window of opportunity might represent a turning point in the development path of these communities. Metaphorically speaking a community might be seen as a river, flowing onto its riverbed (the dependency path), clearly it is not easy to alter its course because the water won't stop flowing and push it to take a different path will require an extreme effort. Nonetheless, it is possible to disturb the system by rolling a big

[1] The Hyogo Framework for Action 2005–2015 (UNISDR, 2005) is the precursor of The Sendai Framework for Disaster Risk Reduction.

[2] The Centre for Research on the Epidemiology of Disasters (CRED) estimates that disastrous events caused an economic loss of almost 1.5 trillion US$ in the last decade, and 334 billion US$ only in 2017 (Below & Wallemacq, 2018).

rock into the river that stops the water flow (this is the suspension of the everyday life caused by the disaster, see Modica, Reggiani, & Nijkamp, 2017 for a study on the evolution of urban systems). Therefore, we will have a temporary window of opportunity—to modify the, now dry, riverbed and create a new path for the water to flow (temporary because the water will soon overcome the rock or start flowing out of its riverbanks).

With a due considerable increase in complexity, the same applies to communities and their development paths. For both the river and communities two are the key elements at work in this process: the suspension of everyday life and a focused effort to ease, encourage and drive both the water and the communities towards a new path. While it cannot be predicted nor controlled, the occurrence of disastrous events causing this suspension of everyday life, the actions can be controlled and the effort put in place to drive the affected communities towards different paths.

This emerging trend of linking disasters' recovery and development programs (Modica, Faggian, & Aloisio, 2019) is embedded and perfectly represented in the Sendai Framework for Disaster Risk Reduction 2015–2030 (Aitsi-Selmi, Egawa, Sasaki, Wannous, & Murray, 2015). With the explicit aim of enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation, and reconstruction, the Sendai Framework aims at connecting disaster' recovery and development programs and builds resilient communities and nations.

This chapter focusing on the local level via the use of the concept of *community resilience* proposed a framework to build connected recovery and development programs. Such framework emerges from the meeting point between the evolutionary perspective in economic geography (Martin, 2011; Modica & Reggiani, 2015; Wilson, 2014) and the community-centered perspective of place-based approach (Barca, McCann, & Rodriguez-Pose, 2012) underlining the central importance of historical and geographical processes in delineating how resilience is differently composed among different communities. Building on this literature, a *Context-Bound Framework for Resilience will be proposed* which produces the specific results tailored for the specific case studies while maintaining a generalizable research strategy and design.

2 Community Disaster Resilience

In its most general meaning, resilience is defined as the ability to react after some kind of stress. With the use of different, and more specific, definitions the concept is, then, adopted in many disciplines from psychology to ecological studies, sociology, natural disaster studies, geography and, of course, economics.

The word of resilience itself is not a specific term of any field in social sciences, it was imported from physics during the 1970s where it describes the ability of a material to bend and then bounce back to its original equilibrium, rather than breaking after a stress is applied (Bodin & Wiman, 2004; Wilson, 2014). Since its first application in social sciences (Holling, 1973), it is clear that the concept of resilience was used as a powerful metaphor linking the study of humans to the one of materials, linking studies in social sciences to those in physical sciences.

It is believed that the resilience is today a very prolific paradigm across many disciplines which, once detached from its metaphorical imagery, can unfold a great potential.

2.1 Concept Definition

Over time, and across different fields, the concept of resilience has been framed—and defined—in many ways. The most prolific of these frames is probably the one of *regional resilience*,[3] which receives most of its contributions from the fields of economic geography (Carpenter, 2015; Christopherson, Michie, & Tyler, 2010; Martin, 2011; Modica & Reggiani, 2015; Simmie & Martin, 2010) and disaster studies (Carpenter, 2015; Cutter et al., 2008; Mayunga, 2007). As argued in Faggian, Gemmiti, Jaquet, and Santini (2018), most of these contributions focus on the traditional economic indicators and fail in representing the complexity of the social world. A very similar—and still very prolific—framework, proposed from more sociological contributions, is the one of *community resilience*; this approach, largely used not only in sociological studies but also in studies on natural disasters, focuses on trying to capture resilience along a series of sub-dimensions of the social structure (Faggian et al., 2018), highlighting the complexity of society and making it a key strength of the approach. In more details,

Norris et al. (2008, p. 130) define community resilience as

> Dynamic process composed by many adaptive capacities to response and change after adverse events.

This definition has indeed many advantages. Other than being light, communicative and very adaptable to different fields, it connects the evolutionary perspective and complex nature of resilience composing the two pillars of our *Context-Bound Framework*.

First, it defines the resilience as a dynamic process—rather than simply an ability—underlining how it is not fixed in time but is sensible to the temporal dimension. Finally, this definition stresses that resilience is composed by many adaptive capacities, highlighting the complex nature of such process.

[3] Linking the concept of resilience to the spatial dimension.

2.2 An Evolutionary Perspective on Resilience

Very recently, the application of notions from Evolutionary Economic in the field of Economic Geography gave birth to a research approach where space and time are the two main actors (Boschma & Martin, 2010). Right from the start, the goal of EEG wasn't only to incorporate historical processes in explaining how the economic landscape change, but also to show how "*situating the economy in space adds to our understanding of the processes that drive economic evolution, that is to say, to demonstrate how geography matters in determining the nature and trajectory of evolution of the economic system*" (Boschma & Martin, 2010 p. 6).

The main focus of this theoretical approach is the spatiality of economic novelty but the ideas they propose can be extended way off this specific field. Geography and history do matter and can sometimes be a sentence for regions and communities that find themselves locked-in in lagging situations or in underdevelopment paths (Boschma, 2015; Simmie & Martin, 2010). Exogenous shocks play a very interesting role over such spatial and historical paths. With a common evolutionary approach sociologists and anthropologists have long studied how proto and early human societies evolved and developed (Turner & Maryanski, 2013), finding out that facing difficult situations is a powerful trigger for social change and adaptation. Large-scale events like socio-natural disasters affecting entire communities therefore will generate ruptures in the social structure (Corbo, Corrado, & Ferriani, 2016; Sine & David, 2003). The occurrence and consequences of exogenous shocks play a key role in suspending what Berger and Luckmann call "the everyday life" (Berger & Luckmann, 1966) of communities, thus exposing rules and practices that had been taken for granted. Organizational studies (Powell, White, Koput, & Owen-Smith, 2005; Corbo et al., 2016) suggest that during these difficult moments there are increased chances for social change and reshaping equilibriums in the social structure (Thornton, 2002). Since the beginning of history, human society has been shaped by our reactions and adaptations to exogenous and environmental shocks. Evolutionary theory suggests that, over immensely long periods, the adaptation to these events triggered the evolution of our species (Hoffmann & Hercus, 2000).

The events and processes we analyze are "smaller" but act on the affected communities in the same way. Ruptures in the social structure are particularly effective on vulnerable communities, struggling to keep the pace with the complexity of contemporary social and economic structures (Devitofrancesco et al., 2016). Connecting recovery and development paths, the aftermath of a natural disaster can be channelled in becoming an opportunity (Fantechi, Urso, & Modica, 2020) for change and adaptation. Being a resilient community means being able to exploit these opportunities to change and adapt, to "bounce forward" (Martin & Sunley, 2006). In this perspective, both time (history) and space (geography) not only matter but are the key actors in delineating the different specificities of resilient communities.

2.3 Resilience of What to What?

Starting from the definition itself, it presents resilience as a process involving two different actors: the *community* (in the definition the implicit subject holding the "*many adaptive capacities"*) and the *adverse events*. An adverse event can indeed take place in many different ways for example, consider how different a flood or an earthquake could be. Moreover, what about a community hit by, for example, an epidemic or an economic crisis? The triggering phenomenon is not natural, but does it mean that it is not an *adverse event*? Of course, not. It is an adverse event, one which takes place in a very different way from one triggered by a volcanic eruption.

The other actor, the community, involved in the process makes things even more complex. It's easier, here, to understand how communities are different between themselves. Indeed, different communities will have—and will make different use of—different *adaptive capacities*. Depending on the space they are situated in the world, different societies, cultures, and economies embedding them, communities will have different sets of adaptive capacities composing—or not—their ability for to be resilient. Moreover, even inside the same society or geographic area sensible differences and sets of the adaptive capacities can be found.

The number of possible interactions of these two groups of objects creates enough complexity around the *dynamic process* of resilience for a single solution to work in different situations. In order to achieve the same goal—being resilient—different communities in different situations (affected by different adverse events) will require the support of different strategies, implementations, and policies.

Is it impossible then to develop a unified strategy to build better resilient communities? The answer is both yes and no. Indeed, while it is impossible to develop a *single solution* working for all different scenarios, we can create a *unified strategy*.

In the next sections, a framework will be presented to approach the linked problems of recovery and development processes together over different scenarios with a unified strategy. Instead of focusing on the *solution*, our framework is focused on the communities, pushing for the implementation of place-based solutions drawn out from the specificities and needs of the communities themselves (Barca et al., 2012). It is important to say that, in the disaster risk management, much attention is focused on the emergency phases and many countries own more or less effective civil protection systems able to cope with the extreme events and implementing "codified" actions. This is not the case for post-emergency situations where reconstruction and development have to be fostered. This claims for a "codified" post-emergency system of actions that, given what expressed before, needs to take into consideration the local characteristics of the places in relation to the affected natural event and suffered damage.

The *unified strategy* to build better the resilient communities is not found in the solution rather in the process of finding the different solutions for different scenarios. From a theoretic point of view, this strategy is perfectly represented by the question:

"Resilience of what to what?"[4] Answering this question will, indeed, force to develop and apply place-based solutions tailored to the interested communities. An example of what—answering this question—implies is noteworthy. Consider two different communities affected (for the sake of simplicity) by the same adverse event (e.g., a major hydrogeological event). The first community is an urban industrialized community of a developing country. The other is a rural community of a rich country with a local economy based on agriculture and rural tourism. The first community (the urban one) is a dynamic and growing community, highly densified, with many production sites attracting people, young people especially, from all the surrounding areas thanks to the working opportunities. On the other hand, the second community (the rural one) will likely be a less dense community, highly sprawled over the jagged, not uniform territory, whose economy is composed mostly by family-owned farms and small activities. The internal demographic situation will likely be different as well, with the second community possibly suffering from decades-long processes of depopulation and aging of the community (and we are not even touching the difference in social capital and administration, to keep thing simple).

It is easily understandable how the ability for resilience of the two communities will be not only different in terms of the strength of their adaptive capacity, but also in their composition. What is less clear—and here is the bedrock of the framework we will propose—is that *being resilient* in response to adverse events has a different meaning for these two communities. In other words, the empirical definition of resilience changes between the two scenarios. So, while the two communities will have some common goals like reconstructing (and improving) buildings and damaged infrastructures, resilience is something more than this. The first community—in order to become more resilient—will focus on the economic and productive sector, and on building policies oriented to improve the dense living situation. In this scenario, the empirical definition of resilience will be correlated to these needs and will be composed by, let's say, an economic indicator.

Applying the same empirical definition of resilience—and the same measurement—to the scenario of the second community, won't bring any useful results. Indeed, the empirical definition in this second scenario will likely be focused on different dynamics and different needs emerging from the community themselves. Concluding the example, a more appropriate measurement of resilience for the second scenario will include demographic indicators, rather than economic ones, as well as their strategies and policies will focus on attracting more—and why not, young—people to live and work there.

The framework proposed in the following sections, rises from this complexity and, orienting itself towards a place-based approach, it gains strength from it. Indeed, having different—and not fixed in stone—empirical definitions of resilience suitable to different scenarios will be the starting point to study the past, develop the tailored strategies in the present, and build more resilient communities for the future.

[4] The question, here used to introduce the process of traducing the concept into a heuristic definition, has been proposed already in similar fashion in a paper from Carpenter, Walker, Anderies, and Abel (2001).

3 Different Paths for Different Needs

For what it can be summarized, four actions need to be implemented in order to recognize the different paths and different need in the aftermath of a natural disaster: first, the phenomenon has to be properly recognized; second, the formal investigation on the degree of susceptibility (when we need more simple and fast kind of probability assessments) and hazard (full probabilistic models); third, defining the effective risk for the population given their exposure, vulnerability, and resilience characteristics; finally, formal place and hazard types of mitigation actions need to be implemented (Iovino, D'Emidio, & Modica, 2020). However, after an extreme event, very immediate actions are typically developed in order to shape the emergency interventions and to define the structural lines of the future reconstruction activities, identifying the types of building damages, the damage compensation to the affected population, and the financial framework sufficient to ensure the continuity of interventions in all the phases of emergency and post-emergency, often without a legislative framework of reference and without considering the disaster history of the affected country. This intense legislation work might sound hard to digest, especially in relation to highly affected countries by natural disasters. However, as mentioned before we are convinced that the natural disasters are not intrinsically the same "between" and "within" them. For instance, hydrogeological damages such as those caused by landslide and floods are different from those caused by volcanos eruptions or earthquakes, and, on the same line, even by considering the same hazard —e.g. the damages caused by earthquakes — these might differ according to the magnitude of the events and for the different characteristics of the areas and communities affected by those events. Furthermore, also when analyzing the effect of extreme events, these are not the same even if caused by the same extreme event because of the different socio-economic conditions of the area affected. Some examples are provided in the next sub-section.

A flexible legislative framework would be therefore pivotal in order to avoid delays in reconstruction activities and confusion in skills and tasks of the stakeholders involved in the reconstruction.

3.1 The Italian Examples

Italy is very seismically active but is also one of the most exposed European country for the impact of meteorological phenomena, like flash floods, tornadoes, droughts, and so on (Guidoboni & Valensise, 2013). Italy is therefore a good example in order to address many important issues in the disaster risk management and in the capacity to shape framework identifying the different paths for different needs.

An example is here provided that derives by the effects of two similar earthquakes (in magnitude) that affected Italy in a short period: the Northern Italy earthquake of 2012 and L'Aquila earthquake of 2009. As mentioned above they have almost the same magnitude; however, they provide very different effects that turns into two different reconstruction models. The 2012 event affected large municipalities and especially their productive facilities in an economically relevant area of the country. The 2009 event instead affected low-density and small municipalities, many of those might be considered as “inner areas”[5] showing a below-average per capita income. Implemented reconstruction policies have thus been quite different often requiring very dissimilar reconstruction interventions in order to ensure and to promote the local development of territories presenting very peculiar and somehow opposite socio-economic features, even if they were affected by “almost” similar event. The 2012 event has acted as a stimulus for the introduction of reconstruction strategies to foster: (1) an increase in the flexibility of the affected firms; (2) the search for new markets; (3) better safety practices; and (4) a greater compliance with the existing regulation, while the 2009 event has acted as a stimulus for rebuilding residential houses and reducing the vulnerability of buildings to seismic risk.

The two earthquakes, even though similarities in the magnitude of the events, affected very different areas of the country. The three affected regions of the Northern Italy earthquake (Emilia-Romagna; Lombardy and Veneto) are considered the economic most developed regions of Italy. The estimated damages were around 13 billions of euro, and the productive system was highly affected. Therefore, the reconstruction had the necessity to be quick in order to allow the productive continuity of the system, with the residential necessity put on the back burner.

Similar damages, at least in monetary terms, have been estimated for the L’Aquila earthquake, even if the reconstruction activities were in some sense slower than the Northern Italy earthquake, with a particular focus on the residential activities in a rural context. Even if some peculiarities arise in this context, 4% of the total reconstruction funds are devoted for the development of the area affected, with the idea that L’Aquila will turn in a “city of knowledge” (OECD, 2013).

Furthermore, as denoted by two different case studies provided above differences in the relationship between degree of rurality and seismic risk might be relevant. The distribution of risk by areas (central or inner) denotes a certain asymmetry, especially with reference to the seismic risk, with a concentration in most remote, mountainous areas, underlining in this way, a potentially different pattern of reconstruction activities between different socio-economic areas—dramatically captured by the very well-known urban/rural divide.

Therefore, local administration has to play a central role and full responsibility in achieving the reconstruction goals but the reconstruction remains a multi-level governance process involving all actors, i.e., municipalities, provinces, and regions, with the guidance of the national administration and other coordinating structures. The new reconstruction setting should be based on the centrality of the affected territories in the reconstruction process and on the socio-economic revitalization of the areas.

[5] Italian classification for rural municipalities. Rural municipalities are defined as “inner areas” and classified over three categories: intermediate, peripheral, and ultra-peripheral (Lucatelli et al., 2014).

3.2 Building Place-Based Resilient Community Strategies

In order to achieve the goal of creating resilient communities, multi-level reconstruction settings should aim at (1) reducing future risks (2) triggering development growth of the areas affected.

Unpacking the concept of resilience into these two aims helps us to partially reduce the complexity of it, so that the separate frameworks can be delineated for actions. Future risks reduction, when looking at the mitigation actions, is directly connected to the type of natural hazard involved. The socio-economic characteristics play a less relevant role, especially so in the planning activities of mitigation actions that do not require different strategies when facing similar kind of hazard in different communities. In other words, when planning for risk prevention, the socio-economic characteristics may create the different inherent conditions but, in the end, from hazard to hazard and from community to community, the socio-economic goals for risk mitigation does not change. Different strategies for mitigation actions are instead driven by the differences "between" socio-natural disasters. Mitigation actions are, hence, primarily ecological and infrastructural issues and their strategic goals are connected mostly with the nature of the hazard. For the implementation of mitigation actions therefore, the socio-economic characteristics of an area are only of residual importance.

On the contrary instead, planning for the recovery of a community (aiming to trigger a positive development path or keep it onto one) is unaffected by the type of natural hazard.[6] Indeed, in a recovery program, the strategies and goals should be the same regardless the hazard. What drives these strategies are instead the socio-economic differences of the area. Most importantly, these differences shape different goals for the recovery program. When the aim is to trigger a positive development path, recovering after a natural hazard, strategies and goals will not change whether the area was affected by an earthquake or flood. Different strategies for the recovery are instead driven by the differences in socio-economic characteristics of the community. This is what we previously called differences "within" socio-natural disasters. Here lays most of the complexity of the concept of resilience. Figure 3.1 is a summary of this complexity.

Resilience and vulnerability (the reduction of possible risks) are two concepts often dealt together. For a long period, scholars discussed if these two concepts were complementary, one the opposite of the other, or conflicting among each other (Miller et al., 2010). The two concepts are connected, and we could say somehow complementary. Sure it is, they are neither conflicting nor one the opposite of the other. They are connected, yet very diverse and should not be treated in the same way.

[6] It is important here that the aforementioned "recovery of a community," does not include those activities put into action in the first emergency phase and in the subsequent reconstruction phase. Indeed, actions and programs put into action for the physical reconstruction after a natural disaster are widely differentiated by the type of natural hazard. Recovery policies instead focus on the socio-economic structure of a community.

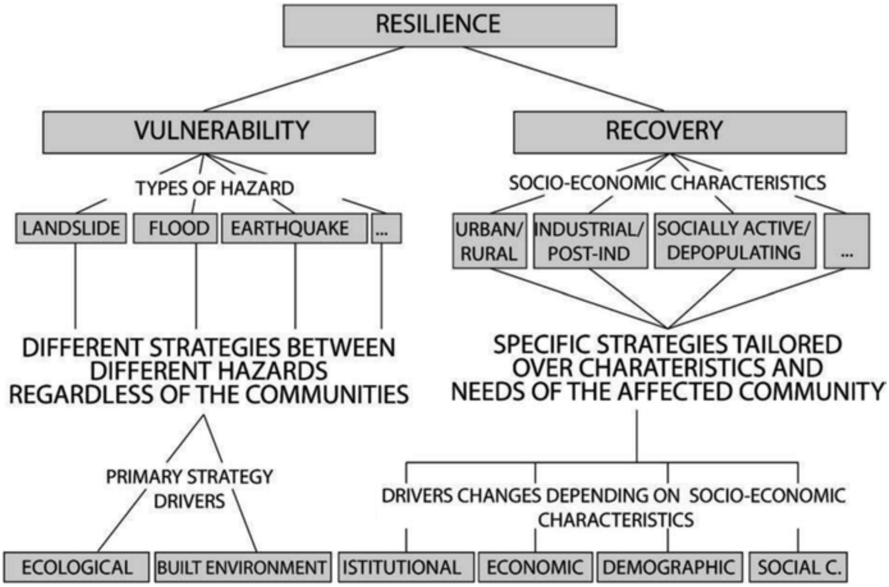

Fig. 3.1 The complexity of resilience concept: concepts and drivers

In delineating a framework for recovery and development paths, both resilience and vulnerability need to be addressed and integrated. Indeed, both are key elements to build communities able to cope, change, and adjust facing up the challenges posed by natural disaster and socio-economic processes.

Despite this interconnectedness, strategies and tools to build towards, one or the other are very different. In order not to confuse them, while addressing both of them, the two paragraphs below will discuss them separately.

4 Framework for Risk Evaluation

A framework for disaster risk assessment and disaster risk prevention is under evaluation in the last years. Disaster risk is a complex concept that encompasses several different aspects of the disasters risk management. It roughly means "*the possibility of adverse effects in the future*" (p. 69, Cardona et al., 2012) as the result of interaction between social and environmental processes that can be summarized by concepts such as physical hazards, exposure, vulnerability, and resilience (Cardona et al., 2012). In fact, it has long been recognized that the hazard event is only the trigger of the risk but it provides more or less effects according to the exposure, vulnerability amd resilience of societies and more general social-ecological systems (Cardona, 2011; UNDRO, 1980; UNISDR, 2011). Therefore, disaster risk can be seen as a function of:

$$R = f\left(H, E, V, \text{Res}\right)$$

It is possible to argue about the right function form of this expression; however, it is possible to recognize it as:

$$R = \frac{H * E * V}{\text{Res}}$$

Therefore, in any disaster risk evaluation of local areas or regions, what it is important in order to take a series of right actions that not only promote the risk mitigation or preparedness, but also the capacity of bounce back or even to improve the development of areas after an extreme event, knowledge on any of these concepts should be taken into deep consideration.

In order to provide an example of the information required for allowing an accurate risk assessment, we rely on three previous works of us that focus on Italy as a case study. Modica and Zoboli (2016) provided the clues on the understanding of the socio-ecological framework for natural disaster analysis. Clearly any socio-economic environment that is contingent to nature might be seen as integral to nature. Hazard per se belongs to the realm of the natural system that can be only indirectly affected by the socio-economic system—think about the effects of global warming on the frequency and magnitude of extreme natural events (LaFontaine et al., 2019; Stott, 2016; Ummenhofer & Meehl, 2017). Instead, exposure, vulnerability, resilience and therefore risk are in between the natural and the socio-economic realm. Exposure can be divided into natural resources or human resources and it is affected by the socio-economic system and by the institutional setting as well as vulnerability and resilience. Essentially, it takes into consideration all the objects that can be affected by a hazard and how it can produce more, or less, damages. What is trickier to understand in a risk analysis framework is the role played by vulnerability and resilience. To our understanding, vulnerability and resilience share common characteristics but they are not interchangeable. Vulnerability might be seen as the intrinsic capacity of a socio-economic context to "suffer" damage and it can be interpreted as the socio-economic characteristics of the areas under analysis that could drive the intensity with which the hazard impacts (e.g., the aging of physical infrastructure or the wealth of the regions). Resilience instead, from a wide perspective, is the capacity to recover and adapt after the extreme event. It is important to underline that in our view, increasing the socio-economic resilience of the regions does not prevent the possibility to suffer damage nor to reduce the impact the hazards (as could derive when reducing the vulnerability) but only to recover and to better and more quickly adapt to changes without any "external help." As an example, institutional capacity is definitively a resilient component because it increases the possibility of the affected areas to better coordinate the reconstruction process after a disaster (Naheed & Eslamian, 2021).

Therefore, vulnerability and resilience are moving in the opposite direction—e.g., an increase in vulnerability increases the risk, while an increase of resilience reduces the risk (and this is why we put resilience in the denominator of the equation above). However, in a risk evaluation framework, improving the resilience of the communities will take a long time and carefully planned and monitored public policies. However, analyzing the resilience at a given point of time might provide useful insights in order to assess the risk of the selected areas and underline which areas are—at least in relative terms—more risk-prone. This will return in a map of places that deserve further attention because the occurrence of an extreme event can cause the high unrecoverable damages (see also Marin, Modica, Paleari, & Zoboli, 2019).

Then, disaster risk, in a restrictive interpretation, is the combination of hazard (e.g., frequency and magnitude of natural events), the elements exposed that own a different degree of vulnerability and resilience, that somehow are more pronounced according to the unequal effects of public policies especially so when unplanned and disorganized reconstruction activities take place. Figure 3.2 provides a sort of summary for what said above. Risk is definitively a combination of natural and human environment and exposure, vulnerability and resilience—that are mainly the human characteristics of the places but in some cases also the natural resources—(e.g., think about natural amenities and their impact on the tourism) are aspects able to turn a hazard in a higher or lower damage. However, public policies are able to affect any of these three components (e.g., defining more restrictive building standards). Addressing singularly these concepts provides a unique source of

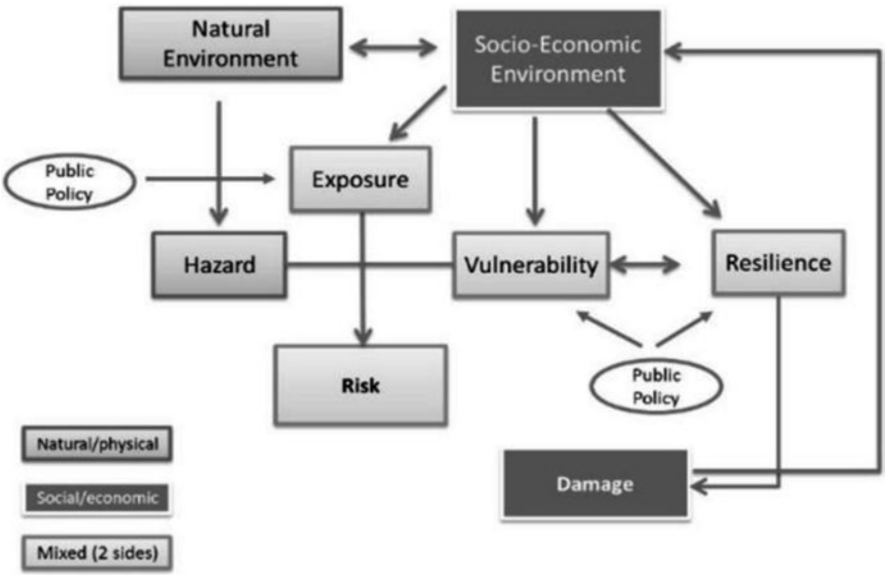

Fig. 3.2 Socio-ecological framework for extreme events, our interpretation of Modica and Zoboli (2016)

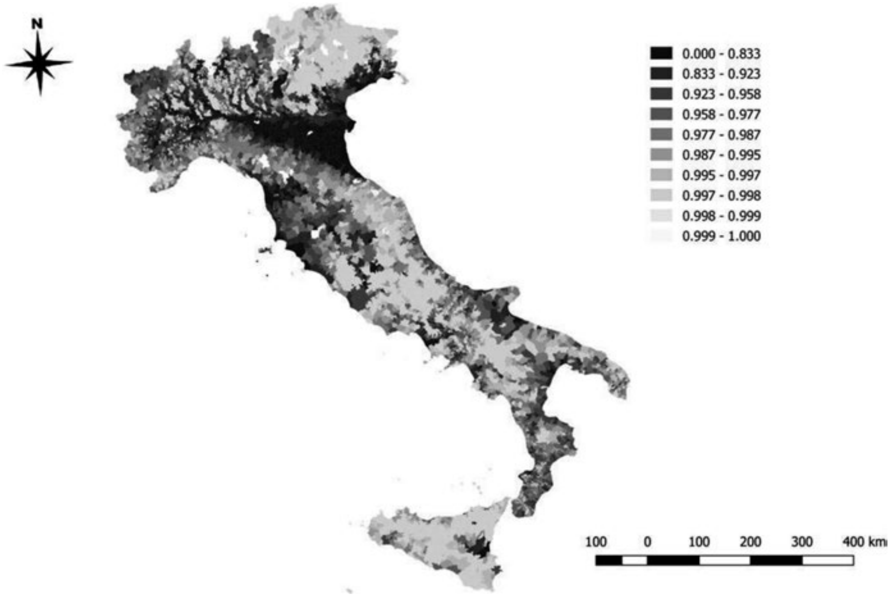

Fig. 3.3 Hydrological hazard at municipal level. Source: ISTAT

information. For natural hazards, public institutions generally provide risk maps. When looking at exposure several proxies can be used in order to include this relevant feature in the analysis. Marin and Modica (2017) provided several exposure indicators starting from the analysis of public data. Common proxies are local: population; employment; per capita income; number of buildings; housing values; agricultural variables; and so on. Finally, vulnerability and resilience can be seen as composite indicators that address several aspects of the socio-economic conditions of selected areas. Based on the work of Modica, Reggiani, and Nijkamp (2019), a systematic review of the indicators of vulnerability and resilience is provided. Marin et al. (2019) built the composite indicators of vulnerability and resilience using 17 variables for the vulnerability index and 13 for the resilience index. As an example, Figure 3.3 shows the hydrogeological risk for Italy aggregated in order to show the municipalities that are at risk of floods, according to the different degrees of probability of hazard occurrence. The data are scaled between 0 and 1.

5 Framework for Recovery and Development Paths

Communicative as it is, the concept of resilience does not indicate a condition or a status that a community needs to reach to be considered so. Resilience indicates the dynamic process of a community facing the consequences of an exogenous or endogenous shock. Therefore, it is not easy to indicate one single measure of resilience. In this paragraph, as in the framework we propose, we will argue that a single measure for resilience is not required.

Most of the attention that the concept of resilience gained in the last decades is due to the concept's linking ability between the academic field and the reality of actions and policies interventions. This communicative and connecting power of the concept is at the bedrock of our framework. Indeed, in our framework, the concept of resilience is tightly interwoven with both the context on which is applied and the shock which affected it. Different shocks can affect communities and regions in very different ways, requiring different strategies to evaluate and reduce risks.

Moving onward from the seminal contribution of Barca et al. (2012), it should be argued that not only development (and recovery) strategies should be differentiated by the characteristics of different places and different communities, but the heuristic measurement of resilience itself should be differentiated. Place-based strategies (Barca et al., 2012; Lucatelli, Carlucci, & Guerrizio, 2014) proved to be very effective by capturing the specificities of communities instead of focusing on general propositions and solutions. Similarly, the framework that we present, exploits the dynamic nature of the concept of resilience to put communities at the center and allowing for different heuristic measures of resilience.

Indeed, such place-based perspective not only requires the different recovery and development strategies for different places and communities, it also requires the resilience to be heuristically measured on the best-suited characteristics able to capture its dynamic variation for different communities and places.

Holding such a place-based, community-centered, perspective at its core, it is impossible to propose generalized indications and strategies on how to build such resilient communities, connecting recovery and development paths. Even considering, as is common in literature, a differentiation based on typologies (such as urban-rural, industrialized-service oriented, traditionalist-progressive, etc.), we would not be taking into account the specificities produced by their particular geography and history.

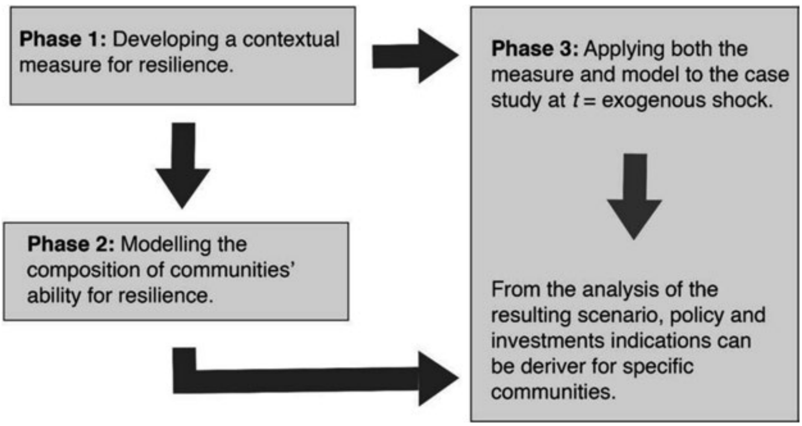

Fig. 3.4 Phases of resilience context-bound framework

Thus considered, the following *Context-Bound Framework for Resilience* is an attempt to deal with such complexity while proposing a generalizable and unified strategy to build resilient communities.

5.1 Context-Bound Framework for Resilience

Taking the field from this place-based perspective, a Context-Bound Framework for Resilience is proposed, connecting recovery and development paths. Considered that in this community-centered perspective, each community or region is potentially unique it is important to allow for generic solutions and policy indications. In this way, the proposed framework is not only a "framework for action" but also a "framework for research," which does not contain policies indications but is designed to extract them from the field.

The framework aims to be highly specific in its results and, at the same time, be completely generalizable in its research design. Performing such a task means to develop a research design rigorous enough to be generalized but also very flexible to be applicable in many different contexts. The framework assumes that resilience, as an evolutionary ability to deal and adapt after an exogenous shock, is composed differently according to different characteristics and historical and geographical processes involving the community. To account for this, the research design is divided into three phases as follows.

The first phase is developing a measure of resilience. This measure is different for different contexts and involves the relevant socio-economic processes affecting the communities. This dynamic measure for resilience is used as a thermometer, alone it does not tell how the resilience ability is composed, it only is a measure of the health of a community over time and it is used to indicate which communities are healthier and which aren't.

The second phase is the most delicate, it involves the modelling how this ability is composed. It is assumed that the ability for resilience can be composed very differently for different contexts, thus implying that we refuse any specific assumption about how this ability is composed. This choice for a context-bound framework imposes us to explore a wide range of factors and characteristics of communities (contrary to a top-down model where the composition of resilience is defined a-priori over a close set of characteristics). A specific model for the resilience ability is developed from this wide range of features for the interested communities. As we will show with an example, it is proposed to employ Machine Learning solution to the problem about how to develop a model for resilience. In phase one, a dynamic measure for resilience is developed; Machine Learning tools (due to their statistical computational ability) allow us to use the said measure, alongside a wide range of characteristics, to fit a model tailored on the interested context. In the best-case scenario—as in the example below—the model is trained (fitted) over the same or similar context (e.g., in the same area, affected by the same socio-economic processes) affected by the comparable shocks in the recent past. The selection of such context on which to fit the model is extremely important and might sometime represent a big challenge to overcome.

In phase three, the developed model is applied to the case study at the time of the exogenous shock, producing a scenario of how the affected communities will be resilient or not. The specific results in the scenario, coupled with the analysis of the model behind it, allow us to derive specific policy directions and indications to improve communities' chances to be resilient.

This simple and very flexible research strategy can be applied to very different cases since the specific results (phase three) depend from how the researcher defines and models the ability for resilience (phases one and two). While both the strategy and methodology applied stay the same, the decisions about how to measure and model resilience need to be tailored by the researcher on the context.

Fantechi and Modica (2020) provided an example of how such a context-bound framework is employed in real case studies.

Problem Definition The research is preoccupied with developing a model of community resilience[7] for the vastly rural area affected by the "Summer 2016 Central Italy" earthquake (Gruppo di Lavoro INGV, 2016). Alongside seismic activity the same area, like most rural areas of the inner part of the country, is also affected by decades-long processes of depopulation, aging and most of its communities fail to keep pace with the contemporary economic structure. How do you model the resilience ability of such communities? Literature on disaster resilience, mostly focused on urban and industrial contexts, mostly consider such areas only in comparison with other contexts (e.g., urban vs rural). As shown in a rigorous comparative study, applying a Resilience Index such as the DROP Model (Cutter, Ash, & Emrich, 2016) indicates that rural areas have a different composition of the ability for resilience. According to this study, the rural areas score the highest points in the social capital component of the index, while scoring the lowest in the economic and institutional components. Comparative studies like this clearly show that the resilience ability is differently composed in different areas, at the same time we would be wrong assuming that, to build better resilient communities, we should target the social capital component.

Phase One In the attempt to develop the specific indications on how to build better resilient communities, for the rural area of Central Italy, Fantechi and Modica (2020) explore the socio-economic processes involving the area. The major problem of this rural part of the area is the decade-old progressive process of depopulation involving the whole area (Lucatelli et al., 2014). As shown in Fantechi et al. (2020) using yearly population variation it is possible to model resilience dynamics across

[7] In the research provided as example of application of the presented *context-bound framework for resilience* communities are proxied at the smallest administrative level for which data are consistently available, the municipality. For a specific discussion on the availability of data and on the reliability of municipal administrative boundaries as good proxies for rural communities for the Italian context, please refer to Fantechi et al. (2020).

an exogenous shock. Specifically, they used the mean yearly population variation over five-year periods before and after the earthquake, classifying as "successfully resilient" those communities which in the 5 years after the extreme events achieve a higher mean rate of population variation compared to the 5 years before. All other communities were classified as "unsuccessfully resilient."

Phase Two Fantechi and Modica (2020) employed a Classification Machine Learning solution for the modelling of resilience ability. A classification solution means that they aim at training an algorithm to discriminate (classify) cases among two or more defined classes. Specifically, in this study, the algorithm is trained to classify among two classes "successfully resilient" and "unsuccessfully resilient"—employing the cases from the recent past for the training of the algorithm. Cases affected from three similar seismic events in the recent past (specifically communities affected by the 1997 Umbria and Marche earthquake, the 2009 L'Aquila earthquake, and the 2012 Emilia earthquake) were considered as candidates for the training of the algorithm. After a thorough evaluation of the three events, and more extensively the different contexts affected by such events, only communities affected by two of the three events (1997 Umbria and Marche earthquake and 2009 L'Aquila earthquake, for a total of 135 observations) were selected for the training of the algorithm. As mentioned above, the selection of such cases is extremely important for the reliability of results and should be performed to ensure the maximum comparability of contexts and socio-economic processes involving the communities.

Literature in community disaster resilience (Aldrich & Meyer, 2014; Birkmann, 2007; Cutter et al., 2008; Mayunga, 2007; Morrow, 2008) indicates that the ability for resilience is composed of a wide range of features describing different spheres of the community's life. Starting from this differentiated literature and purposely avoiding assuming resilience ability to be composed by one set or another for our context, authors gathered data for a wide set of over 40 features and the final model is a specific logistic classification model for rural communities of Central Italy of their resilience ability with an accuracy of 85%.

Phase Three Finally, the model is applied to the communities affected by the "Summer 2016 Central Italy" earthquake. The resulting scenario, coupled with the analysis of the model behind them, can be easily translated into practical policy directions for the communities affected by the earthquake. The scenario developed by Fantechi and Modica (2020) provides the indications about which communities already have the right set of characteristics to be able to successfully recover and which communities need the institutional interventions and investments to avoid falling behind even more. The analysis of such scenario, coupled with the analysis of the model on which is constructed, provides not only indications of which communities are more in need of institutional interventions, but also provide information to design specific and tailored policies for those community.

In conclusion, it can be said that the strength of such design is that the three steps procedure described above allows policy makers, practitioners, and researchers to assess the resilience ability of communities right at the moment of the exogenous shock and delineate a specific profile of the resilient communities. Furthermore, local policy and investments indications can be provided ex-ante, allowing policy makers to immediately outline strategies to improve the ability of community resilience of the territories under investigation, impacting both the reconstruction process and the development path.

The example discussed above (Fantechi & Modica, 2020) is a first attempt to put such context-bound framework for resilience into action employing real data, thus still partially suffering from the relatively small sample on which the algorithm is trained. However, the model presented above is based on sound literature and already able to make accurate predictions. This, coupled with the constant improving of data production and collection, suggests that the employed data-oriented strategy in the application of the proposed *Context-bound Framework for Resilience* is a reliable option, an option which can easily provide a specific ex-ante information to outline the local policies impacting both the reconstruction process and the development path of communities.

6 Summary and Conclusions

Natural phenomena with the intensity and characteristics to trigger a socio-natural disaster are more frequent than ever. These phenomena remain mostly unpredictable and unpreventable with today's technology. Dealing with such reality, as a society, means that we have to shape our social and built environment to reduce the chances of a natural phenomenon to turn into a socio-natural disaster. Even so, the occurrence of disasters triggered by natural phenomenon is not eliminable in the foreseeable future, meaning that we also have to equip communities—especially the most vulnerable ones—to cope with such events and exploit every opportunity to stir them into more comfortable development paths.

In this chapter, the *Context-Bound Framework for Resilience has been* proposed and presented which is composed of generalizable research and design strategy and aims at producing highly context-specific results. Through the lenses of community resilience, the chapter argued for the coordinated strategies and policies focusing on communities, the dynamic processes involving them, their needs and specific characteristics. Major characteristic of this framework is that it inherently interconnects the recovery process to the community's development path. Such interconnection is built upon the idea that exogenous shocks produce a window of opportunity—by suspending the everyday life of the affected communities—which can be exploited through tailored actions and investments.

Being a resilient community means to be adjustable and adaptive. Addressing the issue of building more resilient communities with the proposed framework means addressing socio-economic processes and issues involving the community, equipping them with the improved abilities to cope with the disaster but also to impact positively their development paths.

An important element of nuance is the proposed use of modern computation tools. Employing such tools not only allows to design standardized strategies for very different contexts, but it also allows various degrees of flexibility. Indeed, varying the level of analysis (e.g., from *neighborhoods, to municipalities, to regions*), the research design can be maintained while producing more generalizable results. Indeed, while both the research strategy and the aims remain the same, there is a trade-off between the specificity of the results and their generalizability out of the specific context.

The digital revolution of the last decade already impacted how we think and plan for the world. Every day, the computational capacity at our hands improves as well as the possibilities for data creation and data collection. Following these trends, the future improvement and iterations of this work will focus on exploiting these computational tools to provide more generalizable results while still maintaining a granular level of analysis.

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Chapter 4
Recovery, Development Programs, and Place-Based Reconstruction Policy: The Instrumental Role of Insurance

Lara Johannsdottir and James Wallace

Abstract When natural disasters occur, it is the system's ability to bounce back and recover afterward that defines their resilience. In preparing and responding to disasters of such a nature, different types of collaboration and collaborative systems are critical. For example, mitigation approaches require the coordination of multiple stakeholders with actions adjusted for the local circumstances and events. This chapter aims to explore the instrumental role of insurance in the place-based public-private partnership models. This includes the pre- and post-crisis policies, development, recovery, and risk transfer funding mechanisms. In doing so, the chapter goes beyond normal socio-economic resilience analysis by highlighting more operational aspects for policy-making. The paper draws on a wide range of examples from pre-, during-, and post-event approaches that have been developed to mitigate and/or cope with crises from natural disasters which highlight the role of insurance. The discussion ties into the underlying rationale that developing countries are the most exposed to natural disasters with the most to gain through mitigation and preparedness with insurance playing an important role in reducing the reliance on aid. However, it also ties to the concept of insurance protection gap, or underinsurance, in the case of high flood risk zones in the United Kingdom. The findings suggest that solutions needed to be place-based, taking into account local, national, and/or regional economic, social, and environmental conditions. The findings are of relevance for academia, policy-makers, and other stakeholders enabling further study with the potential to influence actions that can address the crisis management through collaborative coordination. Additionally, it reveals the insurance protection gap that needs to be addressed.

Keywords Collaboration · Crises management · Insurance · Natural disaster · Public-private partnership · Resilience · Recovery program

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1 Introduction

When natural disasters occur, the resilience is the determining factor of the ability of systems to bounce back and recover (Martinez-Diaz, 2018). More specifically, the Intergovernmental Panel on Climate Change (IPCC) defined the resilience as "the ability of a system and its component parts to anticipate, absorb, accommodate or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions (IPCC, 2012, p. 563)." In this case, systems can both be natural and manmade. This paper deals with the impacts on manmade systems, such as communities and societies, and their ability to "resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner." This includes the maintenance and rebuilding of basic and crucial functions and structures (UNDRR, 2020; UNISDR, 2015, p. 9).

Resilience is an umbrella concept that considers the different ways that systems respond to external shocks, major disturbances, and new conditions (Tiernan et al., 2019). Three main resilience themes since 2012 have been identified in a review of the disaster resilience literature. These are: "(1) socialization of responsibility for resilience; (2) ongoing interest in risk management with an emphasis on public-private partnerships as enabling mechanisms; and (3) a nuanced exploration of the concept of adaptive resilience" (Tiernan et al., 2019, p. 68). This review also highlights the different resilience domains. These being individuals, physical, community, hazards research, ecological system, social and city levels (Tiernan et al., 2019).

Three climate-resilience pathways for development have been identified by the IPCC, namely adaptation, mitigation, and sustainable development. These pathways include "strategies, choices, and actions that reduce the climate change and its impacts" (Denton et al., 2014, p. 1104). Furthermore, the climate-resilient pathways include the elements of awareness about climate change risk and capacity. These can include risk management and leadership for sustainable development. Essential resources include expertise in the field of science and technology, finance in addition to the practices based on most recent information. Monitoring impacts of climate change that are emerging, or the frameworks (policy, legal and regulatory) and programs/systems can help to assist those that are most vulnerable to the impacts of climate change (Denton et al., 2014). Building adaptation capacity to climate impacts of "individuals, communities, and governance systems include addressing the deficit-related development such as poverty, famine, and food insecurity whilst making essential risk management improvements. This includes the insurance and "insurance-linked social safety nets," disaster relief and alert systems (Denton et al., 2014; Martinez-Diaz, 2018, p. 71; Warner et al., 2012).

Various forms of public-private partnership (PPP) development models and programs are used to address recovery, strengthen resilience, and place-based reconstruction policy. PPPs can be seen "as a rubric for describing the cooperative ventures between the state and private businesses" (Linder, 1999, p. 35). Furthermore, PPP has to include the provision of public service or infrastructure as well as a risk transfer between partners. It should build "on the expertise of each partner that best meets clearly defined public needs through the appropriate allocation of resources, risks, and rewards" (The Canadian Council for Public Private Partnerships, 2004). It furthermore may relate to management reform, problem conversion, moral regeneration, risk shifting, restructuring public service, and power-sharing (Linder, 1999). A study has, however, shown "that practice tends to be less ideal than the idea," in terms of accomplishing the joint added value and less risk by reasons of institutional characteristics such as behavior rules, perception, and role attitude (Klijn & Teisman, 2002, p. 1). Risk factors identified for the PPP projects include political, constructional, operational, legal, market, economic, and other types of risks, each with a subset of risk factors. Some of these risk factors are shared solely or mostly by the public sector with some allocated to the private sector or equally between both parties. Risk factors shared by the government include a change in legislation, land acquisition, approval, and permits. In the case of the private sector, the risk factors consist of the financial and technology risks, the inability of the consortium, organizational and coordination risk, and a delay in supply. Shared risk comprises for instance of force majeure, payment risk, inflation and interest rates, and weather conditions (Ke, Wang, Chan, & Lam, 2010). Many of the PPP projects have been carried out in the construction industry (LiYaningTang, Shen, & Cheng, 2011), but also in case of catastrophe risk and resilience, such as in relations to the 9/2011 terrorist attacks, Hurricane Katrina, and the US-Canada power-distribution system failure, and the 2004 Indian Ocean earthquake and tsunami. However, in case of economic losses, people are often left without insurance since private and public insurance only cover the parts of the loss (Michel-Kerjan, 2008). Given the scale of risks, the new risk features have been proposed: growing interdependences due to globalization, change in risk scales from local to the global, confusing distribution of the role and responsibilities with regard to preparedness, a rapid movement towards a just-in-time society, and uncertainty or even ignorance (Michel-Kerjan, 2008). The fourth P, people or the end-user, has also been added to the PPP relationship, mainly local communists and non-governmental organizations (NGOs) in case of post-disaster reconstruction situations (Kumaraswamy, Zou, & Zhang, 2015).

The insurance industry plays a critical role in terms of understanding and reducing risks, but also as a risk transferring mechanism on "individual, national, and international levels (Jóhannsdóttir, 2012; Jóhannsdóttir, Wallace, & Jones, 2012; Naheed & Eslamian, 2021, UNEP Finance Initiative, 2015, p. 5)." Through risk transferring mechanism, the insurance industry protects against shocks that "would otherwise be borne by households, businesses and governments (Jóhannsdóttir, 2012; UNEP Finance Initiative, 2015, p. 5)." As a part of integrated disaster risk management, both "physical risk reduction measures and financial risk transfer instruments (Jóhannsdóttir et al., 2012; UNEP Finance Initiative, 2015, p. 5)" play a role. With regard to disaster risk management five categories are critical: (1) understand and assess disaster risk, (2) prevent and reduce disaster risk, (3) disaster response and relief, (4) disaster recovery, and (5) disaster risk financing, and four partnership models articulated (UNEP Finance Initiative, 2015): (1) resource mobilization, (2) implementation, (3) innovation, and (4) engagement and advocacy.

The concept of underinsurance, or the insurance protection gap, is an underlying issue when discussing the collaborative PPP systems for crises management. In this case insurance can, or should, provide "vital support to societies and businesses through the financial compensation for the effects of misfortune disasters or pandemics, for instance, in many emerging and developing economies (Geneva Association, n.d.)." The insurance protection gap is defined as "the difference between the amount of insurance coverage that is economically beneficial and what is purchased for disasters, and pandemics, for instance in many emerging and developing economies (Geneva Association, n.d.)." The insurance protection gap is seen as a pressing societal issue, as it has an impact on the resilience of societies since insurance is not playing its role in mitigating impacts (Geneva Association, n.d.). Although the global trend for the protection gap associated with natural catastrophes has been narrowing since 1989, it is still enormous given that "only about 30% of catastrophe losses [are] insured," and that the narrowing of the gap is mainly taking place in "high- and upper middle-income countries" where the gap is more than 95% in "lower middle- and lower-income countries" (Schanz, 2018, p. 1). This, therefore, highlights the importance of micro solutions, such as micro-insurance (Microinsurance Network, 2018b), discussed in Sect. 3.4.

This chapter aims to explore the instrumental role of insurance in the place-based public-private partnership models for pre- and post-crisis policies, development, and recovery, including discussing risk transfer and funding mechanisms for crisis management, and resilience. Owing to the complexity of the resilience domains, and local place-based conditions and circumstances in case of natural hazards there is a need for the various types of collaborative systems for crisis management, customized to the different circumstances in different locations around the globe. Therefore, one size fits all in suggesting appropriate solutions is therefore not feasible, but rather to point out a portfolio of potential solutions (UNEP Finance Initiative, 2014). To address this issue, the diverse cases of solutions are presented, structured around two focal points: (a) projects and/or collaborations for crisis management with strong elements of public-private partnerships, and (b) risk transfer and funding mechanisms for crisis management and resilience.

2 Public-Partnership Projects and/or Collaborations for Crises Management

Collaborative systems for crisis management take various forms depending upon location and the stakeholders involved. In each case discussed in this section, there are the strong elements of public-private partnerships where the insurance industry provides support to mitigate the impacts of natural catastrophes and other negative issues. The cases discussed in this section are the Sendai framework for disaster risk reduction, the global resilience project of the principles for sustainable insurance, the AON's global rapid response, the city innovation platform (CIP), the Australian business roundtable for disaster resilience and safer communities, and the flood re insurance partnership model.

2.1 The Sendai Framework for Disaster Risk Reduction

The Sendai Framework for Disaster Risk Reduction (Sendai Framework for short) is the first main agreement focusing on disaster risk reduction in the period of 2015–2030. It was approved by the United Nations (UN) General Assembly after the 2015 third UN World Conference on Disaster Risk Reduction (WCDRR) (UNISDR, n.d.). This is a non-binding voluntary agreement, supported by the UN Office for Disaster Risk reduction, and endorsed by the UN General Assembly (UNISDR, 2015, n.d.). It recognizes the role of States in reducing disaster risks, but also that other stakeholders, such as local governments and the private sector, should share the responsibility (UNISDR, n.d.). The Sendai Framework aims for a specific outcome:

> The substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries (UNISDR, n.d.).

The scope and purpose of the Sendai Framework, its goals, and guiding principles, have been defined, in addition to seven specific targets and four priority areas (UNISDR, n.d.). The Sendai Framework helps to contextualize the role of insurers in improving preparedness and response in the event of a natural disaster. This is first and foremost stated in Priority 3, *Investing in disaster risk reduction for resilience* (Pearson & Pelling, 2015), but to achieve Priority 3 it is considered to be important to "promote mechanisms for disaster risk transfer and insurance, risk-sharing and retention and financial protection, as appropriate, for both public and private investment to reduce the financial impact of disasters on Governments and societies, in urban and rural areas (UNISDR, 2015, p. 19)." Implementation of the Sendai Framework is measured, highlighting the worldwide results of achieved targets related to mortality, people affected, economic loss, critical infrastructure and services, disaster risk reduction strategies, international cooperation, and early warning and risk information (UNDRR, 2019).

The Sendai Framework agreement was unique as for the first time there was a widespread insurance industry support to signal the willingness and capacity to support governments in disaster resilience and acceptance from inter-governmental organizations where the insurance industry can play a supportive and valuable role. The economic argument was also brought to the light suggesting that it is more cost-effective to spend on disaster risk reduction, rather than response and recovery, although insurance can support both aspects. To shift countries over-reliance on aid which is subject to donor generosity is regarded particularly appealing (UNISDR, 2015). The essential role of insurance in this regard is to offer business interruption insurance, transfer residual risk to the private sector, take part in public-private risk assessment, offer information on disaster loss data, and more. Additionally, new opportunities are claimed to exist for insurers, namely in strengthening the resilience of the private sector (Haraguchi, Lall, & Watanab, 2016).

2.2 The Global Resilience Project of the Principles for Sustainable Insurance

The Global Resilience Project (GRP) of the Principles for Sustainable Insurance (PSI), under the auspices of the United Nations Environment Programme Finance Initiative (UNEPFI), offers examples of collaboration, partnership, and tools with regard to disaster-resilience economies and communities (UNEP Finance Initiative, 2015). The project is led by Insurance Australia Group Limited (IAG), and has three phases: (1) to report on how to build disaster-resilience communities and economies, (2) to provide a global risk map comprising of historical coverage (115 years) of all main natural disasters, and (3) to offer tools for engaging with global stakeholders to gain support for disaster risk reduction investment (UNEP Finance Initiative, 2015). The vision of the PSI initiative is stated in the following way:

> … risk aware world, where the insurance industry is trusted and plays its full role in enabling a healthy, safe, resilient and sustainable society. Its purpose is to better understand, prevent and reduce environmental, social and governance risks, and better manage opportunities to provide quality and reliable risk protection (UNEP Finance Initiative, 2015, p. 4).

The PSI offers a roadmap towards developing the pioneering insurance and risk management solutions that will improve disaster resilience in communities. There are four guiding principles where (1) environmental, social and governance (ESG) issues are integrated into the insurance business decision-making; (2) where insurers work with relevant stakeholders, i.e., clients and business partners, to enhance the awareness of ESG issues and risk management, besides developing solutions; (3) where insurers work with other key stakeholders, i.e., governments and regulators to advocate extensive actions on the ESG issues; and (4) where insurers emphasize accountability and transparency by reporting regularly on the progress towards PSI implementation (UNEP Finance Initiative, 2015).

The PSI global resilience project draws on a range of international insurance industry stakeholders in developing the global resilience map and overview of the issues (UNEP Finance Initiative, 2014). The first phase of the project resulted in a report titled:

Building disaster-resilient communities and economies (United Nations Environment Programme, 2014). Across three types of natural disasters, cyclones, earthquakes, and flooding, three measures of risk reduction are of significance (UNEP Finance Initiative, 2014):

- Developing more risk-aware communities through education and communication.
- Understanding hazard exposure through risk mapping.
- Robust warning systems and emergency evacuation.

Obstructing effective disaster risk reduction falls mainly into two categories: (1) inadequate data and assessment tools and (2) the absence of standardized decision-making frameworks (UNEP Finance Initiative, 2014). What is increasingly clear in case studies carried in relation to the project is that collaboration for the specific risks often takes place at a local level where people are exposed to the same risk. For example, a dialogue on fires with policy-makers was established in Australia to understand the increasing risk, convene the exposed stakeholders, and agree on a collaborative way forward to mitigate the impact on society (UNEP Finance Initiative, 2014).

2.3 AON's Global Rapid Response

AON is an example of how a global service provider, operating with 1800 risk experts in 50 countries around the globe, can offer pre- and post-loss services to mitigate risk and prepare for natural disasters, such as in case of flooding. The purpose of the AON's Global Rapid Response is to help companies carry out mitigation efforts by sending experts to locations that are impacted so that guidance on loss mitigation can be clear and concise. Different expertise is available around the globe, such as consultants in loss mitigation, remediation, construction, and risk engineering, security, and forensic (Aon Property Risk Consulting, 2020).

The AON's Global Rapid Response includes a thorough checklist for the organization to assess and apply the strategies for hurricane and flood preparedness. The purpose of the checklist is to help businesses recover in case of flooding events. This may then protect both people and business properties (Aon Property Risk Consulting, 2018). Flood preparedness categories include preparedness before, during, and, after the flood, for employees, suppliers, and business clients. Before flood events, it is, for instance, important to formulate an evacuation plan, ensure that toxic chemicals are not released in case of flood events, discuss insurance flood-related policy coverage, create communications plans to stakeholders to name only some of the critical elements (Aon Property Risk Consulting, 2018).

During a flood event saving lives is the most important aspect. This is followed by the operationalization of the business continuity plan. Employees that are not essential during the event are sent home or advised not to come based on the crisis communications plan. Other critical stages include the protecting equipment, following media coverage, ensuring that the business can service or respond to customers, and if necessary evacuate the business if it is required (Aon Property Risk Consulting, 2018).

After the flood, it is important to learn if the water is safe to drink or if it is contaminated. Roads and other infrastructure may have been weakened causing risk related to driving. Other cautions include cleaning and disinfecting everything that became wet or covered in mud, due to potential contamination of sewage or toxic chemicals. The recovery plan of the business is also implemented, and communication of local authorities monitored. Relevant stakeholders, for instance, employees, and insurance agents are contacted (Aon Property Risk Consulting, 2018). Contact information of employees, suppliers, and clients should be available. In case of evacuation central point for all employees needs to be identified, so that location of employees can be determined. Based on damage following the flood key employees need to be notified about the next step in the continuity of the business (Aon Property Risk Consulting, 2018).

Similar lists are available for other types of events, such as hurricanes. This guidance from the risk manager to the client is vital to support when disaster strikes, but collaboration plays a critical role throughout. The insurance company guidance is based on information from the government or local authority on emergency response procedures and available support. In many countries, insurers will be actively involved in disaster drill scenarios as they will often be on-site to support the impacted customers following an event to look after them. Knowledge is obtained from the event based on exposure in terms of severity and geography, this, in turn, impacts the pricing of future premiums and can help to signal to governments where action or spending is needed to protect the exposed customers to ensure insurance remains affordable (Aon Property Risk Consulting, 2018).

2.4 The City Innovation Platform

The City Innovation Platform (CIP) is a multi-stakeholder collaboration on resilience (University of Cambridge Institute for Sustainability Leadership (CISL), 2017). It explores the public-private collaboration between stakeholders such as city officials, the finance sector, including asset managers and representatives from the insurance sector, and other relevant stakeholders from the private sector (University of Cambridge, 2019). This platform has issued a guide on multi-sector collaboration focusing on resilience. Partners to this platform include the University of Cambridge, ClimateWise,[1] in addition to other partners (University of Cambridge Institute for Sustainability Leadership (CISL), 2017).

The focus of CIP is on cities in emerging economies, but the guide is based on a pilot project and a workshop taking place in Dar es Salaam, Tanzania in 2016. The project was stimulated by a widening gap between climate risk protection, evident in the gap between economic and insured losses. This gap is of concern both for

[1] ClimateWise is organized by the CISL. It supports the insurance industry to disclose, respond to, and communicate about opportunities and risks related to the climate risk protection gap.

societies that are faced with economic and physical risks associated with climate change and for the insurance sector which may lose market share and status as important risk managers in the society (University of Cambridge Institute for Sustainability Leadership (CISL), 2017). A (University of Cambridge, 2019) successful CIP platform includes 16 key elements. These are time-related boundaries (start-to-finish), representation of relevant stakeholders, local customs and protocols, the political context, individual and industry expertise and constraints, seniority of partners, the leadership of the project, alignment of objectives, rules of engagement, relevant tools and resources, and having an executive from the insurance industry as one of the lead coordinators. Besides, success factors include experimentation and uncertainty, communication, independent facilitation, contextual information about the city and knowledge capacity in question, and workshop preparation, and relevant materials (University of Cambridge Institute for Sustainability Leadership (CISL), 2017).

The role of insurance is enhancing cities inadequate financial, human, such as in relations to access to the data related to infrastructure projects, since insurers may be in a position to organize academic research, given that insurers would finance the data collection of the city, for instance, number of houses damaged by flooding. Such data collection would have mutual benefits for cities and insurers in terms of decision-making (City Innovation Platform, 2016). This very much aligns with the recognized role of insurers in bridging the gap between the climate change science and heterogeneous actors, whereas gaps identified are between scientific knowledge, policy-making, and public awareness, between North and the South, the rich and the poor, and between the global and local knowledge (Johannsdottir & Wallace, 2018).

2.5 *The Australian Business Roundtable for Disaster Resilience and Safer Communities*

Engagement with policy-makers is critical so as to involve and activate all participants. Insurance Australia Group Ltd. (IAG) is a multinational insurance company headquartered in Sydney, Australia. It is a founding member of the Australian Business Roundtable for Disaster Resilience and Safer Communities, established in 2012, where the focus is on harmonizing national approach that may ensure the resilient communities in case of natural disasters and the safety of the Australian population (IAG, n.d.). It was founded after exceptionally many bushfires, floods, and storms. Members of the Roundtable include, in addition to IAG, the Australian Red Cross, Investa Property Group[2], Munich Reinsurance Company (Munich Re),

[2] Commercial real estate company.

Optus[3] and Westpac Group[4] (IAG, n.d.; The Australian Business Roundtable, 2019). In collaboration with governments and other stakeholders, the members of the Roundtable effetely initiate the research that can inform public policy, increase resilient communities' types of investments, and improve the ability of businesses and communities to tolerate natural disasters (IAG, n.d.).

The purpose of the research carried out on behalf of the Roundtable is to provide policy-makers with evidence that can feed into policy development. Examples of these types of research include a White Paper released in 2012, titled *Building our Nation's Resilience to Natural Disasters.* The report highlights the great emotional and financial burden of natural disasters in Australia, and that costs associated with extreme weather events are on the rise. It furthermore investigates the financial side of mitigating the disaster risks challenging local communities (Deloitte Access Economics, 2013). The following report, Building an Open Platform for Natural-disaster Resilience, released in 2014 (Deloitte Access Economics, 2013). The report highlights the importance of research and data (foundational, hazard, and impact data) input for decision-making of end-users that includes the Commonwealth, state, and local governments, businesses, community groups, as well as individuals (Deloitte Access Economics, 2013).

In 2016, a report titled *Building resilient infrastructure* was published. The focus of the report was on critical infrastructure that is costly and difficult to repair or replace, thus intensifying the impact of communities affected by natural disasters (Deloitte Access Economics, 2016a). The same year another report was published, or *The economic cost of the social impact of natural disasters* (Deloitte Access Economics, 2016b). The analysis carried out demonstrated three types of costs associated with natural disasters: deaths and injuries, tangibles (e.g., infrastructure, private properties, and business and network disruptions), and intangibles (i.e., meaning costs that cannot easily be monetized), for instance, health and well-being and connectedness of communities (Deloitte Access Economics, 2016b). What is of importance is that the intangible costs identified in the report are no less than the tangible costs, and they may carry on over peoples' lifetime having a severe effect on communities. Therefore, studies on how to quantify such medium- and long-term cost of social effects need to be carried out (Deloitte Access Economics, 2016b). The success of the roundtable has led to an establishment of a similar body in New Zealand, supported by IAG (n.d.).

[3] Telecommunications company.

[4] Financial services company.

2.6 Flood Re Insurance Partnership Model

Public-private partnerships can be used as a method to incentivize the flood risk reduction and to provide affordable insurance coverage. A study has been carried out to analyze the flood insurance mechanism in the United Kingdom (UK). It highlights that the national government and the insurance industry are not fully in a position to cope with flood risks, meaning that other actors have to engage so that risk reduction can be incentivized (Crick, Jenkins, & Surminski, 2018). In this case, a new insurance partnership model, Flood Re, was established based on a previous partnership between the Association of British Insurers (ABI) and the UK government (Crick et al., 2018), and the Water Act 2014 (Flood Re, 2018). It is authorized by the Prudential Regulation Authority and regulated by the Prudential Regulation Authority and Financial Conduct Authority (FRN 706046), and started formally to operate in 2016 (Flood Re, 2018).

The main actors of the Flood Re scheme include the customers that buy home insurance, the insurance industry that evaluates both high- and low-risk homes, and decides what policies are transferred to Flood Re which then transfers risks to the re-insurance industry. Additionally, the insurance industry also encourages the government investments in flood defense, but the links between the government and Flood Re include sharing of risk data, and oversight by the government which reviews the process every 5 years (Crick et al., 2018). An overview of key actors identified in this agent-based model (ABM) includes house owners, building contractors, insurers, and the local government. Other actors are recognized, such as architects, house developers, loan providers, planning officers, the Environment Agency, and water companies, although they were excluded from the analysis (Crick et al., 2018).

This structure was aimed at addressing the insurance protection gap as around half a million households, that did not have access to affordable flood insurance given the location of properties in high flood risk areas and were able to obtain coverage (GOV.UK, 2016). The extra cost of the high-risk properties is transferred onto Flood Re, but this is then funded by a charge on the insurance industry, but not passed onto other customers. Owners of properties in high-risk areas will receive an affordable fixed-price premium. The price is based on different premium thresholds that are related to certain council tax bands of properties (Flood Re, 2018; GOV.UK, 2016). For instance, in 2018 the Council Tax band on building policy ranged between £134 and £812, and between £70 and £406 for content policy. Insurers, furthermore, pay an annual levy which funds Flood Re (Flood Re, 2018). Furthermore, the Flood Re structure will last until 2039, as it is expected that a vast majority of household in the UK will already have access to affordable flood insurance by that time, and other measures have been undertaken, including house development taking flood risk into account, and investments made in flood risk management and defense (Flood Re, 2018). In this collaboration, there is a recognition that building has occurred in the wrong location with some exposed properties no longer being affordable to insure. The long-term perspective until 2039 allows greater flexibility and to ensure the building regulations better accommodate future housing development or renovation with flood resilience in mind (Flood Re, 2018). It will be interesting to see if the political will enable the completion of these aspirations.

3 Risk Transfer and Funding Mechanisms

In this section, several case studies on risk transfer and funding mechanisms for crisis management and resilience are introduced. These are the ARC platform, the Caribbean Catastrophe Risk Insurance Facility, Africa Disaster Risk Financing Initiative, and Micro-Insurance Solutions.

3.1 The ARC Platform

The African Union's (AU) ARC is a platform that enables resilience-building and risk management, offering the member states of the African Union with capacity, infrastructure, and tools, that are needed to climate change adaptation and management of natural-disaster risks. The main solutions include (1) early warning, (2) contingency plan, (3) climate risk insurance, and (4) climate adaptation finance (UNEP Finance Initiative, 2015). Furthermore, ARC established a mutual insurance company, ARC Insurance Company Limited (ARC Ltd), in 2013 issuing to governments the parametric weather insurance policies. It uses an Africa RiskView (ARV) platform to assess weather event impacts on exposed inhabitants and the costs of dealing with weather-related impacts before hazard seasons.

Index-based pay-outs occur immediately following weather disasters, i.e., cyclones, droughts, or severe floods (UNEP Finance Initiative, 2015). This is achievable as members of the ARC platform can take advantage of diversification of weather risk throughout the whole continent in a single insurance pool, thus enabling ARC to gain insurance coverage from the private sector international insurance markets and to reduce insurance premiums and the transaction cost (UNEP Finance Initiative, 2015). Paying out immediately after an event-threshold defined by the index occurs, not only helps in the case of climate resilience and in supporting the UN Sustainable Development Goal 2 (SDG2) of zero hunger and food security (Dubreuil & Tabegna, 2018). A systemic literature review reveals that those that benefit most from climate risk insurances in case of extreme weather events are farmers who need to protect both their farms against crop failures and their livelihoods (Awojobi, 2018).

3.2 Caribbean Catastrophe Risk Insurance Facility

Caribbean Catastrophe Risk Insurance Facility (CCRIF) is an example of a regional risk pool and insurance solution. It has developed parametric policies to limit the financial impact of natural disasters, i.e., earthquakes, excess rainfall, and tropical cyclones and hurricanes, on national governments in the Caribbean and Central America (UNEP Finance Initiative, 2015). The World Bank offered technical leadership, the Japanese government contributed with a grant, in addition to multiple donations from other sources such as the European Union, Bermuda, France, Ireland, United Kingdom, and others. The purpose of CCRIF is to reduce socio-economic and environmental impacts of natural disasters, by offering a range of reasonably priced insurance solutions, tools, and services, and by engaging in beneficial partnerships. Payments are made within 1–2 weeks of the event, thus ensuring a short-term cash flow in the wake of a major natural disaster (UNEP Finance Initiative, 2015).

3.3 Africa Disaster Risk Financing Initiative

Disaster Risk Finance (DRF) in Kenya is an example of coordination between various development actors, engaging through the Africa Disaster Risk Financing Initiative (ADRF), funded by the European Union, and the Disaster Risk Finance Analytics (GIZ, n.d.), which is a part of the Disaster Risk Finance and Insurance Program (DRFIP), supported by the World Bank Group (WBP) (Mahul & Cooney, n.d.). The purpose is to bridge "the gap between disaster risk data and risk-informed decision-making," by focusing on macro-economic, fiscal, and loss data, offer economic and fiscal analysis, and analysis on financial capacity building tools and impact analysis, thus offering information for capacity building, decision-making, and monitoring and evaluation (Mahul & Cooney, n.d.). Through this collaboration, the DRF supported the implementation of a "Disaster Risk Finance and Insurance strategy in the Philippines in 2015," that enabled the World Bank to offer a contingent line of credit (CAT DDO), that provides the country with a US$500 million CAT DDO in case of a disaster, as well as the development of a sub-national insurance scheme in the Philippines (Mahul & Cooney, n.d.). Another, DRF example is the development of a livestock insurance scheme in Kenya for farmers. It offers, for instance, coverage for around 14,000 farmers, compensating for droughts (Mahul & Cooney, n.d.), thus having an impact on headers, their families, and local communities. The Kenya Livestock Insurance Program (KLIP) was in 2015, as the first insurance scheme in Africa offered by the government, and supported by Dr. Andrew Mude, from the International Livestock Research Institute (ILRI), Swiss Re, and the World Bank (Swiss Re, 2019).

3.4 Micro-insurance Solutions

Micro-insurance solutions are also of critical importance when dealing with natural disasters. The International Association of Insurance Supervisors (IAIS) defines a micro-insurance as an "insurance that is accessed by low-income populations, provided by a variety of different entities, but run in accordance with generally accepted insurance practices" (International Association of Insurance Supervisors, 2012, p. 11). The protection is against certain perils, and the premium paid regularly as a proportion to the probability and the estimated cost of the risk (Microinsurance Network, 2018a). There are many types of micro-insurance solutions available, such as life and health insurance, property insurance, agricultural insurance, bundle, composite products and reinsurance (Microinsurance Network, 2015, 2018c). In case of micro-insurance customers, they fall under a category of high-risk exposure/high-vulnerability and weak insurance infrastructure, the insurance solutions are sold to insurance clients, with limited insurance experience, by non-traditional intermediaries such as NGOs, retailers, churches utilities, or cell phone providers, and insurance terms and conditions are put forth in simple language, with few, or no exclusions (Lloyd's, and Micro Insurance Centre, n.d.). Other characteristics include, in case of premium calculation, limited historical data, group pricing, price-sensitive market, and higher premiums to cover ratios. Premium payments from clients are irregular and frequent, given the volatility of clients' cash flow. Payments are, furthermore, often tied to other deals, such as repayments of loans. The claims process is simple, and small amounts are paid out quickly. Additionally, there is an efficient fraud control process (Lloyd's, and Micro Insurance Centre, n.d.).

Microinsurance Catastrophe Risk Organisation (MiCRO) is a project operated in the alliance between the "Swiss Agency for Development and Cooperation (SDC), the Multilateral Investment Fund (FOMIN) managed by the Inter-American Development Bank (IADB), Swiss Re and Mercy Corps" (Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, 2018). It was established following the Haiti earthquake in 2010, and the first product offered in Central America was a bundled index-based solution, including protection against earthquakes, excess rainfall, and droughts. The solution was introduced to the Guatemalan market in 2016, and the El Salvador market in 2018 (Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, 2018).

An example of an "insurance-linked social safety net" is parametric insurance mechanisms, but such mechanisms allow for quick transfer of money (within days) in an aftermath of a disaster when pre-defined conditions have materialized (Martinez-Diaz, 2018, p. 71). These include a certain "amount of rainfall in a given region, or the height of storm surge in a given location (Martinez-Diaz, 2018, p. 70)." These risk transfer tools are not solely for post-disaster recovery or response but are the common basis for micro-insurance schemes in developing markets for farmers with adverse weather conditions impacting crops (Allianze, 2018).

4 Summary and Conclusions

The chapter aimed to explore the instrumental role of insurance in place-based public-private partnership models for the pre- and post-crisis policies, development, and recovery, including discussing risk transfer and funding mechanisms for crisis management, and resilience. In preparing and responding to disasters of such nature, and strengthening resilience (e.g., IPCC, 2012; Martinez-Diaz, 2018; Tiernan et al., 2019) different types of collaboration and collaborative systems are critical. In many cases, collaborative systems are established around public-private partnership models or projects (Linder, 1999), in some cases build around the allocation of resources and rewards (The Canadian Council for Public Private Partnerships, 2004) or interest in risk management (Tiernan et al., 2019), such as in case of models of interests to insurers where the aim might be to reduce climate change impacts (Denton et al., 2014). The aim of such systems can be to assist those most vulnerable to the impacts, by building capacities in different resilience domains, for instance at individual, community, or governance levels (Denton et al., 2014; Tiernan et al., 2019). With regard to disaster risk management insurance expertise is in many categories relevant, including understanding and assessing disaster risk, preventing and reducing disaster risk, offering disaster response and relief, disaster recovery, and disaster risk financing (UNEP Finance Initiative, 2015) all of which are of relevance for strengthening the ability of manmade systems to bounce back and recover (Martinez-Diaz, 2018) after disaster events.

A successful response or mitigation approach to natural disasters requires the coordination of multiple stakeholders adjusted for the local circumstances and types of events. Examples can be drawn from pre-, during-, and post-event approaches, but the paper focused both on public-partnership projects and collaborations for crisis management and risk transfer and funding mechanisms for crisis management and resilience. In the former case, the following frameworks were introduced: The Sendai Framework was introduced (Pearson & Pelling, 2015; UNDRR, 2019; UNISDR, 2015, n.d.), the Global resilience Project (UNEP Finance Initiative, 2015), the AON's Global Rapid Response (Aon Property Risk Consulting, 2020), the City Innovation Platform (University of Cambridge Institute for Sustainability Leadership (CISL), 2017), the Australian Business Roundtable for Disaster Resilience and Safer Communities (IAG, n.d.; Deloitte Access Economics, 2013), and the Flood Re insurance partnership model (Crick et al., 2018; Flood Re, 2018; GOV.UK, 2016). In the latter case, the following solutions were presented: the ARC platform and the Caribbean Catastrophe Risk Insurance Facility (UNEP Finance Initiative, 2015), the Africa Disaster Risk Finance Initiative (GIZ, n.d.; Mahul & Cooney, n.d.; Swiss Re, 2019), and micro-insurance solutions (e.g., Lloyd's, and Micro Insurance Centre, n.d.; International Association of Insurance Supervisors, 2012; Microinsurance Network, 2018a, 2018b, 2018c).

A key lesson through all the examples presented in this chapter is that many issues including climate change are becoming too big for a single stakeholder to manage on their own. Effective collaboration of stakeholders with direct stakes in the risk (Jóhannsdóttir, 2012; Jóhannsdóttir et al., 2012; UNEP Finance Initiative, 2015) is an effective way to protect more people and help reduce the disruptions to our economies and societies. Insurers can help play a vital role in assessing the risk, pricing the impacts, and providing critical parts of the solution to protect the general public from weather and catastrophe related crises (e.g., Flood Re, 2018; GOV.UK, 2016; UNEP Finance Initiative, 2015). The discussion in the chapter also ties into the underlying rationale that developing countries are the most exposed to natural disasters and have the most to gain through mitigation measures and of which insurance plays a role, rather than being reliant on aid (UNISDR, 2015). However, it also ties to the issue of underinsurance such as in case of high flood risk and most exposed people in the United Kingdom (Crick et al., 2018; Flood Re, 2018; GOV.UK, 2016), and natural disasters and safety of Australian people (IAG, n.d.).

What the discussion also brings forth is the concern that in case of economic losses people are often left without private or public insurance, as they only—if available—cover parts of the loss (Michel-Kerjan, 2008) drawing the attention to the insurance protection gap which harms resilience (Geneva Association, n.d.; Schanz, 2018). Therefore, the fourth P (people, communities, and NGOs) is of importance in the PPP relationship models and should be included in the discussion as well (Kumaraswamy et al., 2015). It also reveals that owing to the complexity related to the natural disasters and local conditions one-size-fits-all solution does not exist. There is a need for the various types of collaborative systems, a portfolio of solutions (UNEP Finance Initiative, 2014), for crisis management, customized to different circumstances in different locations around the globe. Synthesizing information about available solutions can be a stepping stone towards identifying such a portfolio of available solutions.

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Chapter 5
Development of Multi-Hazard Early Warning System in India

Biswanath Dash and Ajinder Walia

Abstract This paper examines the idea of Multi-Hazard Early Warning System (MH-EWS) from the perspective of its historical evolution, current relevance, feasibility, and challenges. It is argued that the contemporary efforts towards operationalization of such a system require a focus beyond hydro-meteorological hazards and overcoming considerable coordination challenges at various levels. Taking the case of India, this analysis shows that the existing mechanism favors hazard-specific warning and within that framework there exists scope for only limited scale of integration among different EWS components. However the recent initiatives aimed at development of people centered EWS and institutional deliberations for the multi-hazard platforms are ideal conditions to develop an effective disaster risk based EWS. Realization of this goal requires sustained political and institutional commitment, appropriate changes in policies and procedures and importantly participation of citizens and the promotion of inclusiveness as a key feature.

Keywords Multi-hazard EWS · India · Early warning · Hydro-meteorological hazard · Disaster management

1 Introduction

Over the last 30 years, the importance of having an effective disaster warning system is widely realized and it has led to significant efforts across the world. This has resulted in some major accomplishments and that includes development of alternate frameworks to conceptualize warning systems and their refinement with considerable empirical work. These models have brought to the fore significance of "linkages" and "coordination" as important attributes of early warning system and have

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called for integration among different components. Yet another achievement of this period is the recognition of the role played by local communities in making the warning systems effective and sustainable. The growing concern over the neglect of local citizens or people in general within an early warning system (EWS) design and framework has led to the incorporation of "communities" in a more central position, for example, "people centered" or "community based" early warning system.

In spite of these advances, disaster warning continues to remain hazard centric, largely due to a legacy from its historic evolution and also because of practical constraints which are involved in its transition to multi-hazard EWS. Notwithstanding the recent initiatives by various international and national organizations with an aim to forge consensus at different levels and among various agencies to develop multi-hazard framework, much work remains in this aspect as far as operationalization is concerned. For example, take the case of Corona or COVID-19 that was first declared as a "public health emergency of international concern" on January 31, 2020 by the World Health Organization (WHO). A month later, it was identified as a new pathogen in China which coincided with the first case being reported in Kerala, India (Preappadan, 2020). Subsequently it was declared as a pandemic on March 11, 2020 leading to its warning-response across the world. Djalante, Shaw, and Dewit (2020) observed that during these initial days, while WHO was leading the response, there were barely a few disaster risk reduction organizations which played an active role. It points to the continuing gap across the hazard warning system, each operating within its own framework.

This paper aims at an analysis of development of a multi-hazard warning system in India from the perspective of disaster resilience. It illustrates the recent initiatives aimed towards integrating early warning systems within broader developmental processes. The objectives of the paper are to examine the idea of a multi-hazard EWS in Indian context, identifying various challenges confronting transition of the present hazard EWS become an effective disaster risk based warning system. India as a country has made rapid progress in disaster risk reduction and it has introduced wide ranging measures in the form of policy, legislation, plans and programs. This work intends to contribute to such goals by exploring the feasibility of a multi-hazard Early Warning System that is sustainable in the long run. What follows in the first two sections is an analysis of conceptual debates over hazard warning and EWS and the key progress made globally towards the multi-hazard EWS. The third section focuses on India illustrating the existing warning mechanisms and progress towards a multi-hazard EWS, which is followed by discussion and conclusion.

2 Disaster Warning: A System Approach

From at least the late 1960s disaster warning has started to be conceptualized as a system that involved a combination of different interrelated parts, comprising different organizations, groups, individuals and procedures (Anderson, 1967). Foster (1980) illustrates this conception with the example of an alarm clock as a warning system with different components. It serves to prevent habits of oversleeping though having such a clock does not guarantee that it will be effective. The design of an alarm clock has been evolving as well, for example, there is a continual ring until one stops it. A warning from a system perspective entails that inadequacy or a breakdown in one part can lead to a failure of the system as a whole. Similarly modification in one aspect may require change in other parts. The goal of such a warning system is to minimize loss of lives through a successful public response and one which allows maximum time for preparatory and protective actions. Anderson (1967, p. 95) identifies key elements of a warning process to be: detection and assessment of the level of danger, decisions about who should be warned about what danger and in which way, transmission to intended people, interpretation and action by recipients and feedback. Mileti (1975, p. 12) defined the warning system to be one comprising three basic sub-systems; (a) evaluation of the threat, (b) dissemination of warnings, and (c) response to those warnings. Mileti (1975) further highlighted the importance of integration and simplification of different sub-systems. In this particular work, which is part of the first assessment of the warning system in the USA, in addition to integration, another dimension was emphasized as well which is the importance of cross-hazard warning research. It specifically observed, "basic warning system processes may be conceptually the same across hazards. A conclusion that a study of warning systems for one hazard would not be worthwhile may not exclude its utility in studying the basic components of warning systems" (Mileti, 1975, p. xiii).

2.1 Early Warning System (EWS)

A key concept traced to the 1970s is the emergence of the idea "Early Warning System" or EWS and ever since it has remained extremely popular being widely used almost synonymous with disaster/hazard warning. In 1975, following a severe famine in Africa, Food and Agriculture Organization (FAO) had launched a "Global Information and Early Warning System" (GIEWS). In the following decade, the large scale loss of human lives led to the launch of a "Famine Early Warning System" (FEWS), in countries such as Sudan and Somalia (Cowan, O'Brien, & Rakotomalala-Rakotondrandria, 2014; Torry, 1988). In spite of the popularity of concept EWS, there remains a debate over the exact meaning of its use or how early is really early enough? On one extreme, there are hazards such as earthquake for which very little lead time or at best in seconds are being capitalized, for example, in Sendai, Japan to minimize losses through stopping trains before they pass over damaged tracks, evacuating elevators, etc. (Motosaka, 2008). However, the same kind of early warning will have different meaning for those living in high rise buildings. It poses a different scenario or how useful it is if one is not able to take the required safety actions. Conversely, there are slow onset hazards such as famines and climatic change which provide ample lead time but need not really be useful from a warning perspective. Ironically, in the context of a famine in Africa in 2010, Kim and Guha-Sapir (2012) lament that the notion of "early" component of warning will be meaningful only if it results in an early action. Alcantara-Ayala and Oliver-Smith (2019) observed that the term "early" has lost its meaning from its original conception in Famine Early Warning System (FEWS) and is currently being understood largely from the speed of hazard onset or from a purely physicailst perspective.

The conceptual model evolved somewhat by the second assessment undertaken in the USA in 1990. It viewed the structure of a warning system to be comprising three sub-systems: detection, management, and response (Milet & Sorensen, 1990). This study is important for its specific contribution in the form of developing a conceptual framework for a generic warning system. It categorized the hazards into eight types based on their characteristics such as difficulty in detection, prediction time and nature of impact. They have argued that a single design will not fit all hazards. These eight types were seen to have shared components to form the basis of integration across hazard warning. Milet and Sorensen (1990, pp. 7–11) elaborated this aspect further as follows:

> A single cross-hazard warning system would imply one warning system in place for any hazard. Multiple hazard-specific warning systems imply the separate systems for each and every hazard that could impact a particular place. This analysis suggests that a single-system design will not work for all different hazard warning situations but that some events with similar characteristics may fit the same warning implementation strategy.

The decade of 1990s declared by the United Nations as International Decade for Natural Disaster Reduction (IDNDR) brought the major focus on strengthening of early warning systems. At the end of the decade, Anderson (1967) in a review observed that while there is some progress for specific hazards in terms of prediction, forecasting and integration, there are other aspects where progress is missing. As far as a single warning design for all hazards are concerned, Sorensen (2000) pointed out that "an all-hazard warning system is inappropriate unless the specific needs imposed by each different hazard type are also considered." He goes on to add "A key deficiency in the evolution of hazard warning, is its failure to reduce damage to economic or social infrastructure and absence of its linkage to sustainable development goals" (Sorensen, 2000, p. 120). For example, particular hazard warning system, if efficient, potentially leads to the occupation of marginal lands encouraging further development of a low lying coastal area and thus adding to higher disaster risk over the long term.

2.2 *Disaster Resilience: People Centered EWS*

The catastrophic impact of Indian Ocean Tsunami in 2004 and the death of more than two lakh people largely due to unavailability of forewarning put the focus back on the early warning system (León, Bogardi, Dannenmann, & Basher, 2006). The scale of devastation stunned the world and triggered a range of initiatives at different levels, for example, international, national and at local levels (Haigh, Amartatunga, & Hemachandra, 2018). Around this time, much greater emphasis started to be placed on locating early warning within a broader resilience framework instead of viewing EWS as a stand-alone system. Hyogo Framework for Action (HFA) 2005–2015, for example, situated the warning systems as an essential part of resilience building while identifying risk assessment and enhancement of early warning as one of its five top priorities. Further it emphasized that the early warning systems should be people centered and inclusive (UN ISDR (United Nations International Strategy for Disaster Risk Reduction), 2005). In focusing on people and response capabilities, attention was directed towards making the early warning system more participatory, inclusive and decentralized. It led to the development of new models such as "Community based or community driven EWS" characterized as democratic, consultative, empowering, and sustainable (Abon, David, & Tabios, 2012; IFRC, 2012). It was argued that the effectiveness of decentralized EWS may lack precision in prediction but this more than made up through the local's intimate awareness of local conditions and ownership (León et al., 2006). In many ways, this attention broadened EWS knowledge base from science alone to include local knowledge or people's understanding of social and physical environment.

The first international conference on "Early Warning System" was organized at Potsdam, Germany in 1998 followed up with two more in 2003 and 2006 at Bonn, Germany. Following the second conference, a Platform for the Promotion of Early Warning was created under UNISDR to facilitate the establishment of more effective EWS particularly in developing countries (Early Warning Conference (EWC II), 2003). A key outcome of the third international conference held in 2006 was development of a checklist that highlighted a number of aspects including the requirement of a multi-hazard approach. It called for such an approach wherever possible to enhance the economy of scale, efficiency, and sustainability of the warning system. Specifically, it observed that "a multi-hazard early warning system will be activated more often than a single-hazard warning system, and therefore should provide a better functionality and reliability for dangerous high events such as tsunamis, that occur infrequently" (UN ISDR (United Nations International Strategy for Disaster Risk Reduction), 2006). Basher (2006) notes that citizens and public authorities are less concerned with specifics of particular hazards but more with the packages of risk they face. In other words, the danger is not necessarily from the characteristic of hazard but the kind of impact it has on people's lives and livelihoods. Besides a "multi-hazard" or "all hazard" approach can provide synergies and cost effectiveness. However, the author cautioned against overlooking specific characteristics of different hazards and categorically observed "A multi-hazard approach should not be allowed to force generalities or centralized control upon warning system, but must be tailored to the needs of each hazard and built upon the specific capabilities required and the available institutional capacities" (Basher, 2006, p. 2171).

Overall some of the key aspects emphasized during these conferences included inclusion of risk assessment as a basic prerequisite to the establishment of early warning systems, requirement of a legal framework, strengthening capacities at local government level, ensuring collaboration and coordination among the participating agencies, etc. Arguably the most significant achievement of the period is consolidation of different components and a broad consensus over an EWS framework described as "People centered Early Warning System" (Fig. 5.1) (UN ISDR (United Nations International Strategy for Disaster Risk Reduction), 2006; Basher, 2006).

It considers EWS to comprise of four interrelated elements or components: (a) Risk knowledge, (b) Monitoring and warning services, (c) Dissemination and communication, and (d) Response capability. Its objective is to empower the individuals and communities threatened by hazards to act in right time and appropriate manner to minimize losses (UN ISDR (United Nations International Strategy for Disaster Risk Reduction), 2006). Basher (2006) distinguished four stages of an EWS: (a) pre-science EWS based on observations, (b) an EWS based on ad hoc science, for

Fig. 5.1 Four elements of people centered EWS. Source: UN ISDR (United Nations International Strategy for Disaster Risk Reduction) (2006)

example, initiated by scientists or community groups for specific hazard, (c) systematic end-to-end EWS which are linear and largely unidirectional from expert warning to the users, (d) integrated system which provides linkages and interaction among all elements, considers human elements of the system, and overall aims at management of risk rather than warning for a hazard. In essence, this integrated conception of Basher (2006) expands the domain from core warning system to include two other features: (a) actors who are part of the system such as district or local level officials, political leadership, and research community and (b) multiple linkages and feedback, particularly from affected groups.

The Sendai framework for disaster risk reduction (SFDRR) reflects many of the concerns raised periodically over the preceding decade. It aims at increasing availability and strengthening of multi-hazard early warning systems, disaster risk information and assessment to ensure universal access by 2030. It further notes:

> develop, maintain and strengthen people-centred multi-hazard, multisectoral forecasting and early warning systems, disaster risk and emergency communications mechanisms, social technologies and hazard-monitoring telecommunications systems; develop such systems through a participatory process; tailor them to the needs of users, including social and cultural requirements, in particular gender; promote the application of simple and low-cost early warning equipment and facilities; and broaden release channels for natural disaster early warning information (UNISDR, 2015, p. 20).

Generally while there is much endorsement of the progress achieved in creating resilience through effective EWS, there is sharp criticism as well. Zia and Wagner (2015) pointed to the absence of the means of implementation in Sendai Framework to integrate early warning system into development and planning processes across multiple scales of governance structures. The authors argued that Sendai Framework reflects a tension between top-down, techno-centric approach and a bottom-up, people centered approach. It should ideally refocus on consultation with locals, for example, system design, land use development, risk assessment, channel of communication, and user feedback. As a way forward, Marchezini et al. (2017) suggest a first mile approach that situates local people at the center of the ESW design and operation. It advocates actions at different scales, both top-down and bottom-up approaches and dialogue among stakeholders at each stage of the process. In contrast to "last mile," the "first mile" approach does not assume that relevant data, information, and knowledge are outside the purview of communities and it takes into local features such as livelihood, gender, demographics, culture. Alcantara-Ayala and Oliver-Smith (2019) observed that the overall direction of EWS has continued to remain hazard focused. In its aim towards reducing disaster impact it however fails to reduce or manage disaster risk. They call for re-conception of EWS from a social constructivist perspective, through an idea of early warning articulated system that aims at disaster risk reduction.

3 Multi-Hazard EWS

The first international experts' symposium on Multi-hazard Early Warning System was held in 2006 at Geneva, organized by the World Meteorological Organization (WMO). One of the goals of the symposium was to explore the concept "multi-hazard approach" and undertook the studies and demonstration projects, to fully assess different aspects of this approach. The symposium reported specifically:

> There is still no clear understanding of the concept. It has been suggested that a multi-hazard approach could result in enhanced operational effectiveness, cost effectiveness and sustainability of early warning systems through building on and complementing existing early warning system capacities, infrastructures and activities of various stakeholders and strengthening of cooperation among agencies involved in different stages of early warning systems (WMO, 2006, p. 2).

Further in its deliberation, the first symposium recognized that there are different mechanisms for meteorological and hydrological agencies and summarized those under three types:

a. Type I: Hazards for which National Meteorological Services (NMS) and National Hydrological Services (NHS) have the separate mandate to detect, monitor, and develop warning.
b. Type II: Hazards for which NMS and NHS have the joint mandate for warning and
c. Type III: Hazards for which NMS and NHS provide their data and infrastructure to another agency for detection, monitoring, and warning (Golnnaraghi, 2012).

Based on a set of criteria, four cases were initially identified as best practices: Bangladesh, France, Cuba, and the City of Shanghai. Subsequently during the Second International Experts Symposium on Multi-Hazard EWS held at Toulouse, France in 2009, three others, namely USA, Italy, and Germany were included in the list (WMO, 2006). These cases were assessed on the basis of a range of parameters including governance and institutional arrangement from national to local level, organizational responsibilities for detection, monitoring and forecasting, development of warning message, dissemination from national to local level, emergency preparedness and response, sustainability and resource commitment. These cases expectedly varied according to their country specific governance mechanism, history, culture, institutional structures, resources and capacities, but they also showed the commonalities, for example, political recognition of benefits of EWS from national to local level, availability of adequate resources, and clearly defined role of agencies involved (Golnnaraghi, 2012). From a multi-hazard perspective, analysis of nature of warning mechanism in these seven cases shows that countries such as Bangladesh, USA, Japan, and Germany have most of their major hazard warning through a specific agency or under type I, while in Cuba, predominantly it is under type II where two agencies having a joint mandate for detection, monitoring, and warning.

Germany has as many as twenty four of its major hazards serviced by its meteorological agency, "The Deutscher Wetterdienst" (DWD) falls under type I, while the remaining four are of type III categories (Steinhorst & Vogelgesang, 2012, p. 102). Bangladesh reported that Bangladesh Meteorological Department (BMD) is in charge of warning for fourteen of its major hazards under type I and three each falls under type II and III (Habib, Shahidullah, & Ahmed, 2012, p. 39). Similarly, twenty-one major hazards of the USA are of type I, while only two falls under type II and the remaining six are type III category (Keeny Jr., Buan, & Diamond, 2012, p. 129). Japan's warning mechanism is predominantly type I as Japan Meteorological Agency (JMA) has a mandate for ten major hazards, with only two others being type II (Hasegawa et al., 2012, p. 197). Cuba in contrast has nine of its major hazards under type II for which National Meteorological Service and Civil Defense jointly carry warning mandate while one each for Category I and III (Torres & Puig, 2012). France follows a structure in which seven major hazards fall under type I, three of them are type II and the remaining four are type III (Borretti, 2012, p. 75).

These cases prompt Golnnaraghi (2012, p. 218) to observe that a well-designed Multi-Hazard EWS is required to target a number of hazards in order to take the maximum advantages of capacities of all stakeholders. Further elaborating She states, "It leverages resources, monitoring and prediction network, risk analysis capacities, communication and dissemination network and preparedness and response system through well-defined coordinated structures and protocols to ensure the greatest possible efficiency, effectiveness, inter-operability and sustainability for the system as a whole."

3.1 Multi-Hazard EWS: Shanghai

Shanghai a bustling Chinese City with a large population and also a major economic center has envisaged a state-of-the-art Multi-Hazard Early Warning System in association with China Meteorological Administration and Shanghai Municipal Government (World Bank, 2016). As a WMO demonstration Project, this initiative is structured around 4+1 technical platforms and three level multi-agency coordination and cooperation. The technical platforms are: (a) Multi-hazard detection and monitoring, (b) Forecast and warning information generation, (c) Multi-agency coordination and cooperation support, (d) Dissemination and user application platform, and (e) Multi-hazard information database. The three level standard systems are: (a) Multi-agency coordination and cooperation standard system, (b) Safety communication standard, and (c) Regional joint defense standard system (Fig. 5.2). The city identifies fifteen "type I" hazards or major hazards for which Shanghai Meteorological Bureau (SMB) is the responsible agency for warning; six type II or hazards for which SMB jointly issues warnings in association with other agencies and two type III hazards for which different agencies are together in charge of warning (Tang, Feng, Zou, & Mu, 2012, p. 170).

Shanghai, Meteorological Bureau (SMB) has established an MHEWS operation center with a mandate to: (a) implement multi-agency response action, (b) design service products, coordinate response action, and service delivery monitoring, (c)

Fig. 5.2 Shanghai MHEWS (Source: Shanghai Meteorological Bureau, 2010)

dissemination to public, special users, and government agencies, and (d) collect feedback. To ensure that risk assessment, monitoring, dissemination, decision-making, and emergency preparedness elements are better integrated, SMB has formal agreement with number of other agencies including Municipal Food and Drug Supervision Administration for bacterial related food poisoning; with Health Bureau and Centre for Disease Control and Prevention, for Heat wave and Health Monitoring; with Municipal Agricultural Commission for related warning (Tang et al., 2012).

4 Early Warning System (EWS) in India

India with a population of over 1.3 billion and being a rising economic power faces hazards of various kinds: tropical cyclones, flood, drought, landslides, earthquake, epidemics industrial accidents, rail/road/air accidents, air and water pollution, agricultural pest, cloudbursts, hailstorms, tornadoes, economic fraud, and terror attack. Organized warning system exists for some of these hazards, for example, for tropical cyclone it started in 1865 in the backdrop of two deadly tropical cyclones in 1864 (Dash, 2015). Two severe droughts in 1864 and 1866 further expanded the meteorological services and a national organization, India Meteorological Department (IMD) was founded in 1875. Drought monitoring and warning in India is coordinated by the Ministry of Agriculture with inputs from various agencies including IMD, National Centre for Medium Range Weather Forecasting, Central Research Institute for Dryland Agriculture, Central Arid Zone Research Institute, National Agricultural Drought Assessment and Monitoring System, etc. (Ministry of Agriculture, 2009). Flood forecasting center was set up after independence in 1958 at the Delhi headquarters of Central Water Commission (CWC) (Singh, 2018, p. 9). The flood forecasting mechanism has expanded its network significantly and is presently the nodal agency for hydrological observations including flood forecasting.

4.1 EWS Evolution in India: 2000–2020

The super cyclone in 1999 which hit the coastal state of Odisha, killing more than 10,000 people, was a defining moment in early warning system development in the country. Such colossal loss of lives in spite of forewarning being available for days in advance led to severe criticism of the state on the basis of limited EWS conception and lack of integration among the different EWS components (Dash, 2002). The catastrophic impact of the 2004 Tsunami in which 10,000 people lost their lives and a further missing list of over 5000 people reinforced once again the significance of strengthening the country's EWS (Murty, Jain, Sheth, Jaiswal, & Dash, 2006). Following these disasters, the Government of India enacted National Disaster Management Act in 2005 and National Disaster Management Policy in 2009. The National Policy made "developing a contemporary forecasting and early warning system" one of its key objectives and emphasized on technological modernization, cooperation with international agencies and warning dissemination (NDMA (National Disaster Management Authority), 2009). To augment warning communication/dissemination including last mile connectivity, a national guideline on "Disaster Management Information and Communication System" was brought out in 2012, and from a multi-hazard EWS, this gudeline acknowledged that a generic approach can be considered for warning communication of different hazards (NDMA (National Disaster Management Authority), 2012).

In the aftermath of the 1999 Super Cyclone, India Meteorological Department (IMD) undertook a modernization program cutting across its different services. As part of these goals, a collaboration between the Ministry of Earth Science, Government of India and Meteo France International (MFI) was forged in 2006 under a project "Varsamana" and an Integrated Forecasting and Communication System were launched in 2010 (MOES (Ministry of Earth Science), 2010). Following the December 2004 Indian Ocean Tsunami an Early Warning System for Tsunami was established in 2007 at Hyderabad under Indian National Centre for Ocean Information Service (INCOIS), an autonomous body under the Ministry of Earth Science. Tsunami EWS caters for the Indian coast focusing on the North Indian Ocean region. Operationally it is networked with several other agencies including India Meteorological Department (IMD), National Institute of Ocean Technology (NIOT), Survey of India (SOI), Indian Coastal and Marine Area Management (ICMAM), National Remote Sensing Agency (NRSA). INCOIS communicates tsunami advisories/warning to various user groups including emergency managers and disseminates directly to coastal communities as well through its alert system. There have been few studies towards establishment of an earthquake early warning system in India, for example, Baro, Kumar, and Kumar (2016). A pilot project in the seismic prone Uttarakhand region has been completed and based on its success, Indian Institute of Technology (IIT) Roorkee is undertaking an Earthquake EWS for the major cities of northern India (Mohan, 2017).

4.2 National EWS: Existing Mechanism

The National Early Warning System (EWS) of India is elaborated in some detail in the National Disaster Management Plan, 2016 (NDMA (National Disaster Management Authority), 2012, pp. 96–98). Warning responsibilities for specific hazards rest with the various central government agencies (Table 5.1). Though the national plan makes an effort to integrate various recommendations of Sendai Framework including establishment of multi-hazard EWS, there is very little elaboration in this particular aspect. The Ministry of Home Affairs is the apex body at the national level and it coordinates for all disasters, while other ministries coordinate for specific disaster-response (Table 5.2). Designated warning agencies provide input to the Ministry of Home Affairs which issues alerts and warning. The National Emergency Operation Centre (NEOC) at New Delhi acts as the Communication and Coordination hub, being closely linked to other central warning agencies, and concerned State and District level Emergency Operation Centers.

4.3 People Centered EWS Initiatives at Different Levels

Parallel to enactment of legislation, policies, guidelines, and plans, the various EWS demonstration and replication projects have been implemented in India over the last twenty years at different levels. In a bottom-up approach, a EWS pilot project was taken up in 2006 at Cuddalore, Tamil Nadu, one of the worst affected districts during the 2004 tsunami. The project envisaged a multi-hazard framework specifically focused on last mile connectivity and developed a EWS model linking technological systems with community ownership, ease of operation and maintenance, long

Table 5.1 Central government agencies designated for specific hazard warning

Hazard	Designated Government Agency for Warning
Avalanche	Snow and Avalanche Study Establishment
Tropical cyclone	India Meteorological Department
Drought	Ministry of Agriculture and Farmer Welfare
Earthquake	India Meteorological Department
Epidemics	Ministry of Health and Family Welfare
Floods	Central Water Commission
Landslides	Geological Survey of India
Tsunami	Indian National Centre for Oceanic Information Services

Source: National DM Plan (NDMA (National Disaster Management Authority), 2012, p. 97)

Table 5.2 Ministries responsible for coordination of response for specific disaster

No.	Disaster	Nodal ministry/department/agency
1	Biological disasters	Ministry of Health and Family Welfare (MoHFW)
2	Chemical disasters and industrial accidents	Ministry of Environment, Forests and Climate Change (MoEFCC)
3	Civil aviation accidents	Ministry of Civil Aviation (MoCA)
4	Cyclone, tornado, and tsunami	Ministry of Home Affairs
5	Disasters in mines	Ministry of Coal and Ministry of Mines (MoC and MoM)
6	Drought, hailstorm, cold wave and frost, pest attack	Ministry of Agriculture and Farmers Welfare (MoAFW)
7	Earthquake	Ministry of Home Affairs (MHA)
8	Floods	Ministry of Home Affairs (MHA)
9	Forest fire	Ministry of Environment, Forests and Climate Change (MoEFCC)
10	Landslides and avalanche	Ministry of Home Affairs (MHA)
11	Nuclear and radiological emergencies	Department of Atomic Energy and Ministry of Home Affairs (DAE,MHA)
12	Oil spills	Ministry of Defence and Indian Coast Guard (MoD/ICG)
13	Rail accidents	Ministry of Railways (MoR)
14	Road accidents	Ministry of Road Transport and Highways (MoRTH)
15	Urban floods	Ministry of Urban Development (MoUD)

Source: National Disaster Management Plan (NDMA (National Disaster Management Authority), 2012, p. 98)

term sustainability (Singh, 2006). The particular model was subsequently replicated across coastal districts of three other states, Andhra Pradesh, Tamil Nadu, and Kerala. National Cyclone Risk Mitigation Project (NCRMP) a large national government project supported by the World Bank is being implemented in all coastal states of India. National Cyclone Risk Mitigation Project (NCRMP) has included “improved early warning dissemination” as its first component to complement other structural and non-structural disaster risk mitigation measures for cyclone and other hydro-meteorological hazards (NCRMP (National Cyclone Risk Mitigation Project), 2020).

A number of local level initiatives have also been undertaken in different parts of the country, focusing on inclusive character of warning system, community participation, and local level dissemination. Generally they are hazard specific, for example, an end-to-end flood early warning system has been implemented for Surat City in Gujarat (Rajasekhar, Bhat, Dashora, & Chakraborty, 2016). Behar and Naskar (2018) document a volunteer network management system for flood warning, while Pandey and Vyas (2018) describe a community based flood EWS in Bihar. Zutshi (2018) points out that community member’s awareness of EWS is important for the system to be effective. Similarly a landslide EWS has been executed in Giddapahar village, Darjeeling district, West Bengal in which community manages all EWS components including risk assessment, detection, and monitoring (Hindustan Times, 2018).

4.4 Gaps and Challenges for Multi-Hazard EWS

A EWS survey was carried out in seven Indian cities over six components: (a) governance, (b) user's requirements, (c) operational component, (d) product and services, (e) coordination mechanism, and (f) service delivery and user feedback (TARU and UNDP, 2013). These cities were assessed from a multi-hazard perspective and the review showed that in spite of progress under various parameters, there is much scope for improvement, particularly in coordination. The study observes

> For an integrated approach, SDMA (State Disaster Management Authority) should provide an enabling environment to debate, increase coordination and strengthen EWS links across all levels of the government, technical agencies (geological, hydro-meteorological and public health risks), private sectors, city level institutions and non-government organizations (TARU and UNDP, 2013, p. 118).

Thiruvananthapuram City, Kerala one of the seven cities which was reviewed for its EWS, has prepared a detailed multi-hazard EWS plan that includes flood, coastal hazard, and public health risk. This plan outlines key deficiencies within the existing system; for example, it specifies unavailability of micro-level observational network, dynamic nature of vulnerability profile, and lack of institutional support as far as risk assessment component is concerned. In the detection and monitoring component, it notes lack of policies and procedures for inter-departmental data exchange and limited coordination among agencies. The EWS plan further acknowledges that there is lack of institutional structure having required political authority to issue warning. It has found that inter-personal and inter-agency relationship are rather weak, hindering warning communication. Due to limited multi-agency collaboration and lack of clarity in roles and responsibilities at the local level, public response remains suboptimal (Municipal Corporation of Thiruvananthapuram, 2016).

5 Discussion

The concept of a Multi-hazard EWS is seen to have much potential, though operationally it faces considerable challenge inhibiting its realization. Hazard risk assessment, detection and its monitoring are highly specialized in nature and historically its integration with management and communication components has posed enormous challenges. From such a perspective, a Multi-hazard EWS requires a mechanism to evolve that allows the scope and means for multiple warning agencies to work together alongside emergency managers, communication agencies, and community members. There is however a merit in involving a number of warning agencies as hazard risk should be viewed from the perspective of overall disaster (Basher, 2006). This conception envisages that not only protection measures for specific hazard be taken but also similar measures are necessary for various other interrelated risks. It goes without saying achieving such a mechanism has to surmount formidable barriers and involves a significant amount of effort in addition to political commitment and availability of adequate resources. Recent initiatives in different countries and megacities for example Shanghai are encouraging but require sustained commitment from key stakeholders. The case of Shanghai exhibits that such collaboration and coordination can be worked out with multiple agencies on a common platform for realizing the potential of a multi-hazard approach. Though there requires to be further scrutiny of this system, for example, in terms of public participation or the extent to which communities are involved and their ownership of EWS.

Analysis of India's EWS shows that there is little progress from the perspective of a multi-hazard approach though initial groundwork is well laid. India Meteorological Department (IMD) is the principal warning agency for hazards such as tropical cyclones, heat and cold waves, and also for earthquake. IMD provides the inputs for flood warning/forecast to Central Water Commission (CWC), for drought, to Ministry of Agriculture and Farmer Welfare, and for tsunami to Indian National Centre for Oceanic Information Services (INCOIS). Given its diverse warning responsibilities, there is already a consideration within the agency to transform into a multi-hazard framework (Ramesh, n.d.). There is collaboration generally among different agencies during a warning phase and subsequently at the time of response and recovery, but these collaborations require to be formalized, for example, standard operating procedures (SOP) for data sharing and decision making process require to be worked out. In the interim, adequate precautions are needed to ensure that warning quality does not suffer because of transition. Major responsibility in this respect lies with IMD as principal warning agency to carry forward the initiative and to optimize its warning through a collaborative approach.

A major challenge in developing a multi-hazard EWS in India is negotiating the relationship between warning agencies and public authorities. A warning decision is as much as about the threat detection and its assessment as it is about decision over requirement of necessary protective measures, for example, the need and extent of public evacuation or taking precautionary measures such as suspending power supply. Public authorities in India carry the primary responsibilities for ensuring safety and well-being of citizens. In such a situation, arriving at a consensus among different stakeholders is of extreme significance, especially when the stakes are high, and conditions involve greater amount of uncertainties. It is imperative that such integration across diverse set of agencies will require changes in laws and policies and fixing of accountabilities. A key area of weakness within the overall goal of Multi-Hazard EWS is the dominance of hydro-meteorological hazard warning and relatively much less attention to various other hazards, for example, epidemic, food contamination, air and water pollution, traffic disruption, pest attack, earthquake, and landslides.

Considerable work has been done in India towards community based EWS and it has resulted in due recognition for participation and inclusive character of EWS, the value of local knowledge, community ownership, and vital role which last-mile connectivity plays, for example, reaching out to those in the most remote locations and without any kind of means for accessing warning information. A multi-hazard EWS has to build from this platform to synthesize top-down and a bottom-up approach (Zia & Wagner, 2015), providing communities equal partnership in risk assessment, design and operation, communication and ensuring adequate response. Major barriers to this process include varying epistemologies underpinning hazard risk assessment, achieving community involvement and sustainability, particularly in the absence of periodic hazard recurrences.

6 Conclusion

"Multi-hazard EWS" is at best a work in progress and hence it provides scope to redress many of the deficiencies associated with the development of individual hazard warning systems. Lessons learned over the last five decades in diverse settings and particularly since the turn of the century need to be incorporated into its conception and execution. The present analysis shows that there are important initiatives to develop the multi-hazard EWS in various countries in the face of much constraints and challenges. Most of these initiatives are around hydro-meteorological hazards and this can be understood from the continuing impact these hazards have on our society. For example, floods and storms accounted for 68% of the total number of people affected globally in 2019 (CRED, 2020). However a multi-hazard framework demands that risk be conceptualized beyond a specific hazard perspective and it thus calls for various other hazard warning systems to be developed and integrated within a broader disaster risk reduction framework.

India's hazard warning system shows that the country has made significant progress from a people centric approach in strengthening early warning systems. The nation has also done well, seeking to situate EWS within a broader resilience framework. However the overall focus remains hazard centric, though there are some recent initiatives within hydro-meteorological domains to explore feasibility of cross-hazard integration. Any such future work has to take into account considerable coordination challenges, due to intra-EWS integration and inter-EWS collaborations. Much further work is thus envisaged, in terms of various aspects such as changes in policies and legislation which support a multi-hazard approach, a collaborative warning mandate, and a framework appropriate for Indian context, clarity in decision making processes and procedures for data sharing at the different levels. Finally, an effective disaster EWS requires participation of local communities beginning with determining the necessity of a warning system, to their involvement in its design, execution, and maintenance, securing their ownership and periodic feedback. These aspects are important, forming the foundation of an effective disaster warning system and in creating a resilient society.

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Chapter 6
The Religious and Cultural Aspects of Resilience in Disasters: The Case of Typhoon Ketsana Victims in the Philippines

Vivencio O. Ballano

Abstract Applying sociological and social science insights, this chapter explains the religious and cultural aspects of resilience in disasters and contends that an intense spirituality and faith in the divine can be a crucial tool for disaster victims to bounce back after major natural disasters. It investigates the different interpretations, issues, and major perspectives of the concept of resilience in disaster research. It also explains the role of culture and religion in people's capacity to deal and cope with natural disasters as well as presents a case study to illustrate the crucial role of strong religious belief as a coping mechanism of survivors to overcome the challenges of natural calamities. The study showed how a group of Christian Typhoon Ketsana (Ondoy) victims in 2009 creatively used their strong religious faith and belief in God as coping mechanisms to overcome the deadly flood and the subsequent inhuman relocation and return to normal life. It argues that resilience during calamities can best be assessed in individual level with religious faith acting as a potent for resilience tool in deeply religious but disaster-prone countries such as the Philippines.

Keywords Resilience · Philippines · Disaster-prone · Flood · Cultural aspect · Religion

1 Introduction

The number of articles and books published on resilience in its different dimensions has notably multiplied in recent years. In dealing with hazardous events, the concept of "resilience" has become fashionable for scholars recently. It is now a fashionable concept in disaster management research and its literature has also tremendously increased. It has also become a buzzword in the field of disaster risk reduction

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(DRR). Despite its popularity, most research on disaster resilience often overlooks the cultural and religious aspects of people's capability to survive and recover before and after natural disasters. The mainstream literature on disaster risk reduction (DRR), for example, often overlooks some cultural elements when planning and implementing DRR strategies (Hoffman, 1999; Palliyaguru et al., 2010; Wisner, Blaikie, Cannon, & Davis, 2004).

But anthropologists who study human culture believe that the cultural factors influence people's behavior during hazards (Oliver-Smith, 1996), although their effects consist only a small part to human vulnerability compared to economic, social, and cultural factors (Adger & Brooks, 2003; Few, 2003; Pelling, 1997). When dealing with hazards, people do not only evaluate the risk that they could face but also prioritize other factors such as societal merits, spiritual beliefs, heritage, and devotion to a place (Kulatunga, 2011). Culture, therefore, matters in disaster response and resilience. People's cultural orientation and practice usually influence meaning making during emergencies (Button, 2010; Lucini, 2014). Specifically, the crucial role of religion and spirituality in disaster resilience as adaptive strategies in highly religious and disaster-prone developing countries such as the Philippines is often overlooked by disaster scholars.

This chapter, consisting of three parts, therefore, aims to highlight the significance of culture and religion in disaster resilience, specifically with respect to the crucial role of religious faith in God as a coping strategy to live and recover after a major disaster. The first part gives a sketch of the various meanings, problems, and major perspectives related to the concept of resilience in disaster research. The second part explains the role of culture and religion in people's ability to deal with natural calamities. The last part consists of a case study on the function of spirituality and religious belief on God in individuals' adaptive strategies to address and cope with natural disasters. It intends to show how a band of disaster survivors in the town of Rodriguez utilized their strong religious Christian beliefs in God to survive and bounce back after Typhoon Ondoy (Ketsana) which devastated the Philippines in 2009. Ultimately, it attempts to show how strong religious faith and belief can act as the adaptive strategies for religious individuals to survive and overcome post-disaster problems in a predominantly Catholic Christian country such as the Philippines. It argues that disaster resilience as an adaptive strategy can best be measured in the individual rather than in the communal level.

2 Overview of the Various Meanings, Problems, and Perspectives of Resilience

Resilience comes from a Latin word which means to "recover" or "bounce back" (Manyena, O'Brien, O'Keefe, & Rose, 2011). It originated and utilized in physics and mathematics to understand the ability of a system to return to balance after being out of place (Bodin & Wiman, 2004). In social environments, disaster scholars began to apply this term as a metaphor for power, ability, flexibility, and evolution (Alexander, 2013). In calamities, they view resilience as the capacity of individuals to rebound from a tragedy quickly with slightest or no help at all (Malalgoda, Amaratunga, & Haigh, 2013). In the social sciences, researchers attempt to comprehend and explore the mechanism behind people's resilience such as socioeconomic status, public aid, personal control, lofty self-regard, analytical problem-solving, intelligence, and similar factors that can increase people's capacity to bounce back after a calamity (see Caplan & Schooler, 2007; Dumont & Provost, 1999; Florian, Mikulincer, & Taubman, 1995; Masten et al., 1999; Schooler and Caplan, 2009).

Resilience has been widely used by many disaster researchers in recent years. Despite its popularity, it has a multitude of interpretations and usages which led to confusion among scholars (Alexander, 2013). It also has different names and definitions (Masten, 1994): "Ecologists call it an adaptation, economists call it is coping capacity, anthropologists call it bounce back better, and in engineering, it is best known as the capacity of a structure to withstand shock while retaining function" (Dahlberg, Johannessen-Henry, Raju, & Tulsiani, 2015, p. 44). One of the most popular definitions views it as a dynamic process of adjustment to challenges (Luthar, Cicchetti, & Becker, 2000). To Cimellaro and Reinhorn (2010), resilience implies aiming at improving the nature of people's life in danger and to improve opportunities for superior a result. In Masten & Powell, 2003, p. 3), resilience refers to "patterns of positive adaptation in the context of significant risk or adversity."

The term resilience, like other disaster concepts, can explain some dimensions of calamities but could not account their systemic characteristics. It can be useful to describe purposes, goals, mental and bodily condition, as well as conduct of individuals and things. But using the term "resilience" as a comprehensive paradigm can be problematic. "To do so effectively will require the resolution of a series of problems" (Alexander, 2013, p. 2713). As Windle, Woods, and Markland (2008) argue, the present representations of resiliency cannot give a full conceptualization for disaster recovery.

Disaster resilience has a very different formulation in engineering because of its emphasis on constructions and physical structures. Bruneau, Chang, Eguchi, et al. (2003), for instance, built a resilience theory with a focus on infrastructure mitigation, specifically applying engineering concepts such as stamina, repetition, ingenuity, and rapidity. The homeland security perspective basically views it as safeguarding public infrastructures from terrorist attacks (Kahan et al. 2009). Although this perspective can be appropriate to counteract terrorism and protect critical infrastructure, it however disregards the social life and resilient processes within and among communities (Cutter, Burton, & Emrich, 2010).

In the social sciences, social resilience which is defined as "the ability of communities to withstand external shocks to their social infrastructure" (Adger & Brooks, 2003, p. 361). It is generally understood as expressing in three capacities: adaptive, coping, and participative. It finds its popular expression in the concept of community resilience, which was initially used to assess natural hazards, suggesting that resilience is the community's capacity to use its resources to bounce back after a calamity (Mileti, 1999). It also understands it as a process connected with a variety of adaptive abilities like social capital and economic development after disasters (Norris et al., 2008). Thus, resilience can be understood as a system of abilities that can be developed through legislation and programs that can strengthen a community's power to address calamities and bounce back from them.

One of the most popular definitions of social resilience is provided by the United Nations Strategy for Disaster Reduction (UNISR):

> Resilience is the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions (UNISDR, 2019, p. 24).

The concept of social resilience started to become popular with the release of the Hyogo Framework for Action (HFA) 2005–2015 with the subtitle, "Building the Resilience of Nations and Communities to Disasters." This document emphasizes the concept of resilience as the center of all disaster risk management goals (Fjäder & Eslamian, 2021; Matyas and Pelling, 2015, p. 51). Thus, after HFA framework became public, the emphasis of DRR programs is on the connection between disaster recovery and social resilience of communities affected by disasters. With HFA's definition, many current disaster research studies on resilience are now giving more attention to the ability of communities victimized by disasters to bounce back by itself without outside help (Manyena, 2006). The focus of most disaster management efforts is on how to build disaster-resilient communities in which disaster research becomes the key in minimizing disaster losses (Mileti, 1999).

2.1 The Concept of Community Resilience as Problematic

The lack of clarity in the definition of social or community resilience, differentiating resilience as a process or a personal attribute, has led to criticisms by disaster scholars (Luthar et al., 2000). Several scholars and the public possess an intuitive understanding of resilience. Thus, vagueness conceptualization, quantification, and implementation of this concept have resulted in criticism by scholars on its functionality as a conceptual construct (Kaplan, 1999; Tolan, 1996).

The popular use of community resilience to stress the social aspects of disaster recovery has added more criticisms to this term. As the understanding of resilience as a significant component of disaster becomes popular, so also is the criticism of the appropriateness of this term in disaster management (Norris et al., 2007). Those who oppose the use of community resilience contend that the application of community resilience is an analytical tool that can noteworthy, but it is impractical. As Kapucu and Sadiq (2016) argue, community resilience is a complex term that implies a system of sharing of resources and coordination of multiple stakeholders and organizations, both public and private, to become effective and practical.

The use of community resilience is seen by some scholars as impractical. Focusing resilience on communities can overlook other social structures which might have distinct types or origins of social resilience, which need to be recognized (Berkes & Folke, 1998). Building disaster-resilient communities needs organizational capacity and multilevel collaborative governance, adaptive management, and continuous learning (Kapucu & Sadiq, 2016, p. 59). Thus, to some scholars, resilience is best understood and measured as adaptive capabilities of individuals rather than communities to bounce back after disasters (e.g., Bonanno, 2004; Buetler, Morland, & Leskin, 2007; Rutter, 1993). In psychological and micro-sociological studies that view religious beliefs as coping strategies in disaster management, resilience is best measured as the individual's strategies to survive and bounce back after natural disasters (e.g., Pargament, 2007).

2.2 Culture, Religion, and Resilience

The term resilience is a very popular analytical tool in disaster research. Although its social aspects have been accounted by some sociologists and social scientists, disaster studies seldom examine its cultural and religious aspects. Thus, Nunn et al. (2007) and Oliver-Smith and Hoffman (1999) warned that failure to respond to the cultural characteristics of disasters can escalate the weaknesses of communities toward disasters and lead to failures in DRR techniques. Huntington (2000) also warns that if governments and aid agencies ignore the function of cultural values and traits in resilience, DRR programs will be greatly affected (Kulatunga, 2011, p. 307).

Recognizing the important role of culture in disaster management can be partly attributed to the fact that studying disasters necessitates understanding their cultural and social dimensions and not their technocentric aspects (Hoffman and Oliver-Smith, 2002; Ligi, 2009; Quarantelli, 1998). Social scientists view disasters as a mixture of natural, social, and cultural realities. Thus, disaster management should not only understand the natural processes of disasters but also their cultural aspects despite the difficulty of quantifying individual conduct and cultural traits. Thus, social and cultural structures of disasters must be addressed together with their physical and technological characteristics in order to prepare a resilient response against disasters (Benadusi, 2014).

Religion and spirituality, as part of culture, perform a significant function in resilience. Research indicates that religion and spirituality can enhance people's ability to make sense of life events, creating good feelings, and spiritual social support against difficult life situations (Faigin & Pargament, 2011). These two terms are often used interchangeably but each one has a distinct meaning. Pickard and King (2010, p. 262) define spirituality as "a relationship with a transcendent being—God—and refers to the quest to deepen that relationship, to find meaning and purpose, and to make sense of complex life experiences." In connection to disaster resilience, they imply creating relationship with others and a sense of life's meaning (Resnick, Gwyther, & Roberto, 2011).

Religion, however, "denotes the whole of cultural symbol-systems that respond to problems of meaning and contingency by alluding to a transcendent reality which influences everyday life but cannot be directly controlled" (Stolz, 2009, p. 347). Picard and King (2010) argue that religion must be seen from various perspectives rather than as a single concept since it consists of very complex nature and repercussions to society. Religion includes beliefs, values, specific human conduct, rituals, religious community, and attitudes. And religious factors related to resilience can include a sense of life's goal, religiosity, or any subscription to a supernatural power (Boardman et al., 2008).

2.3 Religious Beliefs and Disaster Management

Culture encompasses religion and disasters. Every religion views disasters as connected with tradition, moral decline, as well as material accumulation. An increasing number of studies have focused on the function of religion in calamities (e.g., Gaillard, 2010; Gaillard & Texier, 2010; Johakim and White, 2015) but its discoveries remain inconsistent. Certain investigations have revealed positive and negative effects of religion on how people manage disasters. But other studies revealed the positive effects of religion to people's disaster management such as preventing people from committing suicide during calamities and providing individuals with sense of control, safety, and hope after disasters (e.g., Stratta et al., 2014; Zaumseil et al., 2014).

Despite inconsistent research findings, religious beliefs are often considered as having numerous attributes and functions in connection to disaster management. Beliefs in the supernatural connect between individuals with their environment and are employed for meaning making of the world and human experience. From a religious view, calamities are considered divided acts of God, a product of human failures or the power of nature (Merli, 2010).

Earlier studies have shown that religious beliefs are employed by people as coping mechanisms by individuals facing crisis events (e.g., North et al., 2002; Spence, Laclan, & Burke, 2007) and survivors of calamities (Benight and Harper, 2002; Johnsen, Eid, Løvstad, & Michelsen, 1997; Sumer, Karanci, Berument, & Gunes, 2005). But there is a lack of extensive studies on religious coping strategies of survivors after a crisis event especially during natural calamities.

Coping can refer to ways in which individuals respond using their available resources and set of expectations to reach their different goals in life. It can also refer to "the actions of ordinary people or disrupted remains of institutions, in contrast to official and planned response" Hewitt (1997, p. 36). To Alam and Collins (2010, p. 4), coping can mean "the local people's responses, as well as to the activities (survival strategies) of household members and the interventions of relatives, neighbors and other social networks to mitigate loss in a disaster period." It can imply the mental frame and conduct that individuals pursue to respond to difficult situations. A significant body of literature has revealed the benefits of using spiritual support and religious faith to adapt to various disaster situations (e.g., Levin, 1994; Mackenzie, Rajagopal, Meibohm, &Lavizzo-Mourey, 2000). Religious coping appears as one of the most effective cultural coping strategies of local people to resilient in dealing with major natural disasters.

Spiritual coping can work in many ways to serve as a source of strength and resilience for adults during times of adversity. But some authors highlight the unique place of religiosity in resilience. The capacity of individuals to make religious meaning to disaster events can strengthen their resolve to overcome them (Miller & C'de Baca, 2001); Pargament, 2002). Religious beliefs can be a source of solace and power during stressful circumstances (Clee, Clayton-Smith, & Clancy, 2007). In a crisis, a strong faith in the supernatural can be a source of comfort and control for people to overcome the challenge (Pargament, Smith, Koenig, & Perez, 1998). Lastly, people view prayer as connecting them to their religious faith to decrease social isolation (Meisenhelder, 2002). Doll and Lyon's (1998) study revealed that believers who had more faith in God are more resilient than non-believers.

The case study that follows aims to illustrate how the Christian faith and strong religious beliefs in God are used by Typhoon Ondoy victims in the Philippines, a predominantly Catholic Christian country in Asia, as coping strategies to survive and bounce back after the harrowing disaster.

3 The Case Study

Religious belief and faith in God can be an adaptive resource for social resilience that can be illustrated in the case of a group of Catholic and Christian survivors of Typhoon Ondoy that struck the Philippines in 2009. One of the most disaster-prone and most religious nations in the world in terms of belief in God is the Philippines (Abad, 2001; Abad and de los Reyes, 1994). The country normally receives an average of 20 storms every year being part of the West Pacific Basin (NDRRC, 2011). Stories of God's miracles and strong religious faith of Filipinos against strong typhoons are usually narrated by disaster survivors after calamities. Typhoon Ondoy with the international name of Tropical Storm Ketsana is one of the most dangerous typhoons that ravaged the Philippines in recent memory. Its power has affected four million people and displaced thousands of victims who are mostly Catholics and Christians. Their death-defying experience with Ondoy has resulted in numerous stories and narratives on how their strong faith in God had saved them from the storm and made them resilient in their sub-human condition inside government relocations after the disaster. In this case study using narrative research techniques, a group of 17 Typhoon Ondoy Catholic and Christian survivors who are relocated in the government-owned resettlement called Southville 8A Housing Project (S8AHP) in the town of Rodriguez, Rizal, has illustrated how their strong faith and belief in

God became a coping mechanism to survive the typhoon and became resilient in overcoming the difficulties they encountered inside the relocation site.

3.1 The Research Site

Photo Credit: Author

The Southville Phase 8 Housing Project (S8HP) is a government relocation managed by the National Housing Authority situated in Barangay San Isidro in the town of Rodriguez (formerly called Montalban), Rizal. It is constructed before 2009 when Typhoon Ondoy struck the Philippines. It consists of different phases. The primary research area of this study is Southville Phase 8A Housing Project (S8AHP). S8AHP was built during the administration of President Gloria Macapagal Arroyo. When Typhoon Ondoy hit the country with thousands of displaced people, the H8HP was expanded to accommodate more disaster victims and relocatees. Since then, the S8HP has allowed poor people who were not just displaced because of the local government demolitions but also those who were victimized by man-made and natural disasters. S8HP is part of a large network of relocations sites built for the poor during the presidency of former President Joseph "Erap" Estrada. Thus, this network is named "Erap City" in honor of this former president who started building these relocations in the municipality of Rodriguez, Rizal.

Every phase of S8HP has different sizes of lots and house areas. The first phase of S8HP has a total land area of 8.5 ha, and each housing unit measures 40 m^2. Per lot area and a floor area of 22 m^2. By location, the S8HP is an in-city relocation for the disaster of the municipality of Rodriguez, Rizal. It is situated in Barangay San

Isidro and San Jose, two of the biggest barangays of Rodriguez, Rizal. To the disaster victims of Metro Manila and nearby towns and cities, the S8HP is considered an off-city relocation as it is located outside their jurisdictions. The most serious problems encountered by Typhoon Ondoy victims relocated in S8HP during their early stay in the housing project is the lack of cheap and adequate electricity, weak houses, poor health and social facilities and services, and lack of jobs and livelihood opportunities. Lastly, S8HP is situated in a remote area, less accessible to public transportation, very far from the livelihood sites for many relocatees who are urban poor and who work in the informal sectors outside relocation or in Metro Manila urban centers.

3.2 The Methodology

The data consisted of faith narratives and stories of Typhoon Ondoy victims who are mostly Catholic Christians. They were directly affected by the strong typhoon and rising flood of the raging Typhoon Ketsana in September 2009. The data collection was conducted a year during the period December 2010 to June 2014. It used retrospective research strategy where informants/disaster victims were also to recall past experiences. This is particularly used in asking the victims to recall their experiences during the Typhoon Ondoy flood and write them down.

The study participants consisted of 25 Typhoon Ondoy victims who were relocated in S8AHP (Phase 1A), a government relocation site. They were selected based on their availability, willingness, and length of stay in the resettlement area. Most of the participants are women and housewives as most of the male spouses in the relocation area are gainfully employed as construction workers and informal workers. My key informants were a convenience sample of 25 Catholics, mostly urban poor women ($N = 17$) in their early 30s and 40s who manifest the typical characteristics of the privately religious: Catholics who claimed to be spiritual but are inactive in the parish church activities and rarely attend the Mass and receive the sacraments. In short, these informants can be characterized as “spiritual but not religious” (Cornelio, 2010).

To document know how their strong religious beliefs in God provided them with adaptive strategy to survive the terrifying typhoon and flood as well as the hazardous relocation, the study provided some guide questions to describe how God saved them from the storm. Interviews and Focused Group Discussions (FGDs) were done to clarify their answers to the guide questions which asked them to write down their narratives and personal prayers on how their faith in God helped them to overcome the hardship during the typhoon. The dialogues during FGDs were recoded and transcribed carefully. The content of all their prayers, narratives, responses to the interviews and FDGs was analyzed with the constant comparison method (Lincoln & Guba, 1985). They were divided into categories to bring out the major themes. The primary objective is to understand how their strong faith and belief in God help victims to be resilient during and after the horrifying disaster.

Filipinos are generally privately religious rather than publicly religious. In the Philippines, less than 10% of Catholics attend Sunday masses regularly, participate in religious rituals and activities, and are considered publicly religious, but the great majority are privately religious with the strong personal belief, prayer, and faith in God. The Catholic hierarchy often labeled those who are actively engaged in their parish churches as the “unchurched.”

3.3 Findings

The overall results of the study showed that a strong belief in God (*Pananampalataya sa Diyos*) became central in the victims’ religious beliefs in dealing with Typhoon Ondoy. Two major themes emerged from the faith narratives of the Typhoon Ketsana victims on how they viewed and experienced God during and after the storm and flood: Powerful belief in the divine providence that gave them spiritual strength and comfort to respond to the difficulties during and after the typhoon and seeing God as a Savior, Miracle Worker, and Ultimate Hope. The survivors believed that it was through the power of personal God through their Christian faith that provided them with strength and courage to face the hazard and bounce back after the disaster. The results showed that the victims primarily employed three major coping strategies to survive and recover after the typhoon: (1) believing in God’s providence, (2) trusting God as a savior, and (3) adopting a positive outlook, trusting God’s power, and resigning to His will (*bahala na*) the major coping strategies for resilience. Eggerman and Panter-Brick (2010) contend that robust spiritual faith and personal struggles are the values that form the conversation of resilience in the face of challenges, usually through the acceptance of God’s will and with the hope that God will reward His mercy and guidance to those who are faithful to Him.

3.3.1 Christian Faith as a Comforting and Controlling Mechanism

The Philippines is the only dominant Catholic country in Asia with more than 85 percent of its population being baptized Catholic. The Catholic faith has been rooted in Philippine culture for more than 300 years with Spanish colonization that started in the early sixteenth century up to the late nineteenth century. The local culture is largely permeated with Christian religiosity and strong faith in God, making the country Philippines as a highly religious country in the world in many international surveys. The results of the study did reflect this strong Christian faith in God (*pananampalataya sa Diyos*), which was utilized by Typhoon Ondoy victims as the main coping mechanism to deal with dangers and difficulties of the disaster. The term “faith” (*pananampalataya*) here is understood as the person’s belief in his or her religion rather than the institutional teachings (see Meisenhelder & Chandler, 2002). While resilience would mean the ability of individuals to overcome not only to the people to endure or survive a serious disaster but also to acquire adaptive schemes that would lead them to growth and development (Poling, 2009; Walsh, 1998).

In religiosity studies, an individual's faith in God can either be private or public. Private religiosity primarily refers to the personal faith of the individual as reflected in frequency of prayer, private devotion, or personal beliefs in God. Public religiosity refers to the person's participation in public rituals, religious organizations, and attendance in parish activities. More than 90% of the study's informants considered themselves only as privately religious. They said that they privately pray to God almost every day, but they rarely attended public rituals and religious activities such as attending the Mass. They also confirmed that they never joined religious organizations in their churches. But they strongly professed they have strong belief and faith in God, which provided them comfort and a sense of control during Typhoon Ondoy.

One survivor, Aling Tita, a mother and a sidewalk vendor, confessed that her faith in God realized all her dreams, guided her family, and provided comfort to them in times of calamity:

> I trust the Lord. He fulfills my aspirations and guides me and my family in life. He is our comfort in times disaster.

Another survivor, Aling Petra, saw their strong Christian faith in God as the creator who will never abandon them in times of need. My informants accepted their vulnerability during Typhoon Ondoy's ferocious flood but their faith in God provided them a sense of control since their God is the creator of the universe who can protect them from any disaster:

> I fully believe in God who created the universe. I only Him who I believe. The Lord is always present to assist and guide me during tragedies and difficulties. He is always there in all my challenges in life!

Aling Marta:

> Jesus, I pray that this suffering would pass. I implore to please don't allow crises and trials to overwhelm my family, relatives, and close friends. To you we entrust our lives! Amen.

Aling Korina:

> Dear Lord, save my family and relatives from this disaster!

Typhoon Ondoy is a ferocious typhoon, pouring in two-month amount of water swiftly in only 6 h, leaving the study's survivors and informants who were residing near riverbanks and in low areas unprepared for the tragedy and highly vulnerable during the storm. The local government disaster teams in the country underestimated the impact of the typhoon and were unable then to respond immediately to the flash flood of Ondoy that killed many people. The informants were urban poor of Marikina City and Rizal province area living in makeshift homes near waterways. Informants confessed that it was only their strong faith in God's power as a savior, miracle worker, and hope that provided them with a sense of control and hope to overcome Typhoon Ondoy during and after the typhoon, especially when they were relocated in a sub-human condition of the relocation area provided by the government.

God as a Savior

Typhoon Ondoy is one of the strongest super typhoons to hit the Philippines, one of the strongest typhoons to hit the Philippines in September 2009, displacing more than four million people and relocating thousands of poor survivors, mostly Catholics, in public relocation sites. Unlike previous typhoons, it immediately flooded large part of the provinces of Luzon area with its continuous heavy rains. A month's rain was poured out in few hours resulting in massive flooding that caught many urban poor in the low areas and near rivers by surprise:

> When the flood water started to rise swiftly, I began praying to God to save me and my family: "Lord Jesus, save me and my small children from this typhoon. My children are still young, and I am presently pregnant. Protect us, Oh Lord, from this devastating flood. Whatever happens we would be grateful if save us alive even if we lost our belongings." After this prayer, I felt relieved. After a few minutes, the town rescue team arrived and brought us to the evacuation center of Barangay San Isidro. Later, we were allowed to apply for a housing unit by the local government in the S8HP relocation.

God as a Miracle Worker

The second controlling mechanism used by survivors to withstand the danger of the flood is believing in God as miracle worker. All key informants believed that God intervened during Ondoy to miraculously save them from the dangerous flood. These informants resided near the Marikina River and creeks. With that heavy rain that lasted for 6 h, the survivors did not have enough time to evacuate. The flood had swiftly reached the roofs of their shanties. Thus, they really believed that God had somehow rescued them from danger and death. The participants of this research did not hesitate to characterize their survival as a miracle (*himala*).

Aling Gloria, a 35-year-old sidewalk vendor and mother of 5 children, for example, believed that the Lord rescued her children from the disaster. She maintained that the rescue and survival of her children was God's work. Through a friend, her children were rescued from the raging typhoon:

> As an ambulant vendor, I was selling breakfast to my neighbors on that morning, not knowing that Typhoon Ondoy has already arrived in our town. The rain was heavy. And while peddling food to different houses, somebody recognized me and told me that the flood in our area was already very high. The informant told me that I should return home to monitor the situation and look after my kids. Wasting no time and worried about my children, I started praying for God's help and immediately left for home. When I reached home, my kids were already rescued by a neighbor who brought them to higher place. I was very much touched upon learning this. It was the same time that I prayed that my neighbor went to my house and rescued my children. Indeed, God is merciful and kind. He saved us from Typhoon Ondoy!

Another survivor, Aling Nenen, also remembered on how God has rescued her and family during the typhoon:

> Our Lord is indeed merciful. Through the Holy Spirit, He delivered me and my loved ones from for the second time! He rescued us from Tropical Storm Reming. And now He rescued us again from the anger of Typhoon Ondoy! Praised be His Holy name!

For the informants and survivors, it was clear that they were miraculously saved by God from Ondoy. And this experience had deepened their trust and belief in God's providence and power. In the Catholic Church, a miracle is usually seen as a divine sign or power, revealing God's mercy and salvation to humankind. In sum, my key informants and Ondoy's survivors believed that they were saved by miraculous saving power of In general, my informants believed that the miraculous characteristic of God's saving act and not just by accident or considered as *suwerte* (luck). To some informants, it may appear as luck. But analysis of their narratives revealed an implicit belief in God's miracles as one survivor narrated: "We are considered *masuwerte* (more lucky) because our Lord saved me and my family members from the wrath of Typhoon Ondoy!"

God as Hope

The third emerging image of God used by my informants as a control mechanism to overcome the difficulties during and after the Typhoon Ondoy flood is seeing God as their ultimate hope. In anthropology, hope is linked to people's well-being and social structures. Although anthropology of hope has not attracted much attention from scholars, it nevertheless provides a comparative significance for people and social resilience, social identity, and social dynamics across successive generations (e.g., Carbonella, 2003; Loizos, 2008; Miyazaki, 2004). Hage (2003, p. 20) argued, hope is about "one's sense of the possibilities that life can offer… Its enemy is a sense of entrapment, of having nowhere to go, not a sense of poverty."

Hope is an unrealistic assessment of the future that something would turn out to be favorable. Rather, it is "the certainty that something makes sense" (Havel, 1990, p. 181), unified story that can explain private and a coherent narrative that explains personal and collective experiences. Being resilient and religiously strong against trials are founded on hope, an understanding that sees all trials to be finally be resolved through meaning making that provides integration of experiences from past to future (Eggerman & Panter-Brick, 2010). In Philippine culture, hope (*pag-asa*) is usually communicated through cultural value of *bahala na* (come what may). It is an expression of value that "one is not hopeless" (Jocano, 1999, p. 116) and that the individual can bounce back to improve his or her difficult life circumstances. For Filipino Christians, "bahala na" usually entails a strong trust and faith in God's providence in facing the future.

The S8HP relocation site had several negative unintended consequences for Typhoon Ondoy survivors. The key informants' assessment revealed that the government relocation program for typhoon victims was from what the Philippine disaster laws say about the resettlement and post-disaster housing for disaster survivors. That law says that the resettlement for poor and homeless calamity victims should be humane, safe, and appropriate for the rehabilitation of disaster victims. However, the reality is far from the ideal. The actual relocation is more dangerous than their previous residence, desolate and far from their livelihood and informal jobs, and lack social and health facilities. Several Typhoon Ondoy survivors in S8AHP expressed concerns that they were transferring from "danger zone" before the typhoon to "danger zones" of the relocation because of its sub-human conditions:

Aling Liza:

> Our condition in the relocation is terrible. We are happy that the government has rescued us from the danger zone of our former home near the Marikina River and brought us here in Southville with concrete raw houses. However, living here is like moving to a death zone. The relocation is in highly disaster-prone area, the houses were built with sub-standard materials, no available jobs and clear livelihood assistance. There is no potable water, hospital, cheap electricity, and security of tenure to our homes.

Aling Dang, confirmed Aling Lydia's observation:

> I agree that our local government has rescued us from Typhoon Ondoy and brought us to Southville resettlement. But we did not expect that we will be relocated in "death graves." The relocation is obviously dangerous: weak homes, no jobs and livelihood for the residents, prone to disaster, and absence of security.

Informants felt that God saved them not only during Typhoon Ondoy but even after the disaster when they were relocated in S8AHP. Despite the risks and sub-human conditions in the relocation area—residing in weak houses in an earthquake-prone settlement, lacking in livelihood opportunities, health facilities, and social services, my informants continued to entrust their life to God and hope that one day will save them from all their problems. They said that their experience of God's saving power during the typhoon had given them strength and hope to face the future.

Their strong faith and trust in God provided them with strength and hope that somehow things would get better after the storm. This is manifested in my informants' belief of the Filipino cultural value of "bahala na," a shorter term for "bahala na ang Diyos." Interestingly, a review of our local history showed that "bahala na" belongs to the Philippine values of the local culture (Enriquez, 1993; Jocano, 1997). Lagmay (as cited in Enriquez, 1993) discovered that Filipinos are generally brave in dealing with challenging conditions and risk-takers. Thus, the cultural value of "bahala na" for many Filipinos is considered a desirable tool especially when dealing with disasters.

Strongly spiritual individuals can usually transcend the challenges and difficult trials of daily living. Their deep relationship with the divine can provide them with strength and reason to overcome tragedies in life, which cannot be given by material things and values (Niebuhr, 1986). For Filipino Catholics, the ecclesial teaching on the prophetic aspect of God's saving power is related to the cultural value of *bahala na* (entrusting everything to God's will).[3] During interviews with Ondoy survivors, the frequent expression was *bahala na ang Diyos* (entrusting everything to God) when asked how they would face the future after the disaster. The most common understanding of *bahala na* is seeing God as their only hope and guide in facing the problematic future.

Aling Agnes, 42 years old, a mother of 7 children also sees *bahala na* her only hope for all their problems in the relocation area, believing in the Biblical injunction that God provides those who ask:

> In the midst of all our suffering here in SV (S8AHP), of all the calvary we experienced here: lack of jobs, food, debt-trapped, but God will find means for all these. There is a living God who can provide all our needs since the bible says, ask and you shall receive….

The expression *bahala na* was commonly mentioned by the study's key informants and residents of S8AHP to manifest their hope and personal faith in God that one day their situation in the relocation would improve. Survivors are convinced that the government has left them in the remote settlement without sufficient aid to bounce back from the typhoon. However, they did not lose their deep faith in God and hope that one day their situation will improve:

> Despite our sub-human condition in the relocation, I always trust in divine providence and still hope that God would assist us in this difficult predicament. We are very poor and lack food and income. We have no permanent employment in the relocation. We always rely on the generosity of other people and government assistance. What would be the future of our children?

Despite the prevalence of religious meaning of the expression "bahala na," the folk interpretation of *bahala na* as *swerte* (luck) or *kapalaran* (destiny) can still be seen in their narratives such as Aling Ludi's testimony:

> Right now, we are helpless in dealing with our current problems in the relocation. I often thought that maybe this is our destiny. This is the reason why we believe that "bahala na and Diyos" (It's up to God) on how we can survive in this man-made disaster in S8AHP. I already entrusted our fate to the Lord.

But the overall understanding of the informants on "bahala na" implied strong trust and faith in God in facing the difficulties in the relocation area.

3.3.2 "Bahala na" and the Case of Aling Edna and Family

The sad story of Aling Edna is one of the many stories of suffering, lack of jobs, and sustainable livelihood program in government-owned relocation areas such as the S8AHP.

Aling Edna's husband, the only breadwinner, who worked as a casual construction worker in the relocation area, was just dismissed from his work because the company discovered his heart problems. Her husband was struggling for his breath when the interview was conducted in her home. She informed us that she could afford to bring her husband to the hospital because of poverty. The nearest public hospital at that time was Amang Rodriguez Hospital in Marikina City, around 25 km away from the relocation site. They had no money even for the transportation fare. In fact, they always worry for their next meal especially that her husband is now sick and unemployed. She was too timid to approach her neighbors for help since she knew that they too are in serious financial problem. Besides, they had already helped her many times and lent her some money.

Aling Edna was only a plain housewife with no regular, although she participated in some livelihood projects sponsored by the local government in the relocation to earn some income. She also joined in some livelihood seminars offered by private organizations in the resettlement but capital to start a small business is scarce. Her husband's income is insufficient to support her 6 young children. Her trust in God as expressed in her attitude on "bahala na" is her only hope for surviving for her family:

> I have no idea how my family can continue surviving in the relocation area. That is our Lord is our only source of hope and strength. We believe that He will not leave us. Our government has stopped helping us. My husband and I have no permanent job and livelihood. How can we survive? The future is bleak especially for our 6 children. That's why we entrust our lives to God, "bahala na" ang Diyos sa amin" (It's up to God on what will happen to us).

For Aling Bettylyn, 36 years old and a mother of 5 children, for example, understands *bahala na* as believing in God as the only hope (*pag-asa*) and guide (*gabay*) for all their problems in the relocation site:

> *Bahala na* means that God is the only hope for all our problems. He alone can help us in our suffering here in the relocation. I pray that He will guide and give us a strong and energetic body. He is our only guide in my life and my children and husband….

4 Conclusion

This chapter has shown that resilience is a popular and problematic term in disaster research. It has also examined the various meanings, problems, and major perspectives of the concept of resilience in disaster research and explained the role of culture and religion in people's capacity to deal and cope with natural disasters. The concept of resilience in engineering is quite different from the social perspectives. But the chapter has argued that resilience can best be measured in the individual level. Despite its popularity, the concept of community resilience remains impractical since it is a complex term that implies a system of sharing of resources and coordination of multiple stakeholders and organizations, both public and private, to become effective and practical. This chapter has also illustrated in a case study that culture can be crucial in disaster resilience, specifically on how religion and strong religious faith and belief in God can be utilized by people in highly religious but disaster-prone countries such as the Philippines as a comforting and controlling mechanism to survive during the disaster and become resilient in the midst of the inhuman conditions inside S8HP, a government relocation site assigned to Typhoon Ondoy victims in the province of Rizal and Marikina City. Finally, the study has illustrated how the Filipino value of "bahala na" can be a potent tool for resilience in disaster and suffering.

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Part II
Building a Socio-Ecological Resilience in Various Communities

Chapter 7
Socio-Ecological Resilience by Design for Flood-Prone Waterfront Cities: A Comparative Study of New Orleans, USA; Brisbane, Australia and Christchurch, New Zealand

Gillian Lawson, Nada Toueir, and Shachi Bahl

Abstract With climate change having increasing impacts on our cities and regions, the need for long-term and sustainable solutions is critical. Natural hazards are increasing in occurrence and intensity, and the cities are proposing plans to increase their capacities to resist and withstand these occurrences. Resilience of cities to environmental hazards is often dominated by a worldview of 'a system in equilibrium', but this negates the wide diversity of social and ecological systems responding to change around the world. Three cities are used in this chapter as the case studies to show how each has similarities in flood and disaster-prone physical landscapes and human influences. New Orleans (USA), Brisbane (Australia) and Christchurch (New Zealand) have had similar colonial-influenced histories, have managed water as both an asset and a liability and have begun city planning for improved socio-ecological resilience. The case studies illustrate the barriers and enablers that are context-specific and require the landscape architectural design solutions to contribute to more robust and resilient cities in the face of likely hazards in their part of the world. The three selected cities have numerous experiences specific to their own unique circumstances that are related in this chapter to socio-environmental drivers that enhance their adaptive capacity. By comparing the cities with similar histories but divergent experiences specific to their own geomorphological and meteorological hazards, it is suggested that the cities must find what is appropriate for their particular socio-ecological contexts through resilience by design.

Keywords Flooding · Natural hazards · Infrastructure · Communities · Adaptive capacity · Resilience · Socio-ecological

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1 Introduction

Flooding in coastal cities is becoming a priority that needs to be addressed in developed and developing countries. With climate change concerns on the rise, the discourse around flooding is an urgent one and spans multiple disciplines. Perceived disasters are more frequent and are still causing tremendous losses to human, economic and biophysical systems (UNISDR, 2015). Resilience is a key concept in planning, designing and building cities and their communities. This chapter supports 'Priority 4' of the Sendai Framework for Disaster Risk Reduction report that focuses on 'enhancing disaster preparedness for effective response and to "build back better" in recovery, rehabilitation and reconstruction' (UNISDR, 2015, p. 14).

Three cities on the east coasts of three countries have been selected: (a) New Orleans (USA), a city prone to hurricanes and flooding in the broad delta of one of the world's longest rivers; (b) Brisbane (Australia), a city prone to cyclones and flooding after volcanoes and sea-level changes created a broad floodplain behind two large sand islands and (c) Christchurch (New Zealand), a city prone to earthquakes and flooding on a broad floodplain below a major tectonic mountain chain and blocked by two extinct volcanoes.

This chapter starts by giving an overarching look at each case study to then focus on how each city has dealt with post-disaster recovery and planning as part of building their resilience strategy. The following pages are structured as follows: (1) brief outline of the case study selection process; (2) summary of the physical landscape of each city's context over time; (3) background information related to the human settlements of each city, and the population that is changing its perception of water with major events over time; (4) an outline of similar barriers and enablers to resilient planning and design strategies; (5) drivers for landscape resilience and (6) a summary of resilience and adaptive capacity by design. The chapter advocates for the site-specific strategies rather than well-meaning, global solutions shared from one part of the world to another, without careful investigation of the unique biophysical and socio-environmental processes in each location.

2 Case Study Selection

The starting point for our investigation of resilience of flood-prone waterfront cities was the 100-Resilient Cities Report produced by the Rockefeller Foundation (Resilient Cities, 2019). This report subdivided the cities taking action into 15 categories. Two of these categories were 'Post-Disaster Resilience' and 'Resilience Districts'. Christchurch and New Orleans both appeared under Resilience Districts with a strong community engagement approach at a submetropolitan level. Both cities were also a good fit for Post-Disaster Resilience, having suffered substantial earthquake and hurricane damage in 2010–2011 and 2005.

While planning policies tackle coordination of resilience strategies across a city, design approaches generally work closely with local community members at a site level and can be very wide-ranging. Secondary sources (including recent national and state policies, plans and strategies) are used here to give an overview of the background, barriers and enablers and drivers for design approaches to each city's unique challenges. Cities taking action at a district level provide useful lessons for designing socio-ecological resilience (Jaramillo et al., 2021). As the authors had a direct post-disaster experience in both these cities, it was decided to focus this study on Christchurch and New Orleans. Brisbane was added as it also suffered severe drought from 1996 to 2020 and severe flooding in 2011. Although not included in the 100-Resilient Cities report, it has a similar story to tell, and it has a design approach applied to improving city resilience.

3 Physical Landscapes and Human Influences

3.1 New Orleans, the Mississippi River and Wetlands

Located in the south-east of the USA and part of the state of Louisiana, New Orleans came to be some 7200 years ago, at the end of the Ice Age, 'when melting glaciers sent sediment-laden runoff down the Mississippi to the Gulf of Mexico (Table 7.1). The river's mouth began moving seaward depositing sediments faster than currents and tides could transport them away. The mud accumulated and lower Louisiana gradually emerged from the Gulf shore' Campanella (2018, p. 3) (Fig. 7.1). Due to the constant deposition of silty sediments, the area closest to the river became higher in elevation, making it a natural levee. Crossing through ten states, the Mississippi River is the second-longest river in the USA. It has multiple tributaries at the source and when it reaches Louisiana it turns into one large stream flowing into the Gulf of Mexico (National Park Service, 2018).

Pre-colonisation, New Orleans was mainly inhabited by the Native American tribe Chitimacha until the French landed in 1718 (Campanella, 2006, 2008, 2018; Swanton, 2013). These indigenous people knew the land well and had adapted to living close to the swamps. They were accustomed to the fluctuating water levels, and they knew when to move to higher ground when necessary. Europeans were not adapted to living in such an environment and needed to control it (Campanella, 2018).

New Orleans was one of the many cities bordering the Mississippi River, it was settled by the French and remained so until the 1760s. Due to the frequent floods that rendered New Orleans uninhabitable, the early settlers abandoned the city in 1719 to settle in Baton Rouge, a neighbouring city further up the river. In 1721, the French returned with ships that had easier access to the continent, especially after a long journey from Europe. The city was first established on the land closest to the river as it was the highest part of the area (Campanella, 2006). Cypress forests and aquatic plants covered the swamps and wet areas, which spread north towards Lake Pontchartrain.

Because New Orleans was a low-lying city with a very high water table and saturated soils, hurricanes added strong winds combined with high rainfall, which meant

Table 7.1 Comparative attributes of three flood-prone cites

Attributes	New Orleans	Brisbane	Christchurch
Location	South-east of the USA. Part of the state of Louisiana	South-east region of Australia. Part of the state of Queensland	East coast of South Island (Te Waipounamu), New Zealand. Part of Canterbury region
River names and catchment area	Mississippi River 3,220,000 km² (Fijalkowski et al., 2015)	Brisbane river 13,570 km² (Queensland Government, 2020)	Three catchments of • Styx river: 70 km² • Avon river: 89 km² • Heathcote river: 103 km² (Christchurch City Council, 2016a, 2016b, 2017)
History			
Indigenous group	Chitimacha tribe (Native American Indian)	Yuggera and Turrbal tribes (Aborigine)	Ngāi Tahu tribe (Maori)
Colonial settlement	1718 French	1843 British	1850 British
Major events	• 1927: The great Mississippi flood • 1961: End of segregation • 1965: Hurricane Betsy • 1968: Building the Mississippi River-gulf outlet • 2004: Hurricane Ivan • 2005: Hurricane Katrina • 2008: Global financial crisis • 2010: The Deepwater horizon oil spill • 2020: COVID-19 pandemic	• Major floods (1841, 1893, 1974 and 2011) • 1996–2010: Millennium drought • 2008: Global financial crisis • 2020: COVID-19 pandemic	• Floods (1868 and 1977) • 2008: Global financial crisis • 2010–2012: Earthquakes • 2017: Port Hills bushfires • 2019: Al Noor mosque and Linwood Islamic Centre shootings • 2020: COVID-19 pandemic.
Demographics			
Population (2019)	3,90,144 (46th) (United States Census Bureau, 2019)	25,14,184 (3rd) (Australian Bureau of Statistics, 2019)	3,96,700 (3rd) (Statistics New Zealand, 2019)
Density	783/km² (United States Census Bureau, 2019)	145/km² (Australian Bureau of Statistics, 2019)	270/km² (Statistics New Zealand, 2019)
City area	906 km² (United States Census Bureau, 2016)	15,842 km² (Australian Bureau of Statistics, 2016)	1426 km² (Statistics New Zealand Geographic Data Service, 2019)

(continued)

Table 7.1 (continued)

Attributes	New Orleans	Brisbane	Christchurch
Environment			
Climate	Humid subtropical climate	Humid subtropical climate	Temperate oceanic climate
Ecology	Nationally significant coastal wetlands of bogs, marshes, fens and swamps	Banks of the Brisbane River and Moreton Bay dominated by mangrove wetlands, saltmarshes and eucalypt forest	Riparian, tidal freshwater wetlands and saltmarshes dominated by flax, fern and raupō
Government			
Local	Mayor, New Orleans City Council	Mayor, Brisbane City Council	Mayor, Christchurch City Council
State/region	Louisiana state government	Queensland government	Canterbury regional council
National	United States government	Australian government	New Zealand government
Urban structure			
Central City	Lafayette Square with streets radiating out from a central point	Central business district (CBD) with Queens St mall located on bend in Brisbane River	Cathedral Square surrounded by the four avenues
Suburbs	Metropolitan area encompasses eight parishes, divided into the Eastbank and Westbank by the Mississippi River	Metropolitan area divided into north and south side by Brisbane River	Metropolitan area south of the Waimakariri River, north-west of the Port Hills
Satellite towns	North shore includes the towns of Slidell, Mandeville and Covington	Urban growth into sunshine coast (north), Gold Coast (south) and Ipswich (west)	Dispersed pattern of towns outside metropolitan area from Kaiapoi, Port Hills to Lincoln

that the city was regularly exposed to flooding and thus it was deemed necessary to build levees to protect it. By continuously pumping the water out, the saturated soil that relied on sediment deposition from recurrent floods was deprived of moisture and slowly subsided. Over the decades, the city was sinking as the natural processes that helped it maintain the balance were stopped (Campanella, 2006, 2008; Colten and Sumpter, 2009; Freudenburg et al., 2009; Vale and Campanella, 2005).

New Orleans has always been surrounded by water with the Mississippi River to the south and Lake Pontchartrain to the north. Water was perceived as a threat by colonists since it was either associated with floods or with major diseases causing thousands of deaths during the development of the city. What was misunderstood was that these swamps and marshes helped to store excess water and facilitated sediment deposition. This natural process contributed to keeping the city above sea level. Early settlers were also unaware that their incoming ships brought the

Fig. 7.1 New Orleans and Mississippi river adapted from Google Earth (Author, 2019). (**a**) Louisiana State and New Orleans city, adapted from Google Earth (Author, 2019). (**b**) Lower catchment of Mississippi river showing New Orleans, Gulf of Mexico and Mississippi river- gulf outlet (MR-GO), adapted from Google Earth (Author, 2019)

mosquitoes that were responsible for the spread of diseases. New Orleans suffered from numerous outbreaks where its population shrank drastically due to mosquito-related diseases like malaria (Campanella, 2018).

Early settlers could only live on narrow strips located on high ground; they built the city following a grid pattern, which later was skewed by the crescent shape of the river. With technological advances, people managed to control the surrounding water and expand the city (Campanella, 2006; Gotham and Campanella, 2011). At first, canals were used to drain water; then levees were built, and pumps pushed the water behind the walls. Water was transformed from always being visible to disappearing altogether. The building of the levees was the turning point for New Orleans, and these levees played an important role in giving a false sense of safety to the residents of the city (Burby, 2006). The levees made the city even more vulnerable to floods during the high rainfall events as the city turned into a big ‘bowl’ where water had nowhere to go and remained within the embankments (Campanella, 2018; Gotham and Campanella, 2013).

3.2 *Brisbane: City and River*

Brisbane is a subtropical city located in the south-east region of the state of Queensland (Table 7.1), on Moreton Bay, sheltered from the Pacific Ocean by two major sand islands—Moreton Island and North Stradbroke Island (Fig. 7.2). It is a

Fig. 7.2 Brisbane river and North-pine catchments, adapted from Google Earth (Author, 2019). (**a**) Queensland region and Brisbane city, adapted from Google Earth (Author, 2019). (**b**) Brisbane river catchment showing Brisbane, Ipswich, Moreton bay, port of Brisbane, Gold coast, Somerset, Wivendoe and Northpine dams, adapted from Google Earth (Author, 2019)

city that probably has the most complex geological history of all the Australian capital cities. About 400 million years ago, the Brisbane area was buried under deep ocean sediments (Willmott and Stevens, 1992). The coastal edge slowly extended eastward with several periods of continental shelf uplift, volcanic eruptions, intrusions of molten magma, mountain building, erosion and deposition of ash flows (forming volcanic tuff) and sediments. The oceanic crustal plate was being forced westward by the Australian continental plate in a subduction zone. Eroded sediments formed coal deposits in swamps, river flood plains and lakes (Willmott and Stevens, 1992). The Tweed Caldera, centred around Mt. Warning south of the Gold Coast, is the most visible and well known of the remnant volcanoes from 24 to 23 million years ago (Willmott, 2010). However, Brisbane is still ringed by the extinct volcanoes to the south and south-west of the city.

As the Ipswich coal measures were being deposited during the late Triassic period, streams were draining the hinterland to the west of Brisbane between older mountains (Willmott and Stevens, 1992). Sandy sediments filled the fluvial corridors and connected lakes and streams in a west to east direction. The present course of the Brisbane River was established as a series of meanders on a broad plain, cutting down into underlying rocks. As sea levels rose and fell over 200,000 years, stream flows were both vigorous then slow, depositing coarse gravels then fine alluvium in the terraced river valleys. At the river mouth, there was a complex interdigitation of alluvium and estuarine sediments, eventually covered by mangrove forests along the coastline (Willmott and Stevens, 1992).

The Brisbane River catchment now covers an area of approximately 13,750 km^2 (5300 sq. mi). The river travels roughly 300 km from the Great Dividing Range and Mt. Stanley into Lake Wivenhoe, created by the Wivenhoe Dam, built after the devastating floods of 1974 (Davidson and Bowstead, 2017). Six major tributaries drain the catchment above the dam. It meanders through grazing land to converge with the Bremer River at Ipswich City, through Brisbane's western suburbs to the city centre and finally makes its way to the sea, past Luggage Point to the shipping container wharves of the Port of Brisbane on Moreton Bay (Davidson and Bowstead, 2017) (Fig. 7.2).

Prior to European colonisation, the land, river and sea were occupied by the Yuggera and Turrbal aboriginal tribes who camped in open woodlands and rainforest pockets to hunt and gather abundant food among the mangroves in the tidal estuary. European settlement in Brisbane began as a penal colony in 1843 when free settlers in Sydney petitioned the Governor of New South Wales, General Sir Thomas Brisbane, for the worst of the British convicts to be sent to the Queensland colony. When Queensland separated from New South Wales in 1859, Brisbane became a free settlement, eventually expanding its population to become the capital of the new colony (Laverty, 2009). They established a rectilinear grid system of roads from Spring Hill to Gardens Point on the river, named after the kings and queens of England like many British settlements of the time.

3.3 *Christchurch: A Floodplain with Three Rivers*

Christchurch is located on the east coast of Canterbury plains (Table 7.1), next to an extinct volcanic complex of Banks Peninsula on the South Island of New Zealand (Brown et al., 1995). It is situated on a seaward side of a floodplain which gradually slopes to the coast from the foothills of the Southern Alps. This floodplain comprises three catchments of Styx, Avon and Heathcote Rivers (Fig. 7.3) that were formed by the outwash of Southern Alps glaciers. One of Canterbury's glacier-fed rivers, the Waimakariri River, flows along the northern edge of the city.

Historically, the site of Christchurch was both inland (when sea levels were lower during glacial periods of Pleistocene age) and below sea level. The lowering of sea levels led to the accumulation of sediments and gravel against the northern side of Banks Peninsula (Christchurch City Council, 2005). The consistent fluctuation of sea levels made Christchurch a swampland that lay behind dunes with lagoons, estuaries, sandflats, gravel and silt deposits from the four rivers (including the Waimakariri River) (Brown et al., 1995).

Geologically, Christchurch had three overriding structures that made up its landscape: the floodplain, the volcanic Port Hills on the southern edge and the foothill ranges of the Southern Alps on its west (Christchurch City Council, 2005). The city's surface water environment comprised wetlands, numerous spring-fed streams and the three small coastal rivers (and their estuaries), the Styx, Avon and Heathcote Rivers. The Port Hills were entirely forested before the arrival of European settlers

Fig. 7.3 Christchurch, Waimakariri river and Banks Peninsula, adapted from Google Farth (Author, 2019). (**a**) Canterbury region and Christchurch City, adapted from Google Farth (Author, 2019). (**b**) Styx, Avon and Heathcote river catchments in Christchurch city, adapted from Google Earth (Author, 2019)

(Christchurch City Council, 2005). This natural system sustained and supported local Māori people for 800 years (Watts, 2003).

It is believed that before the arrival of Canterbury Association in 1850, three consecutive groups of Māori settlers arrived in Christchurch and established a different pattern of displacement and changing dominance over the landscape. Ngāi Tahu was the third group of Maori settlers who took over the Canterbury region and South Island at large. The early nineteenth century saw the arrival of the fourth wave of migrants, the Europeans, who depended on Ngāi Tahu for provisions (Christchurch City Council, 2005). They established the classical rectangular grid system in Christchurch (Ignatieva and Stewart, 2009), which contained streets occupying approximately 1000 acres (400 ha). Higher dune belts marked a retreating shoreline on the east, north and south sides with peat swamps between them. Christchurch was planned to grow on its west and the northern parts (Wilson, 1989).

The first European settlers made use of waterways for transport, but they struggled with extensive swampland areas in Christchurch. Over time, as the population of the settled areas grew, problems such as high groundwater levels, flooding and waterborne diseases emerged. In 1875 Christchurch Drainage Board was established to drain excess water away from the land along with managing storm and wastewater in the city (Watts, 2011). They followed a utilitarian approach for more than a hundred years to manage surface water. Distribution and conveying of excess urban runoff were achieved with an extensive network of pipelines, drainage channels and enlarging existing waterways of Avon, Heathcote and Styx Rivers (Watts, 2003). The drainage board protected the low-lying neighbourhoods near the estuary from flooding through the construction of stopbanks, tide gates and local area pumping stations. The combined effect of such measures created the land upon which the current 'Garden City' would grow (Watts, 2011). This long history of capital expenditure on utility structures resulted in a loss of natural aquatic environments in Christchurch (Watts, 2003).

4 Transformation of Water: From Angel to Demon

4.1 The 'Bowl' Effect in New Orleans

Having an active port, New Orleans was one of the major entry points into North America. In the nineteenth century, the city hosted new European immigrants and free people of colour to settle in the city. Both groups were seeking a better life in Crescent City. Building higher levees and pumping the water away from the settlements drained the neighbouring wetlands and helped to develop more areas. This process allowed the city to grow its footprint and to improve its economy (Campanella, 2006).

There were two reasons for building on these low-lying areas. Firstly, buildable land was scarce and new developments increased the economic benefits for the city. Secondly, being prone to flooding, these properties were cheaper, therefore more affordable for the working class. In the growing city, with the building of the streetcar, the richest people started moving to the high ground in the outskirts and the central areas were slowly inhabited by the low-income working-class migrants. These migrations within the city had an immediate effect on the socio-economic distributions of the population. This configuration immediately created an unjust risk exposure for poorer residents, which was witnessed during and in the aftermath of Hurricane Katrina in 2005 (Beck, 2013 [1992]; Brunsma, Overfelt, & Picou, 2010; Gotham and Campanella, 2011).

New Orleans has experienced numerous major events during the twentieth and twenty-first century that have contributed to the vulnerability of the city, most of which were either major hurricanes or the result of government decisions made over time (Toueir, 2015a). These events were: The Great Mississippi Flood (1927), end of Segregation (1961), Hurricane Betsy (1965), building the Mississippi River-Gulf Outlet (1968), Hurricane Ivan (2004), Hurricane Katrina (2005), the Great Recession (2008) and the Deepwater Horizon oil spill (2010) (Campanella, 2006, 2018; Gotham and Campanella, 2013; Toueir, 2015a, 2015b) (Table 7.1).

During flooding, New Orleans has been subjected to inundation by the Mississippi River, the overtopping and breaching of levees and the accumulation of water in neighbourhoods due to excessive tropical rain. These events have led to disastrous consequences for residents and have stayed in people's memory. For instance, to save New Orleans in 1927, the city government had to dynamite the levees in one of the neighbourhoods located down the river, which inundated these residential areas and people lost their homes (Campanella, 2006). During Hurricane Betsy (1965) and Hurricane Katrina (2005) levees were breached and parts of the city flooded (20% during Betsy and 80% during Katrina). Post-Katrina, new and higher levees were re-built to withstand hurricanes as strong or stronger than Katrina.

Halfway through the twentieth century, the city needed to re-invigorate its economy and revitalise its port activities, so an outlet was recommended to connect the city to the Gulf of Mexico. This solution was proposed to help ships reach the city faster and to avoid sailing upstream on the Mississippi River. In 1968, the Mississippi River-Gulf Outlet (MR-GO) was opened, and it had already acquired the name 'Hurricane Highway' as it made it easier for strong winds and elevated water levels to reach the city. Constant dredging was required to maintain the water at a certain depth to build and ensure the continued safe passage of larger ships. The dredging had a direct impact on the local ecosystem and aquatic life existing in the marshes and wetlands surrounding the city. It also allowed saltwater to enter freshwater wetlands that were mainly full of cypress forests. The latter did not survive and slowly died and the buffer zone that helped slow down the strong winds disappeared rendering New Orleans even more exposed to storm damage without vegetation cover; hence the MR-GO was labelled the 'Hurricane Highway' (Freudenburg et al., 2009).

4.2 Brisbane: Valleys of Flood and Drought

Aboriginal people had a detailed understanding of the physical and cultural landscape of the Brisbane River catchment. Social organisation was based on the seasonality of food abundances and language groups travelled along pathways, often along rivers and creeks, to be hosted by neighbouring clans for trade, feasting, ceremonies and dispute resolutions (Winterbotham, 1982). Early colonists had marginal success with their English crops and animals, becoming dependent on local Aboriginal people for food, shelter and firewood.

Convict labour from England was initially used to construct stone buildings from volcanic tuff, a rock quarried locally, along a treeless grid of streets with rough timber slab huts on rural holdings (Horton, 1988). As free settlers arrived in Brisbane Town after 1838, high set (or elevated) timber homes with corrugated metal roofs were extensively built in response to the city's steep topography, subtropical climate and availability of good quality hardwood timber felled in nearby forests (Davidson and Bowstead, 2017). High set timber homes allowed airflow for cooling and drainage of floodwaters under the floor level of houses on flood-prone land without compromising the liveability of the home. Before rail transport, rivers were often used to transport logs from nearby forests to timber mills located close to riverbanks.

Dredging of the river began in 1862 for navigation purposes between Ipswich and Brisbane, followed by dredging for extraction of construction materials which was stopped in 1998. After World War II, Brisbane expanded rapidly, and 'post-war housing' created new metropolitan suburbs around the city centre and along river and stream lowlands (Davidson and Bowstead, 2017). In the 1990s interstate migration pushed large greenfield developments towards Ipswich in the west, Narangba in the north and Logan to the south. Many of these suburbs were in low-lying flood-prone areas and were severely damaged by flooding in 2011.

Major floods in Brisbane have occurred in 1841, 1893, 1974 and 2011 as the Queensland coast has been hit regularly by cyclones moving across the tropical zone to the north (Table 7.1). Flood mitigation infrastructure began in 1893 with the proposed Somerset Dam on the Stanley River near Kilcoy, a tributary of the Brisbane River (Davidson and Bowstead, 2017). Downstream from Lake Somerset, the Wivenhoe Dam was constructed in 1985. This meant that over half of the Brisbane River catchment is now regulated for flood mitigation.

Water supply, however, has been an even bigger challenge as drought and bushfires continue to affect Australia. Wivenhoe Dam can hold 1.15 million megalitres of precious drinking water and can also store an additional 1.45 million megalitres, equal to 2.5 times the volume of Sydney Harbour. This additional capacity is the dam's flood storage compartment and works to hold back floodwaters (SEQ Water, 2019). Management of dam levels remains a difficult balance between flood control and water supply to this day.

Major floods in 2011 tested this balance for Somerset, Wivenhoe and North Pine dams specifically tasked with flood mitigation as well as water supply in South East Queensland. A Queensland Floods Commission of Inquiry made clear to flood victims that no dam can guarantee the prevention of flooding in areas downstream of it and that all dams have limits to the amount of water they can hold without their structural integrity being at risk (Queensland Floods Commission of Inquiry, 2012, p. 438).

4.3 Christchurch: Prioritising Multi-Functional Stormwater Infrastructure

The Christchurch Drainage Board succeeded in managing the city's waterways and sewers between 1875 and 1989 (Watts and Greenaway, 1999). Local government reforms in 1989 led to the merging of Christchurch Drainage Board (CDB) with Christchurch City Council (CCC) (Watts, 2011). In 1996, CCC formulated the 'Waterways and Wetlands Natural Asset Management Plan' to introduce a value-based approach for the sustainable management of surface water environments in the city. This asset management plan employed an area-planning approach and was centred around ecological functioning of waterways through six main values: landscape, recreation, culture, ecology, heritage and drainage. It covered broad categories of assets in Christchurch such as rivers, waterways (with tributaries) and hillside waterways (Watts, 2003). This approach included the spectrum of flood-risk reduction through civil defence measures, emergency management and it expanded

Christchurch City Council's responsibility in land use and stormwater management (Regenerate Christchurch Te Kowatawata, n.d-b).

Christchurch is a low-lying city with areas that are prone to flooding during heavy rainfall. Christchurch's recognised vulnerability towards many hazards such as flooding, coastal erosion, slope instability, liquefaction and tsunami increased following the 2010–2011 earthquake (Table 7.1). The flooding patterns in the city were modified due to land subsidence (dropping from 200 to 1000 mm) and lifting occurring extensively in the city. Water storage capacity in river stretches and streams was reduced with stormwater infrastructure being damaged. The areas of greater risk were low-lying areas located near the coast and the rivers (Regenerate Christchurch Te Kowatawata, n.d-a) that had undergone a phase of previous urban development. This created problems for people residing in floodplain areas, as there were no adopted measures to detain water naturally (Watts, 2003). The flat land of the residential 'red zone', where homes were demolished after the 2010–2011 earthquakes, was also at high risk with projected extensive flooding from a 1 in a 50-year flood or less (Regenerate Christchurch Te Kowatawata, n.d-a).

The Council identified opportunities to continue with their six-value asset management approach by developing the flood mitigation infrastructure that enhanced cultural, social, ecological and cultural connections for local communities. Also, the Council set up a Land Drainage Recovery Programme (LDRP) in 2012 to address the issue of flooding in waterways and restore flood risks to pre-earthquake levels. The LDRP prioritised properties that were at high risk and worked actively to develop area-wide solutions offering maximum benefits to people. One of their notable works was the Bells Creek catchment project in Woolston, south-east of Christchurch CBD, that was at greater risk of flooding due to ground subsidence (Bell, 2019). This area of 160 ha included both commercial and residential land, and it experienced significant land-damage due to the Canterbury earthquakes. This land subsidence caused the upper part of the catchment to sink (by 200–300 mm) and the lower part to rise, thereby reducing the ability of the catchment to drain and increasing the number of houses at risk of above-floor flooding (Bell, 2019). The Bells Creek catchment drained into the Heathcote River (being susceptible to flooding).

In Christchurch, wide-ranging post-earthquake maintenance and repair works were commenced in 2017 to improve the city's water storage capacity of drains and waterways. Developments over the last decade include retrofitting measures such as the construction of open drains, concrete-lined channels and stormwater basins, dredging, positioning of tide gates, stopbanks and pumping stations on its high flood-risk zones. New subdivisions were identified and designed to cope with a 1 in a 50-year flood event. More recently, the CCC engaged in construction and restoration of large natural wetlands in the upstream catchments of Avon, Styx and Heathcote Rivers to detain and store excess floodwaters within the catchment (Christchurch City Council, n.d.).

5 Resilient Landscape Planning and Design: Barriers and Enablers

5.1 Resilience by Design

The relationship between resilient planning and design seems to be an obvious one, but the literature does not offer substantial input on supporting this view. In disaster research, resilience planning takes place at the higher levels (United Nations, national governments and local councils). Design solutions become the result of this planning process instead of being part of it. Landscape architecture, a discipline that crosses humanities, sciences and the arts, ought to be at the heart of such a conversation. 'Understanding resilience is central to understanding sustainability [...]. Resilience theory is at the frontier of contemporary urban planning and design, serving as a robust platform for shaping and articulating the regenerative work of landscape architects, planners, and architects' (Novotny et al., 2010, p. 145). With climate change on the rise and sustainability at the core, resilient design ought to be part of the discussion.

In the three chosen cities in this chapter, the decision to plan for a resilient future took place after major disaster events that caused major damage and loss of life. In order to achieve such a goal, many barriers and enablers influenced the process, and all three cases dealt with these obstacles and opportunities differently. Therefore addressing these barriers and enablers is important in understanding how these cities are transitioning to a better future.

5.2 Barriers to Resilience

The three selected cities, New Orleans, Brisbane and Christchurch are all flood-prone cities, and they each have had to face, historically and current, multiple devastating flood-related events, and they have to adapt to the consequences by learning to live with water and rebuilding better. All three of them have had to: (1) face existing natural threats that are exacerbated by climate change, (2) cope with a complex existing urban fabric and infrastructure network, (3) restore lost or damaged ecosystems due to the human impacts and urbanisation, (4) address the different levels of social stresses to help the communities rebuild themselves and (5) rethink the transit services due to a major disruption.

5.2.1 Natural Threats from Geomorphologies

All three cities are located within broad floodplain landscapes that rank water (both excess and scarcity) as the most hazardous risk factor affecting population resilience (Table 7.2). They are all affected by floods as the most frequently occurring

Table 7.2 Comparison of barriers and enablers for three flood-prone cities

S.No.	Description	New Orleans	Brisbane	Christchurch
Barriers to resilience				
1	Natural threats from geomorphologies	• Flooding and storm surges • High water table and saturated soils • Accelerated land subsidence (Colten et al., 2008a; City of New Orleans, 2015)	• Flooding and sustained rainfalls over Brisbane River catchment • Climate variability • Tsunamis in the Pacific Ocean (Brisbane City Council, 2013; Iezzi ^ Perera, 2017)	• Seasonal flooding, storm surges and inundation • Earthquakes and the alpine fault as the primary seismic threat • Climate change—Sea level rise, drought, wildfires (McSaveney, 2006; Greater Christchurch Partnership, 2016)
2	Standardised urban structure and protective infrastructure	• Building in low-lying areas • Below sea level, bowl shaped location (Colten et al., 2008b)	• Lack of standardised building codes • Inadequate structural measures to reduce the impacts of 'backwater' flooding (Brisbane City Council, 2013; Queensland Government, 2017; Queensland Reconstruction Authority, 2019)	Low-lying city with areas prone to flooding during heavy rainfall (Christchurch City Council, n.d.)
3	Vulnerable wetland ecosystems.	Excess saltwater due to wetland drainage, directly impacted local ecosystem and aquatic life (City of New Orleans, 2015)	Food and habitat shortages were experienced. Terrestrial biodiversity, habitats and wildlife were significantly impacted by flood events (Queensland Government, 2017)	Earthquakes caused excess silt clogging that caused reduction of population and diversity of freshwater creatures in Christchurch's waterways (Scimex, 2015)

(continued)

Table 7.2 (continued)

S.No.	Description	New Orleans	Brisbane	Christchurch
4	Poor planning and short-term thinking.	Lack of social equity and opportunity (Colten and Sumpter, 2009)	Physical and psychosocial health of residents was significantly impacted during the floods (Queensland Government, 2017, 2020)	• Lack of housing and social equity—affordability, low wage economy • The earthquakes impacted mental health of many people and recovery was expected to take 5–10 years (Greater Christchurch Partnership, 2016; New Zealand Parliament, 2014)
5	Disruptable transit services	Lack of comprehensive regional vision for transit service (City of New Orleans, 2015)	More stress created on the existing transport system in the city that required an estimated $2 billion AUD for repair of its public infrastructure (Queensland Reconstruction Authority, 2019; Van den Honert and McAneney, 2011)	Post-earthquakes, rapid transformations were seen in transport network and its surrounding land uses in Christchurch (Koorey, n.d.)

(continued)

Table 7.2 (continued)

S.No.	Description	New Orleans	Brisbane	Christchurch
Enablers of resilience				
1	Planning for urban resilience	**2013**: Greater New Orleans urban water plan (UWP) released (Waggonner and Ball, 2013, p. 13) **2015**: Resilient New Orleans: Strategic actions to shape our future city (City of New Orleans, 2015)	**2011**: Flood action plan released **2013**: Brisbane's flood-smart future strategy 2012–2031 released **2017**: Resilient Queensland in action released **2018**: James Davidson architects in Brisbane initiated a design charrette **2019:** The Brisbane River strategic floodplain management plan released (Brisbane City Council, 2013; Iezzi & Perera, 2017; Queensland Reconstruction Authority, 2019; Davidson and Bowstead, 2017)	**2016**: Resilient greater Christchurch plan released to mobilise government agencies to develop a risk reduction framework in Christchurch **2019**: Ōtākaro Avon river corridor regeneration plan released (Greater Christchurch Partnership, 2016; Regenerate Christchurch Te Kowatawata, n.d-b)
2	Restoring ecosystems for frequent flood events	• **2008**: MR-G0 canal closed to start the process of restoring wetlands • **2012**: A wetland restoration plan initiated • **2017**: Louisiana comprehensive master plan released. (Coastal Protection and Restoration Authority of Louisiana, 2017)	**2017**: Queensland Strategy for disaster resilience released (Queensland Government, 2017)	**2011**: Restoring wetlands and stream enhancements measures are being undertaken in Christchurch (Regenerate Christchurch Te Kowatawata, n.d-b; Watts, 2011)

(continued)

Table 7.2 (continued)

S.No.	Description	New Orleans	Brisbane	Christchurch
3	Preparation for frequent but less intense events	• Redundant and reliable infrastructure proposals worked with natural systems and provided multiple benefits to residents • **2013**: Greater New Orleans urban water plan (UWP) released (Waggonner and Ball, 2013, p. 13)	• Retrofitting measures proposed • Forecast radar and drones were used for flood surveys • Flexible and responsive building and infrastructure design proposed • Construction of new sea walls and modification of existing sea walls for providing additional protection to properties affected by storm tide flooding (Brisbane City Council, 2013; Iezzi & Perera, 2017; Queensland Government, 2017, 2020)	• Developed a risk reduction framework for efficient interventions around threats and hazards • Hard engineering solutions • Creating adaptable places. Reinvestment and revitalisation of neighbourhoods • Improving the quality, choice and affordability of housing • Supported community preparedness programs in response to risk acceptance (Greater Christchurch Partnership, 2016; Murphy and Smith, 2016; Regenerate Christchurch Te Kowatawata, n.d-b; Watts, 2011)
4	Reliable and affordable communication and transport	Investment in creation of a multi-model regional transportation system with a reliable and affordable communication network (City of New Orleans, 2015)	Planned phase adjustments in transport infrastructure (Hayes et al., 2019)	• Coordinated transport and infrastructure delivery with the potential of local rail transport being explored • Christchurch cycleways network established (Brownlee, 2012; Koorey, n.d.)

(continued)

Table 7.2 (continued)

S.No.	Description	New Orleans	Brisbane	Christchurch
5	Knowing our neighbours.	Restoration of community organisations with multiple steps taken to improve community resilience in terms of anticipation, response, recovery and reducing future impacts (Colten et al., 2008b)	Brisbane's volunteer response: • 'Knowing your neighbour' • Brisbane's 'mud army' Brisbane Council developed a volunteer management strategy and established a capability for registering, equipping and deploying volunteers to where support was most needed (Cheshire, 2015; Queensland Government, 2020; Van den Honert and McAneney, 2011)	• Strengthening of community risk management • Student volunteer army was created to clear liquefaction and offer support for other residents and organisation. More than 11,000 students participated (Greater Christchurch Partnership, 2016)
6	Improvements for affordable insurance premiums	Low-interest capital and a potential reduction in insurance premiums served as incentives to property owners for investing in stormwater resilience infrastructure (City of New Orleans, 2015)	Post-Brisbane floods, the official review of national disaster insurance proposed models to ensure flood-insurance to more homeowners, with flood-studies be made available to them for determining the cost of the risk (Van den Honert and McAneney, 2011)	Role of insurance as a tool for rebuilding and risk mitigation and risk transfer in a post-flood event was considered critical. Insurance premiums were kept at affordable range, with information available to people to help them understand the extent to which they could protect their interests (Greater Christchurch Partnership, 2016; Regenerate Christchurch Te Kowatawata, n.d-a)

natural hazard, even on a global level (International Actuarial Association, 2019), before storms, earthquakes, extreme temperatures, landslides, drought, wildfire, volcanic activity and mass movement.

With flooding being the main hazard for each of these cities, the natural threats that they confront differ according to the geomorphology of each landscape. New Orleans is surrounded by water from the north (Lake Pontchartrain) and the south (the Mississippi River) and the canals that cross through it. It is at risk of becoming inundated from more than one place where storm surges can raise the water level of the Mississippi River, or the canals can be overtopped and levees can break

(Hurricanes Katrina and Rita 2005) (City of New Orleans, 2015). These events are exacerbated by existing geomorphological factors like high water table and saturated soils, accelerated land subsidence and coastal and wetland erosion (Colten, Kates, & Laska, 2008b). Brisbane can flood from either elevated water levels of the Brisbane River due to heavy or sustained rainfalls over the catchment or from sea level rise because of climate variability. It is also at risk of tsunamis coming from the Pacific Ocean (Brisbane City Council, 2013; Iezzi & Perera, 2017). Christchurch is a coastal, low-lying and flat city, and its main threat is earthquakes and it is located on the alpine fault. Any seismic activity in or around the Pacific Ocean has the potential to generate a tsunami. Its topography makes it vulnerable to coastal flooding, storm surges and seasonal floods (Greater Christchurch Partnership, 2016; McSaveney, 2006). All three cities are directly impacted by climate change with sea level rise and drought.

5.2.2 Standardised Urban Structure and Protective Infrastructure

New Orleans and Christchurch are both low-lying cities, where the first is known for its levees that act like a double-edge sword (protecting it from water entering but also traping the water within the walls), and the latter for being mostly flat (Table 7.2). Due to the fact that both used to be wetlands and swamps, they both have a high water table and saturated soils, they can easily flood following heavy rainfall event (Colten et al., 2008b). In the case of Brisbane, it lacks standardised building codes against flooding, and in the case of an event, the existing structural measures are inadequate to reduce the impacts of 'backwater' flooding (Brisbane City Council, 2013; Queensland Government, 2017; Queensland Reconstruction Authority, 2019).

5.2.3 Vulnerable Wetland Ecosystems

All three cities have suffered from the significant loss of ecosystems which in turn have increased their exposure to major flood events (Table 7.2). In New Orleans, the draining of wetlands to develop residential areas and the building of the Mississippi River-Gulf Outlet (MR-GO), labelled 'Hurricane Highway', allowed saltwater to enter freshwater ecosystems that destroyed existing cypress forests, hence exposing the city to hurricane winds and water surges (City of New Orleans, 2015). In Brisbane, the flood events had significant impacts on the loss of terrestrial biodiversity, habitats and wildlife, and the city experienced food and habitat shortage (Queensland Government, 2017). After the 2011 earthquakes, Christchurch's population and diversity of freshwater creatures were significantly reduced as a result of excess silt clogging the city's waterways. Pollution-sensitive insects and fish diversity diminished and were severely affected by siltation (Scimex, 2015).

5.2.4 Poor Planning and Short-Term Thinking

When disasters hit, not only do they affect built infrastructure and ecosystems, but also they leave short- and long-term impacts on communities and their well-being (Table 7.2). In all three cases, the most devastating consequence is the loss of life; also, each of the events exposed underlying issues of social inequity and injustice. The rebuilding process was long and tedious, uncovering a lack of management and planning to accessible and affordable housing opportunities. Both Christchurch and New Orleans were experiencing a decline in their population numbers prior to the events which were exacerbated post-disaster (Colten and Sumpter, 2009; Greater Christchurch Partnership, 2016; New Zealand Parliament, 2014; Queensland Government, 2017, 2020).

These cities are blessed with recognised indigenous populations that have very different relationships with hydrological landscape processes compared to contemporary migrant populations (Table 7.2). They provide good examples of illustrative European settlements (both English and French) that introduced engineering and architectural methods of controlling and mitigating the impacts of landscape processes such as flooding, storms, earthquakes, extreme temperatures, drought and wildfire. They are recognised as the cities that utilised colonial construction strategies that allowed relatively short-term successes but long-term vulnerabilities, while diverse infrastructure, architectural and landscape strategies are now required in an era of climate change.

5.2.5 Disruptable Transit Services

Transit and transportation services were heavily impacted by the disaster in each of these cities (Table 7.2). In New Orleans, there was a lack of comprehensive regional vision for transit service due to which the city faced significant challenges in connecting residents to jobs and services, attracting new residents and remaining competitive for scarce federal transportation funding (City of New Orleans, 2015). In Brisbane, the floods created stress on the existing transport system that required an estimated amount of $2 billion for repair of its public infrastructure such as eroded roads, river crossings and culverts (Queensland Reconstruction Authority, 2019; Van den Honert and McAneney, 2011). In Christchurch, the city experienced rapid transformations in both transport network and its surrounding land uses after the earthquakes (Koorey, n.d.).

5.3 Enablers of Resilience

Building resilience for the three chosen cities did not come overnight. After witnessing loss at the human, ecologic and economic levels, each of the cities set a new course of action towards a more resilient future. The planning process focused on the social, economic, ecological and infrastructural levels. The main enablers of resilience for New Orleans, Brisbane and Christchurch are: (1) developing rebuilding plans for urban resilience that meet the needs of citizens and the city (Table 7.3), (2) putting in place measures to restore damaged ecosystems, (3) preparing for more frequent but less intense events, (4) planning for a future with more reliable and affordable communication and transport services, (5) getting to know our neighbours and (6) setting up a reliable and affordable insurance system for future events.

Strategies for stability and predictability in these three cities reduced the populations' abilities to deal with unexpected events, as suggested by Gunderson and Holling (2002). Reliance on levee construction reduced water table levels and

Table 7.3 Comparison of critical characteristics of plans, policies and strategies for designing socio-ecological resilience in the three flood-prone cities based on the 100-resilient cities framework (2019)

City	Title	Champions	Connections	Health and Education	Infrastructure	Governance	Place-Making	Heritage	Finance	Services and Amenity
New Orleans										
National and State Policies	**2011:** National Flood Insurance Program (NFIP)					■			■	■
	2014: Federal Resilience Policy			■	■	■				■
	2015: Federal Flood Risk Management Standard			■	■	■				■
	2019: Flood Resilience and Risk Reduction: Federal Assistance and Program.			■	■	■			■	
Plans and Strategies	**2007**: Unified New Orleans Plan (UNOP)			■	■	■		■		■
	2013: Greater New Orleans Urban Water Plan (UWP)		■		■	■	■			■
	2015: Resilient New Orleans Strategic Actions to Shape our Future Cities.	■	■	■	■	■	■	■	■	■
	2016: Housing for a Resilient New Orleans, Five-Year Strategy		■	■	■	■	■		■	■
	2017: Louisiana Comprehensive Masterplan for a Sustainable Coast.		■		■	■	■	■		■
Brisbane										
National and State Policies	**2016**: Policy for Offers of Assistance		■			■			■	■
	2017: State Planning Policy		■	■	■	■	■	■		■
	2017: Strategic Policy Framework Riverine Flood Risk Management and Community Resilience.				■	■		■		■
	2017: Queensland Climate Adaptation Strategy		■	■	■	■			■	■
	2017: Queensland Climate Transition Strategy		■	■	■	■	■			■
	2017: Queensland Strategy for Disaster Resilience	■	■	■	■	■	■	■	■	■
	2018: Queensland State Disaster Management Plan		■	■	■	■		■	■	■

Tab. 7.3 (continued)

City	Title	Champions	Connections	Health and Education	Infrastructure	Governance	Place-Making	Heritage	Finance	Services and Amenity
Plans and Strategies	**2011**:Brisbane Flood Action Plan.		■		■	■		■		■
	2011: National Volunteer Management Strategy		■	■		■				■
	2012: Brisbane Flood-Smart Future Strategy (2012-2031)				■	■	■			■
	2018: Design Charette by James Davidson Architects	■	■	■	■	■	■			■
	2019: Brisbane River Strategic Floodplain Management Plan	■	■		■	■				■
Christchurch										
National, State and City Policies	**1991**:Resource Management Act				■	■		■		■
	2002: Civil Defence Emergency Management Act				■	■				
	2002: The Local Government Act			■	■	■				■
	2016: Christchurch City Council Housing policy			■	■	■			■	■
	2014: Christchurch Food Resilience Policy	■	■	■	■	■		■		
	2017: Christchurch Flood Intervention Policy				■	■				■
	2013: Canterbury Regional Policy Statement		■	■	■	■	■	■		■
Plans and Strategies	**2012**: Recovery Plan and Strategy for Christchurch.		■	■	■	■	■	■	■	■
	2012: Greater Christchurch Transport Plan		■		■	■	■			■
	2012: Land Drainage Recovery Program (LDRP)			■	■	■		■	■	■
	2013: Land Use Recovery Plan		■	■	■	■	■	■	■	■
	2015: Christchurch City Council Long Term Plans (2015-2025)			■	■	■		■		■
	2016: Resilient Greater Christchurch Plan	■	■	■	■	■	■	■	■	■
	2018: Christchurch City Council 30-year Infrastructure Strategy (2018-2048).			■	■	■	■	■		■
	2019: National Disaster Resilience Strategy	■	■	■	■	■	■	■	■	■
	2019: Ōtākaro Avon River Corridor Regeneration Plan		■	■	■	■	■	■		■
	2019: Resilience Strategy for Natural Hazard Risk Reduction (2019-2029) by Earthquake Commission (EQC)			■	■	■			■	■

increased the vulnerability of New Orleans to major storm events. Dam construction to regulate the water supply and mitigate floods has not prevented drought and flooding in Brisbane. Drainage infrastructure in Christchurch exacerbated liquefaction and impacts of earthquakes in the Canterbury region. Institutions are now seeking the means to continually learn from environmental feedback and capture a greater understanding of ecological attributes and human efforts. However, the past experiences have shown us that institutional management inevitably leads to less flexibility, more dependence and greater control over populations and water regimes (Holling, 1995). New Orleans, Brisbane and Christchurch have all suffered from inertia and rigid responsiveness to critical events such as Hurricane Katrina, Brisbane floods and Christchurch earthquakes. However, the three cities are moving forward with integrated planning strategies, responsive designs of structures and spaces and participatory processes for citizens to learn from successes and failures in their neighbourhoods. According to the resilience discourse, if this occurs, these cities will then be 'bouncing forward' (Manyena, 2011), and setting the course to a new way of planning their future.

5.3.1 Planning for Urban Resilience

All three cities proposed numerous plans after the disastrous events they had witnessed (Table 7.2). The 100-Resilient Cities framework (Table 7.3) was adopted by New Orleans and Christchurch, and in both cases, plans brought other plans together to propose one coherent proposition for each of the cities. In New Orleans, many plans were proposed after 2005, some tackled the rebuilding of the city, others concentrated on the restoration of the wetlands and ecosystems and others focused on disaster management and mitigation. In 2015, the 'Resilient New Orleans: Strategic Actions to Shape our Future City' was proposed to help bring a coherent view to a more resilient future with an emphasis on concrete solutions from the 'Greater New Orleans Urban Water Plan' that was proposed in 2013. The latter plan was proposed by the architects and urban designers to bring sustainable and design solutions to the recurrent floods that the city had witnessed (Table 7.3).

In 2016, the city of Christchurch published its 100-Resilience Cities plan 'Resilient Greater Christchurch', which followed many plans that focused on land use, drainage and transportation. The plan was followed by the 'Ōtākaro Avon River Corridor Regeneration Plan' in 2019 which proposed a series of culturally appropriate and design solutions to revitalise one of the main rivers that travels through the city. In both cases, the 100-Resilient Cities framework helped to bridge differences between community leaders and representatives from local government to formulate solutions that respected people's need and aspirations (Table 7.3).

Brisbane developed its own plans to be more prepared against floods. The two main plans were the 'Resilient Queensland in Action' in 2017 and the 'Brisbane River Strategic Floodplain Management Plan' in 2019. The latter was a strategic resilience plan which was state supported, regionally focussed and locally led; it provided a framework for a consistent approach to managing the Brisbane River floodplain (Table 7.3). In 2018, James Davidson Architects in Brisbane initiated a design charrette for pushing institutional flexibility for creating multi-scalar ways of dealing with water across Brisbane catchment at city, neighbourhood and property levels. A wide ranging team of participants focused on bringing forward design solutions to build a city that can easily adapt to future floods.

5.3.2 Restoring Ecosystems for Frequent Flood Events

Multiple steps needed to be put in place to restore the damaged ecosystems of each of the case studies (Table 7.2). In New Orleans, the first step was taken in 2008 with the closing of the Mississippi River—Gulf Outlet (MR-GO) to help freshwater wetlands to be re-established. In 2012, a wetland restoration plan was initiated, to finally reach a Louisiana comprehensive master plan in 2017. The master plan's focus was to set out projects that aimed to respond to loss of coastal land and storm surges threats (Coastal Protection and Restoration Authority of Louisiana, 2017). In Brisbane a 'Queensland Strategy for Disaster Resilience' plan was published in 2017. Its focus was on maintaining the natural environment to preserve the natural buffers and critical ecosystems that contribute to resilience (Queensland Government, 2017). In Christchurch since 2011, wetlands are being restored and constructed to act as temporary detention ponds for mitigating water-flow regulation. Stream enhancements measures are also being undertaken by the Christchurch City Council (Regenerate Christchurch Te Kowatawata, n.d-b; Watts, 2011).

5.3.3 Preparation for Frequent but Less Intense Events

In order to manage the future threats and risks to flood, the city of New Orleans had to not only focus on restoring neighbouring swamps and wetlands, but also revise the way the city was designed (Table 7.2). The canals, levees, building codes and standards had to be re-thought to minimise recurrent floods and protect against major flood events. The 'Greater New Orleans Urban Water Plan' (UWP) was presented in 2013 as a roadmap for improving flood management and the threats of subsidence through innovative urban design solutions (Waggonner and Ball, 2013; Waggonner et al., 2014). In Brisbane, the proposed solutions were to retrofit and renovate existing properties; design new buildings and infrastructure to provide more flexible and responsive means of adapting housing stock; use forecast radar, drones and 3D scanning for flood modelling and surveys; introduce more adaptation planning measures to address sea level rise and build new sea walls and modify existing walls to provide the additional protection to properties (Brisbane City Council, 2013; Iezzi & Perera, 2017; Queensland Government, 2017). In Christchurch, a risk reduction framework was developed for efficient interventions around threats and hazards; engineering solutions were proposed such as stop banks and stormwater pump stations and seismic land strengthening and flood storage basins were employed as trial projects (Greater Christchurch Partnership, 2016; Regenerate Christchurch Te Kowatawata, n.d-b; Watts, 2011).

5.3.4 Reliable and Affordable Communication and Transport.

All three cities needed to revise their underground infrastructure networks, whether from floods or earthquakes, each of the cities witnessed extensive damage and massive repairs needed to be done to restore access to water and electricity and a functioning sewage system (Table 7.2). With an inequitable transportation network and an absent evacuation plan, New Orleans is now planning for a more equitable city and is investing in a multi-modal regional transportation system with a reliable and affordable communication network that connects its people to jobs, services, education and recreation (City of New Orleans, 2015). Brisbane has set in place phased adjustments to its transport infrastructure (Hayes et al., 2019). Christchurch is investing in transport alternatives like coordinated transport and infrastructure delivery, cycleway networks and proposing local railway branch lines (Brownlee, 2012; Koorey, n.d.).

5.3.5 Knowing Our Neighbours.

Following any disaster, communities come together and cities witness a great level of community involvement, participation and volunteering (Table 7.2). Community resilience has not always been part of the planning process but post-disaster cities realise the importance of promoting and cultivating community resilience. In New Orleans, community participation now plays an important role in the planning process, therefore recognizing community organisations with volunteers and non-profit organisations playing an important role in restoring housing and in providing the essential services. Multiple steps have been taken to improve community resilience in terms of anticipation, response, recovery and reducing future impacts (Colten, Kates, & Laska, 2008a). In Brisbane, many volunteer responses took place: ‘Knowing your neighbour’ and ‘Mud army’. Brisbane City Council developed a volunteer management strategy and established a capability to register, equip and deploy volunteers to where support was most needed (Cheshire, 2015; Queensland Government, 2020; Van den Honert and McAneney, 2011). In Christchurch, community resilience came through the partnership of the city with local community leaders to develop, improve and sustain support programmes for vulnerable people, and student volunteer army was created to clear liquefaction and offer support for other residents and organisations (Greater Christchurch Partnership, 2016).

5.3.6 Improvements for Affordable Insurance Premiums.

In post-disaster situations, insurance becomes problematic. In the three chosen cities many issues arose around accessing funds to rebuild homes (Table 7.2). In order to avoid repeating the same mistakes, all three cities proposed different approaches to dealing with insurance. In New Orleans, low-interest capital and a potential reduction in insurance premiums served as incentives to property owners for investing in stormwater resilience infrastructure improvements such as elevating floor levels, flood proofing and integrating stormwater management features (City of New Orleans, 2015). After the Brisbane floods, numerous insurers did not provide riverine flood-insurance due to absence of information for determining the price of the risk. An official review of national disaster insurance proposed models to ensure flood-insurance to more homeowners, with flood studies made available to them for determining the cost of the risk (Van den Honert and McAneney, 2011). In Christchurch, the role of insurance as a tool for rebuilding, risk mitigation and risk transfer in a post-flood event was critical. Keeping insurance premiums within an affordable range, with information on values and types of insurance was important to help people understand the extent to which they could protect their interests (Greater Christchurch Partnership, 2016; Regenerate Christchurch Te Kowatawata, n.d-a).

6 Build Back Better: Drivers for Landscape Resilience

Resilience is connected to the capacity of vulnerable components of a system to respond to disturbances and to the overall capacity of response of socio-environmental systems (Gallopín, 2007). Developing urban resilience is about *sustaining* capacity and prospects for development and about *securing* social, economic and environmental developments in our cities in both the present and future (Folke et al., 2002). The three cities—New Orleans, Brisbane and Christchurch—demonstrate how risk of future vulnerabilities is being reduced through attempts to think creatively about the drivers of landscape change that 'build back better' in our urban landscapes.

While designers often outline design principles that guide their work, their efforts are generally location-specific. The common inspiration for high quality landscape planning and design is the uniqueness or genius of each place, the *genius loci*. The difficulty then is how to apply the site-specific innovations from elsewhere to a current project. Ahern (2013) suggested the five strategies connected to socio-ecological theory to associate design innovation with empirical monitoring for further development. In this chapter these strategies are reworked and proposed as the potential drivers of landscape change to sustain and secure functional urban systems into an initial framework for examining initiatives undertaken in New Orleans, Brisbane and Christchurch.

6.1 Multi-functionality of Land Uses

Multifunctionality in landscape planning and design is the combining of functions to operate independently or interdependently within the same physical space. Ways of achieving this include time-based land uses (time shifting) or colocation (space stacking) (Ahern, 2013, p. 1208). This not only improves the efficiency of use of limited resources, but also offers potential in facilitating the support for maintaining these valuable resources by greater numbers of community stakeholders. For example, Christchurch is fortunate to have large open green spaces such as Hagley Park where sports fields and recreational facilities are shared with festivals and large multi-day events. These events have similar requirements to emergency evacuation centres for displaced people during a flood or natural disaster. After the 2010–2011 earthquakes, many less affected schools in Christchurch shared their classrooms each day with students from schools that were badly damaged. One school would teach in the mornings and the other school would teach in the afternoons in the same classrooms. The sharing of resources, in this way, to maintain the functionality of schools, parks and communities was enabled by seeing the potential of existing places for widely varied activities at different times of the day, week, month and year.

6.2 Response Diversity of Communities

Response diversity can be understood as a diverse group of individuals or assemblages that function collectively but respond differently to shock events or long-term trends of changing circumstances. This is highly advantageous in the context of unpredictable events. For instance, in Brisbane, many residents who were less affected by flooding joined together to clean up public and private land with those who suffered significant damage and loss along the Brisbane River and Bramble Bay (where much of the flood debris was deposited) in 2011 and 2012. Some had shovels and brooms, other had excavators and bulldozers so the responses to the clean up were wide ranging. Older suburbs also had greater housing diversity so that households in more resilient homes could offer refuge to those in need. The diverse volunteer responses that took place in Brisbane were enabled by a shared belief in 'knowing your neighbour' even towards strangers across the city and the capacity to register, equip and deploy to where support was most needed.

6.3 Short Circuitry of Networks

Circuitry is an attribute of networks or chains of activities that comprise loops and circuits (Forman, 1995, p. 261), including those connections within a circular economy between production and consumption. The more short loops or circuits in a system, the more resilient it is to unexpected events than long distribution and delivery chains. They allow the system to sustain basic human needs such as food, water, power and waste services across the city. For example, urban agriculture in Christchurch is a growing civic movement of local food activists that grow and sell local produce to local residents, shortening the loop between producer and consumer. Growing food in public open spaces close to residential areas supplements the provision of food from supermarkets and broad scale agriculture, which can be badly disrupted by floods and other disturbances. The ability to create shorter cycles between producer and consumer, generation and usage, discard and reuse, in our economies is enabled by having the knowledge and expertise to share, the will to short circuit existing distribution chains and the time to contribute to both smaller local enterprises and larger institutional endeavours.

6.4 Multi-modal Connectivity of Functions

Urban connectivity is usually well developed for utilities such as water supply, energy, waste, communication and mobility such as private and public transport. However, connectivity for the dispersal of species movement, water quality and distribution, micro-mobility, recreation and cultural heritage are often less well developed in many urban environments (Ahern, 2013, p. 1207). Spatial organisation that offers high connectivity through many open corridors for the continuing flow of objects, despite faults and failures within parts of a system, increases urban resilience. For example, Christchurch is expanding its cycling routes along shared traffic corridors across the city, encouraging residents to travel further and more frequently by bicycle, thus reducing the dependence on fossil fuels from overseas. This city is also celebrating its cultural heritage along the Avon River, through constructing the National Earthquake Memorial, Ngāi Tahu representations of artefacts and language, the Margaret Mahy Playground, numerous art installations and historic sites of significance. This adds to the development and usage of new cycleways and the ecological restoration of habitats for aquatic species along this waterway. The development of ecological, social and cultural connectivity is enabled by a strategic commitment of local government agencies and community members working together to develop the strong ownership and stewardship of our waterways and wetlands.

6.5 Decentralised Modularity of Systems

According to Ahern (2013), planning and designing of urban environments would be better served by a modular series of decentralised and redundant components (p. 1201). This prevents failures from replicating and spreading through a system and increases overall resilience. For instance, in Brisbane, government subsidies for installing solar power systems on residential homes have had a significant impact on the demand for coal in Queensland leading to increased costs for energy from the grid, further encouraging the installation of solar panels on roofs. Water charging was introduced during the drought (1996–2010) when water restrictions were introduced as dam supply levels fell to 17% capacity in 2007. Individual household usage was metered and many water tanks were installed in backyards and commercial premises to reduce the reliance of households and companies on the potable water supply. The shift from a centralised supply of power and water to decentralised modular systems was enabled by consumption monitoring, government incentives for early adopters, perceived restricted or unreliable city-wide supplies and interests in shortening the loop between production and consumption.

7 Resilience and Adaptive Capacity By Design

Design approaches using socio-ecological theory (Folke et al., 2003; Gunderson and Holling, 2002; Gunderson et al. 1995) are slowly being recognised as offering a new way of facilitating resilience in cities. National building codes, local government planning schemes and insurance policies have largely focused on risk management (International Actuarial Association, 2019) rather than adaptive capacity, which is needed when 'surprise events' occur. Landscape architecture, ecology, planning and design are shifting from sustainable development, based on the notion of a stable equilibrium, to resilience capacity, that takes account of spatial and functional changes in complex, self-organising, socio-environmental systems. Cities can be understood as multiple systems operating together but vulnerable to shock the events and long-term landscape changes.

Physical landscapes and human influences of the three selected cities were shown to have many similarities, such as being home to local indigenous groups, migration of European settlers in the eighteenth and nineteenth centuries, major natural and man-made hazards occurring with increasing frequency, three tiered governance and centralised urban structures. They differed in their population size, area and landform changes over time. Adapting to changing socio-ecological environments was found to be centred on both social attitudes and actions as well as dynamic ecological processes.

The three case studies emphasise how three cities have dealt with change and the transformation of water from angel to demon, showing the importance of building adaptive capacity. In each case, major disturbances have prompted socio-ecological systems to respond to crises, reorganise themselves and redevelop the landscape and its communities to improve its survival in the future. New Orleans' urban design plans, seven demonstration projects and eight landscape planning projects are utilising design opportunities to reorganise civic spaces for more sensitive water management in the future (Waggonner and Ball, 2013, p. 106). Brisbane's example of the 'mud army', where thousands of volunteers came together to engage in helping flood victims with cleaning their homes, demonstrates the emergence of resilience within the communities (Zolli and Healy, 2012). Reviewing the role of insurance by the Christchurch City Council as a tool to assess risk transfer in areas of high flood risk will redistribute risk and share the possible vulnerabilities between those who are able to accept greater risks and those who cannot (Greater Christchurch Partnership, 2016). Change, renewal and diversity alone are not enough for success in the long-term. Social and collective memory have been directly correlated with response and preparedness (Colten and Sumpter, 2009). Experience, history, remembrance and trust are also necessary for resilience to develop in a particular context (Folke et al., 2003).

Barriers and enablers to resilient landscape planning and design were identified to promote sustainable and long-term solutions with the right combination and balance between predictability and transformability of social and ecological systems. By comparing cities with similar histories but divergent experiences specific to their own geomorphological and meteorological hazards, it is believed that the cities must find what is appropriate for their particular socio-ecological contexts. In designing places and spaces, the 'human element' is central (Ikeda, 2014). Building resilience capacity depends largely on strengthening social practices that encourage communities to come and act together in the aftermaths of disastrous events.

Drivers for reducing the risk of future vulnerabilities were proposed according to the work of Ahern (2013) in order to 'build back better' after hazard events. Each city demonstrated how wide ranging these drivers can be through attempts at thinking creatively about landscape system change. Building multifunctionality into the use of land in our cities; facilitating response diversity to the major and minor events; short circuiting distribution and delivery chains; improving connectivity for water, species, micro-mobility devices and cultural heritage and decentralising modular components for water, energy and transport systems are already being recognised as building resilience capacity in these three cities.

What is needed now is a series of adaptive institutional and community organisations that self-organise and learn as change occurs (Chen and Graham, 2011). Increasing the frequency of less intense hazard events such as burn-offs, water releases, flash floods and seismic tremors may help interweave incremental changes into our man-made systems to better prepare us for major events.

8 Conclusion

This chapter aimed to demonstrate the journey that three cities have taken on the road to more sustainable futures in the era of unpredictability and climate change, as suggested by Folke et al. (2003), rather than the stability and equilibrium. It focused on socio-ecological resilience using three cities that each have their context-specific vulnerabilities. Earth processes, with water as the formative agent, have created their unique regional contexts. Indigenous people largely adapted to their environment before colonisation that adapted the environment to suit human needs. While these cities have all experienced different natural events as disasters, they have collectively faced the consequences of storms, floods, droughts, fires and earthquakes. Their colonial history forged their modern identity, with a complicated relationship between habitation and water, as both angel and demon, that ended up rigidly controlling natural flows. They are aiming to enable a more sustainable and long-term approach to rebuild and plan resilient social and ecologic infrastructures. City planning using socio-ecological drivers must now overcome barriers to promote adaptive capacity building, which can be translated into the design of flexible and multi-functional places and spaces to accommodate people and their needs as well as the environment and its fluctuations.

While New Orleans, Brisbane and Christchurch seem to have been successful at proposing national, state and district plans based on current thinking, they still have to face further barriers to resilient futures. The most important two are financing large-scale projects and setting up efficient insurance mechanisms for an uncertain future. These challenges extend beyond these three cases and are concerns for the coastal cities around the world, which are facing the direct consequences of climate change and sea level rise. Allowing people to build in high-risk areas is no longer the norm and may become very costly in potential loss of life and the disruption of both social and ecologic infrastructures. These processes will have a direct impact on the property values and can shatter the economy of a city or even of a nation. Flexible and multifunctional spaces will need to be put to the test, and design solutions can become the pillars for a more flexible and adaptable future.

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Chapter 8
The Key Role of Wetlands to Build Socio-Ecological Resilience against Drought: Case Study from Bhachau, Kachchh, Gujarat

Dushyant Mohil, Aditi Sharan, and Harsh Ganapathi

Abstract This study aims to understand community perceptions of wetlands' ecosystem services, their role in disaster risk reduction, threats and reasons for degradation in Bhachau, Kachchh district in Gujarat, India. For the study participatory approaches were used to collect data using questionnaires, interviews and field observations. The study also presents a quantitative investigation of the variability of meteorological dry/wet conditions of the Kachchh region during 1950–2020 by using the standardized precipitation-evapotranspiration index (SPEI). The study shows that the wetlands governed by village institutions are currently in decline and their use has gone down considerably over the years. The study also shows based on a practical case from a Partners for Resilience program examples showing that wetland conservation and management can offer effective solutions for disaster risk reduction against drought/floods by providing multiple benefits. By generating knowledge on wetlands in the region its integration within developmental planning can trigger wetlands conservation as disaster risk reduction intervention against droughts/floods.

Keywords Disaster risk reduction · Wetland conservation · Ecosystem service · Community perception · Standardized precipitation-evapotranspiration index · Developmental planning

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1 Introduction

This study aims to understand community perceptions of *wetlands' ecosystem services,* their role in disaster risk reduction, threats and reasons for degradation in Bhachau, Kachchh district in Gujarat, India. Wetlands are known to play an important role in disaster risk reduction, with the ability to capture more rainwater than other surfaces and assist with groundwater recharge, slowly releasing water during seasons with lower rainfall (Davies et al., 2016; Endter-Wada, Kettenring, & Sutton-Grier, 2020; Kumar, Tol, McInnes, Everard, & Kulindwa, 2017; Renaud, Sudmeier-Rieux, & Estrella, 2013).

Droughts, floods and desertification are directly connected with monsoon/rainfall patterns, ocean circulation, soil moisture and water availability. The problems of Indian rainfall are diverse, in terms of both the geographical distribution and seasonality, and spread over a period of years. Wetlands are productive, essential ecosystems that support and maintain the hydrologic resilience in landscapes, storing and supplying water for use especially in drylands accounting for variations in hydrologic functions (Acreman & Holden, 2013, Davies et al., 2016;).

The well-being of people in any given community is generally dependent on the availability and management of water resources such as wetlands. Issues related to water often have an impact on the livelihoods of people and the ecosystem at large. A lot of investment has gone into the development of water resources over the years, both by public and private institutions (Ballabh, 2008; Davies et al., 2016). Governance of water therefore entails a 'range of political, social, economic and administrative systems that are in place to develop and manage water resources, and the delivery of water services, at different levels of society'. The need for collective action and the organization of the governments play a key role in achieving the same (Rogers and Hall, 2003). There have been shifts and changes in the management of water resources overtime; developments of new alternative sources of water are observed despite the presence of freshwater wetlands which are increasingly getting neglected over time.

However, the use of hard engineering approaches for dealing with the water shortages such as dams and reservoirs is predominantly used. This approach has many risks, including the costs of construction, maintenance, posing dangers of dam failure and further ecological risks especially due to flow reduction downstream.

What is more, there are still several opportunities that upscale the role of wetlands as ecosystem-based solutions for their role in drought mitigation and climate adaption, instead of hard engineering approaches, proving cost-effective alternatives to store and release the captured water (Endter-Wada et al., 2020).

2 Wetlands' Role as Ecosystem-Based Solutions: A Case from Partners for Resilience Program

This case study elaborates how wetland restoration can build socio-ecological resilience (Jaramillo, Stone, Benson, & Eslamian, 2021) against drought as seen from implementation of Partners for Resilience program in Kachchh District, Gujarat state, India. As part of the Partners for Resilience Programme, Integrated Risk Management (IRM) solutions for resilience building are being promoted globally. IRM is a multi-sectoral approach for managing disaster risks in development approaches which blends Disaster Risk Reduction (DRR), Ecosystem Management and Restoration (EMR) and Climate Change Adaptation (CCA) to address the multi-faceted dimensions of vulnerability reduction and building community resilience. The programme in Gujarat is being implemented in Bhachau block of Kachchh district.

The PfR program focussed on capacity strengthening of CSOs/CBOs to work through participatory multi-stakeholder approaches to integrate IRM approaches within policies, and influence practices and investments.

PfR uses the GPDP for mainstreaming the IRM measures in local development plans, having Community Managed Ecosystem-DRR measures included. PFR does so by working together with local CSOs to conduct participatory hazard vulnerability and capacity assessments (HVCA) to identify gaps and concerns to be addressed with regard to infrastructure, livelihoods and ecosystems. The participatory approach enables communities, including the most vulnerable groups, to voice their opinions and include their ideas within the local development plans. This approach enhances the governance by local communities due to their involvement in the development process and leads to Community Managed Drought Risk Reduction measures that conserve and protect wetlands, thereby contributing to enhanced community resilience. The IRM informed GPDPs are receiving a great recognition and praise from state authorities. A key achievement is that one GPDP has been awarded for risk informed models for replication by the other GPs in Gujarat.

3 Physiography of Kachchh and Bhachau

As part of the programme, the study aims to understand the extent of drought in the landscape examining records from 1950 to 2020, to understand the spatial and temporal extent of droughts in the region, along with mapping of wetlands which offer natural resilience and assessment of community perceptions of wetlands and water resources.

The Bhachau block of Kachchh district (Fig. 8.1) falls under the Rapar stony waste region which extends over the north-eastern part of the district and a part of the coastal plains, a section of the block[1] touches the Greater Rann and is also a part of the Banni grasslands (GEC, 2011).

The block inhabited by 70 villages is sandwiched between Greater Rann (desert) of Kachchh (the largest saline wetland in India) in the north, Banni grasslands on the west, the Little Rann of Kachchh in the southeast and the inter-tidal flats of Gulf Kachchh in the south. Being located in the arid zone, the region is characterized by low rainfall (355 mm annually), extreme temperatures (reaching a high of 46 °C in

[1] An administrative sub-division of a district.

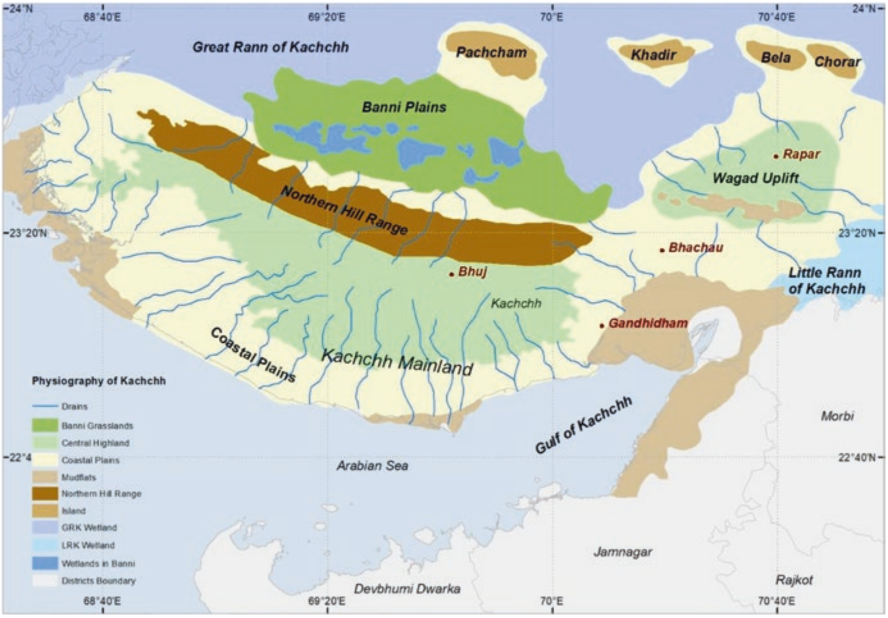


Fig. 8.1 Physiographic map of Kachchh (Source: Wetlands International South Asia 2020)

summer and 2 °C in winter) and scanty vegetation. The livelihood systems in the region are primarily livestock and agriculture based with the high seasonal migration to escape the vagaries of extreme weather. The Little Rann Kachchh region produces 30% of country inland salt and ginger prawn is exported as a major source of livelihoods to the communities living in Bhachau.

The Disaster Management Plan (DDMP) of Kachchh district formulated in 2019 by Gujarat State Disaster Management Authority (GSDMA) lists droughts, cyclones and floods as the key water mediated hazards. Ineffective integration of water management, particularly wetlands in developmental planning is one of the key causative factors for above mentioned hazards. Yet is insufficiently recognized in planning and policy making processes. The block by its inherent nature undergoes a prolonged dry spell. The communities living in the region conserved wetlands to ensure that the limited rainfall is adequately captured and groundwater recharged. In the 1970s, with the advent of diesel pumps, and energy subsidies, the dependence on surface water drastically decreased. The role of wetlands in recharging aquifers was not taken into account, and these were allowed to degrade due to community apathy as well as limited prioritization by government.

4 Water Scarcity Due to Droughts in Bhachau

Drought is associated with a moisture deficiency or dryness that leads to water shortage, crop damage, etc. Among all of the disasters, droughts are characterized by a slow onset and often considered as the most destructive in the long run. It can spread from months to years and results in an increased mortality of livestock, reduced income for farmers, increased food prices, unemployment and migration. The Irrigation Commission in 1972 classified areas vulnerable to drought as 'drought-prone' and 'chronically drought prone'. The Kachchh region of Gujarat falls under the second category, characterized by 40% probability of rainfall deficiency of more than 25% of the normal rainfall (Unnati, 2011).

Historically, the Bhachau region has been affected by water scarcity due to droughts. To understand the impact of droughts in Kachchh, as per the 1983 Census, 9600 cattles and 17,800 buffaloes were reported to be grazing in the Banni grasslands alone. In the years with good rainfall, the Banni area had more than 20,000 small ruminants along with the big cattle. The area suffered a 4-year long drought from 1986 to 1989, which eradicated most of these animals or scattered them in pockets across the area and in the long run witnessed massive livestock die-offs and outmigration of cattle at the time to South Gujarat and further up to 800 km for Kachchh. It also resulted in the decrease of grass coverage in the region from 8 to 1.5–3.5%. Seasonal migration is very common for pastoralists in Bhachau block and Kachchh in general. This is often due to unaffordability of continuous supplies of good quality fodder. In addition to that, the caste political protection for trade is also a reality which has often led to the loss of ownership of herds by pastoralists, especially during droughts (Cincotta & Pangare, 1994). The years 1999, 2000, 2013, 2014 and 2018 were the drought years as well.

5 Water Resources and Focus on Hard Engineering Approaches

The arid region of Bachau is blessed with the smaller freshwater wetlands in the form of village ponds, lakes covering an area of 15.25 km^2. The recent investments in development of industrial and communication infrastructure in the region (particularly during reconstruction phase after the 2001 Kachchh earthquake) have led to a substantive increase in water demand within a naturally fragile region. The remaining wetlands have been polluted due to discharge of domestic and industrial sewage.

The groundwater levels in the block variate from 2 to 55 m in the block, the plains have a water available closer to the surface when compared with the undulated hills of the Rapar region. Bhachau block has shown two distinct trends for salinity over the years, first, the regions bordering the Great Rann have the salinity touching 2000 ppm with a depth of 55 m (GEC, 2011).

Increased dependence on groundwater in Kachchh had created a situation in which Bhachau fell under the overexploited categories (previously known as dark zone) previous to 2011. According to a report by Gujarat Ecological Commission in 2014, the urban water demand for Bhachau is likely to double owing to the increase in urban population. Since 44% of water demands in Bhachau are met through groundwater which is saline, the extraction of the same will become a serious challenge.

Apart from the groundwater sources, the Chang river rises in the Sarsala hills near Gamdau village in the Bhachau block and flows the past villages like Kanthkot, Kakarva and Chobari among others. A minor irrigation dam was also constructed on this river in the first 5-year plan. There are a number of dams in Bhachau which are used for the purpose of irrigation such as Adhoi-1 dam, Bambhanka Dam (Gangui Nadi river), Bharudia Dam (Bharduia river), Chang Dam (Chang river), Halara Dam, Jadsa Dam, Vamaka Dam (Vamaka river) and Vasatava Dam (Khari river) (Geological Survey of India, 1964).

The streams in Bhachau are seasonal, or ephemeral, thus only flowing due to heavy rain in the monsoon. The central upland's east-west alignment forms a kind of a drainage divide. This is because, from here, the streams either flow north or north-westwards towards the Rann of Kachchh, or southwards to the estuaries in the Gulf of Kachchh. The most important source of water however is the Kachchh Branch of the Narmada Canal which flows for a length of 360 km. As a result of focus on hard engineering approaches, drought, a natural characteristic of the block has turned into a hazard. In recent times the region has also been exposed to extremes in rainfall resulting in flash floods, for which in absence of absorbing capacity within the landscape the communities are rendered vulnerable.

Agriculture in Kachchh is rain dependent and the area under cultivation is directly correlated with the rainfall in Kachchh. In Bhachau, the average rainfall after 2002 has increased that has positively affected the groundwater quality. However, the agricultural produce has shown a decreasing trend (GEC, 2011). As per the study conducted, this is attributed due to mismanagement of wetlands and ineffective water governance. Further rapid industrial development in the region after the Bhuj Earthquake of 2001 has led to exploitation and contamination of water resources (GEC, 2011).

6 Role of Wetlands in Drought: Lessons from Other Districts in India

Healthy wetlands can act as sponges within the landscape, absorbing the excess flows and storing them in groundwater (Renaud et al., 2013). Wetlands additionally play a major role in building a local resilience by provisioning resources (food, water, fuel) and sustaining local livelihoods (Renaud et al., 2013). The regulatory role of wetlands such as the climate regulations also helps to reduce the intensity and frequency of weather and climate-related hazards (Intergovernmental Panel on Climate Change [IPCC], 2014; WI, 2016). The cases from the other regions and districts presented here below examine how loss of wetlands has led to increase in drought and drought like conditions. They provide(d) input to the case and implemented program and show the need for actions on wetlands conservation and management for drought resilience.

6.1 Nagpur

The district and city frequently face the water crisis during summer due to depleting and unprotected groundwater sources, this in turn affects the base flow and increases dependency on reservoir water for irrigation. The crisis is linked with loss of wetlands and biodiversity in the district, the current water management is focused on dams. Currently, 54 dams are in operation in the district but have the limited capacity to adapt to changing climatic variability as the focus up until now has been on population increases and water loss (Dhyani, Lahoti, Khare, Pujari, & Verma, 2018).

6.2 Bundelkhand

The region spread across several districts has seen a drought every 5 years from the period 1968–1992. The situation in the eighteenth and nineteenth century seemed better as one drought in 16 years was the norm. Since the beginning of the century it has already suffered 7 years of drought. There are a number of rivers draining the region but the seasonal fluctuations remain large, the river Ken sees almost a 60% reduction in water flows. Being an arid region, the water during the lean is captured in the natural wetlands and constructed wetlands such as reservoirs or tanks. In 2011, the region received above normal rainfall but still water scarcity prevailed in some parts of the year and Lalitpur district even witnessed floods in some parts. Ecological imbalance remains one of the major problems that have accentuated drought conditions in the region. With the government recommending improving the resilience of ecosystems and their services and enhancing the natural resource base in the areas by convergence with government programmes (Gupta and Nair, 2014).

6.3 Chennai

Chennai houses some of the largest wetland systems in South India, and till the 1980s, 80% of the city was covered by wetlands. Now that the number has reduced to 15%. Historically, the wetlands were important in providing Chennai with water during the drought periods, but this function has been lost to the urban expansion. The wetlands in the city are surrounded by areas where economic development is rampant and the pressure to build on them is enormous. The recent infrastructural development in Chennai, such as the construction following the boom in the IT industry and construction of the MGR highway, all cut across the wetlands altering the water systems of Chennai. The Pallikaranai marsh, situated in the heart of Chennai has shrunk extensively (90%) owing to ever-expanding real estate, industrial development and dumping of waste. Development initiatives like the newly constructed Ennore harbour have further aggravated wetland loss. The drought conditions in 2019 and floods of 2015 all point out to loss of the natural ecosystems and little space for storing water.

6.4 Kashmir

In Kashmir valley, conversion of marshes associated with Wular Lake for agriculture has reduced the capacity of the wetland complex in regulating flow regimes, and thereby, leading to increased floods and droughts (WISA, 2007).

7 Methodology

This paper as part of the Partners for Resilience programme aims to undertake a systematic understanding of the region and its wetlands to generate a knowledge base for supporting integration of wetlands conservation as the disaster risk reduction intervention within Gram Panchayat Development Plans (GPDPs).

A mix of quantitative and qualitative methods was used to carry out a study in Bhachau for understanding ownership rights and privileges, trends in wetlands area, role in water security, current management arrangement, major reasons of degradation and community conservation practices within the whole landscape. The purpose of such an activity in partnership with local communities is to address the key issues of degradation in the basin and to develop a strong evidence base for action and understand the role of wetlands to the communities and their livelihoods.

Households were selected using a stratified random sampling method. Responses were recorded from 268 respondents from 10 Gram Panchayats of the Bhachau block with the help of a detailed questionnaire. The respondents included a mix of gender and occupation groups, constituting farmers, agricultural labourers, pastoralists, salt pan workers, private job holders and others.

The questionnaire was developed through focal group discussions with the field staff of the CSO, Unnati. The questionnaire is broken up into four parts: (i) demographics, (ii) wetland characteristics, (iii) wetland use, (iv) threats, (v) governance. The surveys were conducted during January–March 2020 by a group of trained surveyors employed by Unnati at Bhachau. The extracted variables were assessed for their relevance in explaining differences in perception and current practice for wetland management, trends in drivers of degradation, impacts and management needs.

8 Standardized Precipitation-Evapotranspiration Index (SPEI)

Apart from the community perceptions, the paper attempts to examine the intensity and duration, and the onset and end of drought episodes constructing a Standardized Precipitation-Evapotranspiration Index (SPEI n.d.). The SPEI is a multiscalar drought index based on climatic data. Unlike other drought indices, it incorporates the use of parameters such as temperature variability and temperature extremes beyond the context of global warming. It can be used for determining the onset, duration and magnitude of drought conditions with respect to normal conditions in a variety of natural and managed systems such as crops, ecosystems, rivers, water resources. The index can help to understand the impact of droughts.

The index is constructed using an SPEI database based on monthly precipitation and potential evapotranspiration from the Climatic Research Unit of the University of East Anglia. Currently version 4.03 of the CRU TS dataset has been used for constructing an index for Bhachau block (Accessed from SPEI website).

The SPEI index is calculated based on the supply and demand concept of the water balance equation and thus incorporates prior precipitation, moisture supply, runoff and evaporation demand at the surface level along with the incorporation of temperature. The SPEI uses different time scales from 1950 to 2020, the time scale is broken up into short, medium and long term that display the meteorological dry/wet episodes for several severe droughts that occurred during the last 7 decades as follows: over 1 month (SPEI 1), 3 months (SPEI 3), 6 months (SPEI 6), 1 year (SPEI 12), 2 years (SPEI 24) and 3 years (SPEI 48).

9 Mapping Approach

A region of interest was defined based on interactions with community members. It is comprised of the basin of Chang River, as well as the area situated south of Greater Rann of Kachchh and east of the city of Bhuj. The total surface of this region of interest amounts to approximately 1981 km^2. Land cover classification was performed with QGIS Semi-Automatic Classification Plugin on two satellite imageries. Two Landsat imagery scenes were selected for the area of interest:

(a) Landsat 8 OLI satellite imagery of May 2019.
(b) Landsat 8 OLI satellite imagery of October 2019.

These datasets were downloaded for free from the US Global Survey (USGS) Global Visualization Viewer (GloVis) website (https://glovis.usgs.gov/) (Figs. 8.2 and 8.3).

Nine land cover classes were defined in accordance with the scope of intervention in the area. 1% of the area in Bhachau is covered by freshwater bodies 15 km^2 and 7% by marshes, covering an area of 145 km^2 providing significant scope to retain the water in the landscape (for use primarily in freshwater bodies). The region also boasts of coastal wetlands such as mangroves and mudflats covering an area of 33 km^2 further offering coastal protection and as buffer from cyclonic storms. The locations of wetlands covered in the study are marked in the two maps. Seasonal variations are recorded in the maps to understand hydrological patterns. A detailed comparison with land use and land cover over a 30-year period can further shed light on wetland loss.

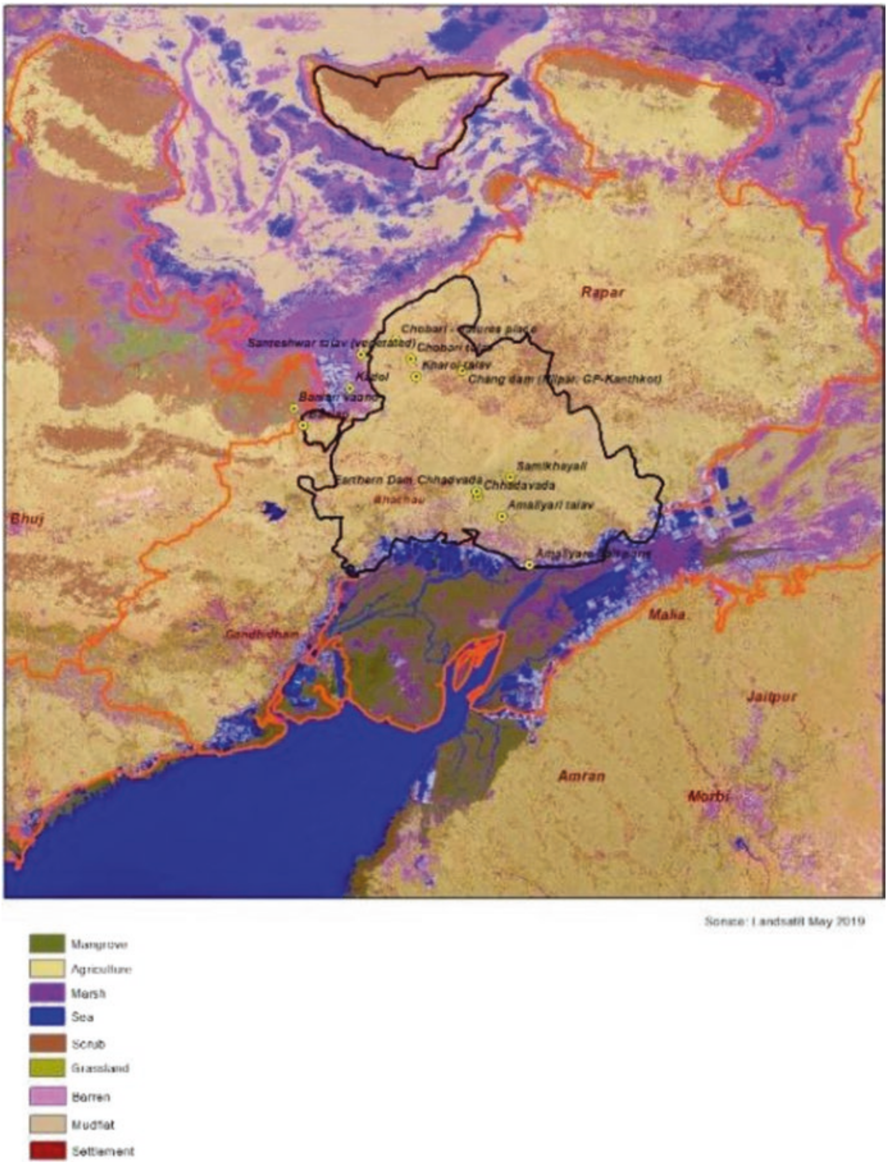


Fig. 8.2 Pre-monsoon land use and land cover map of Bhachau (Source: Wetlands International South Asia 2020)

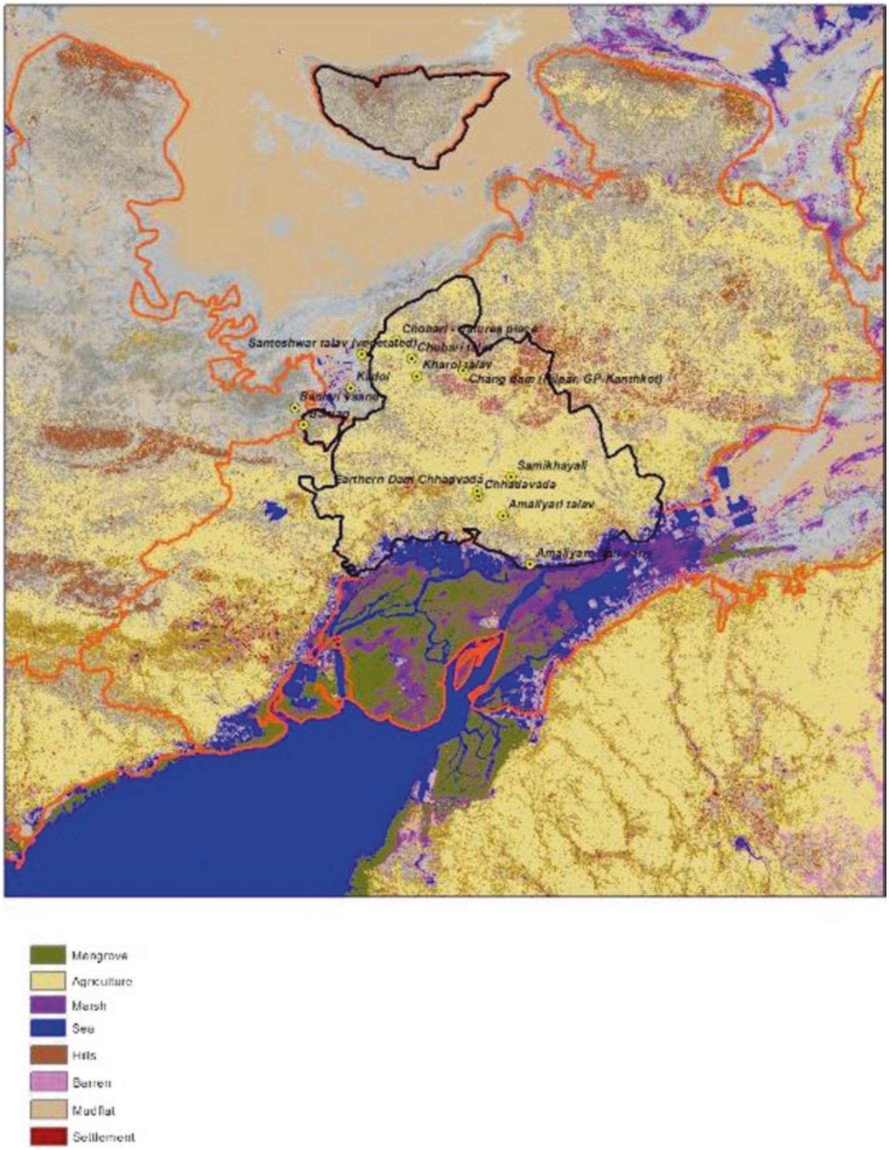
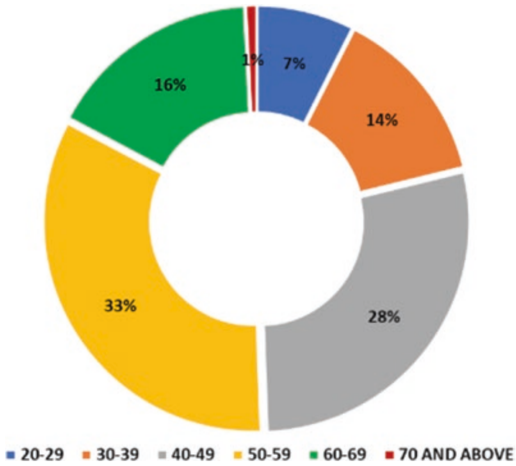


Fig. 8.3 Post-monsoon land use and land cover map of Bhachau (Source: Wetlands International South Asia 2020)

10 Results of Community Assessments

The maximum respondents were from the age groups 50–69 (Fig. 8.4), with 68% male respondents and 32% female respondents. The majority of respondents were from the farmer occupation groups, followed by daily wage earners and pastoralists (Fig. 8.5).

Fig. 8.4 Age represented by the respondents



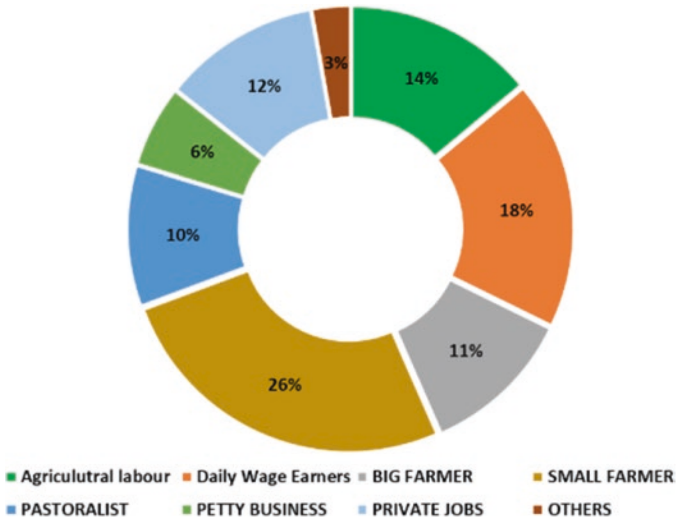


Fig. 8.5 Occupation groups represented by the respondents

The majority of wetlands covered in the assessment based on their use and proximity to households were village ponds, followed by salt pans and reservoirs. The size of the wetlands varies in the landscape with 27% being less than 10 ha in size, 25% being 100 ha or over and 17% ranging from 50 to 100 ha in size or less than 2.5 ha in size (Fig. 8.6). Majority of the wetlands assessed in the study are owned and governed by Panchayati Raj Institutions [(PRIs), Fig. 8.7]. The field surveys further reveal that 93% of the wetlands source of water is rainfall, 4% from canal water and 2% from groundwater.

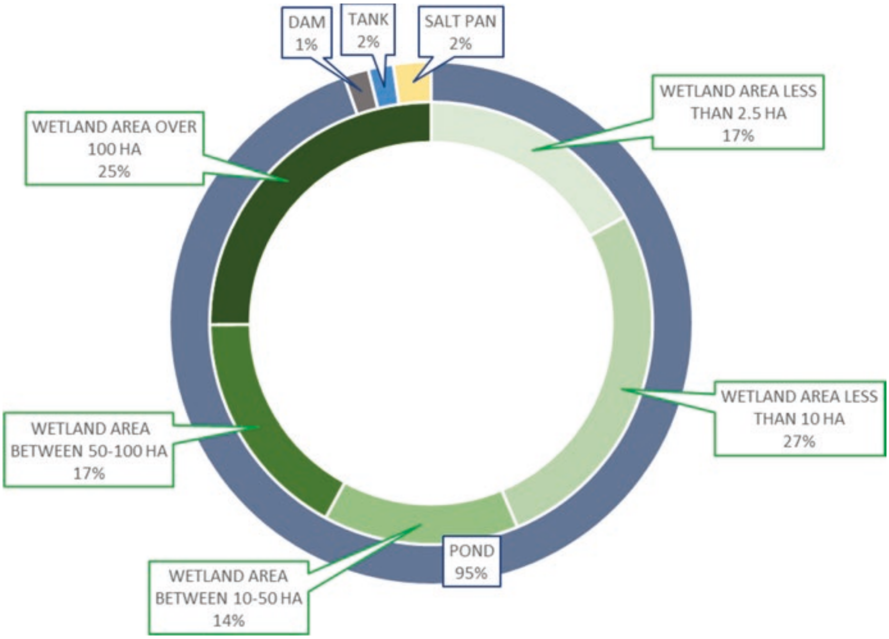


Fig. 8.6 Wetland type and size covered during the study

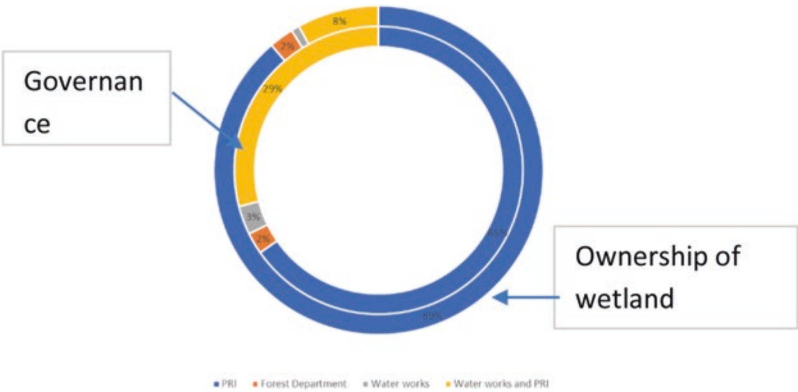


Fig. 8.7 Current ownership and management responsibility of the wetland

The use of wetland for its ecosystem services has been greatly reduced as per the community respondents. The respondents ranked highly the significant changes observed over the three different time scales (Fig. 8.8) where the provisioning

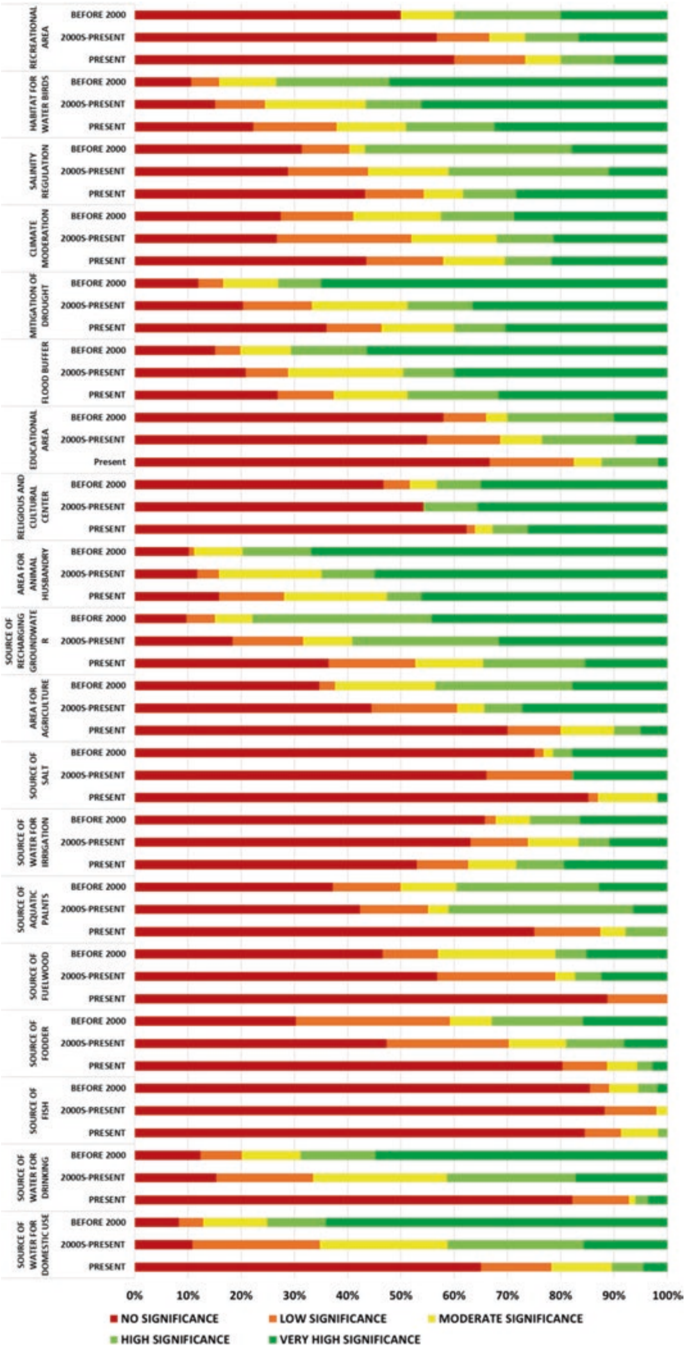


Fig. 8.8 Community perception of benefits derived from wetlands over the years

services are ranked higher than supporting or cultural services of wetlands, especially as use for drinking water (64%) and for domestic use (55%). The changes in regulating and supporting ecosystem services of wetlands have reportedly decreased as well, the highly significant is observed in the role of wetlands for groundwater recharge (44%), drought mitigation (65%), flood buffer (55%), salinity regulation (18%) and climate moderation (29%). The community members also feel there is a negative trend as a habitat for water birds. Rights and privileges related to the withdrawal of water for agriculture, bathing or wallowing of domestic animals, religious practices and grazing were the most frequently reported.

There is in general a perception that the health of wetlands in the block is on the decline. More than half of the respondents indicated that condition of the wetlands is on the decline. Reduced inflow of freshwater/rainfall, ineffective management, loss of connectivity with sources of water and increase in invasive species were indicated as the most significant trends (Fig. 8.9).

Respondents' perceptions of threats to the wetlands are varying in nature but offer a good understanding of the need for building capacities related to wetland wise and management. Climate variability is seen as the most significant threat, lack of awareness of wetland benefits, followed by dumping of sewage, increase in the invasive species and conversion of wetlands to agriculture (Fig. 8.10).

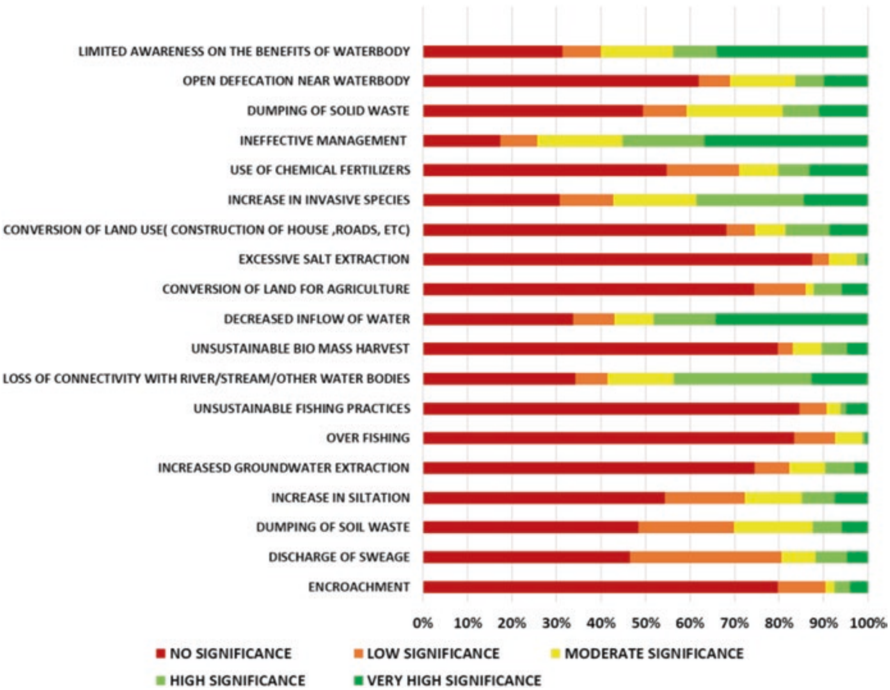


Fig. 8.9 Community perception of wetland health

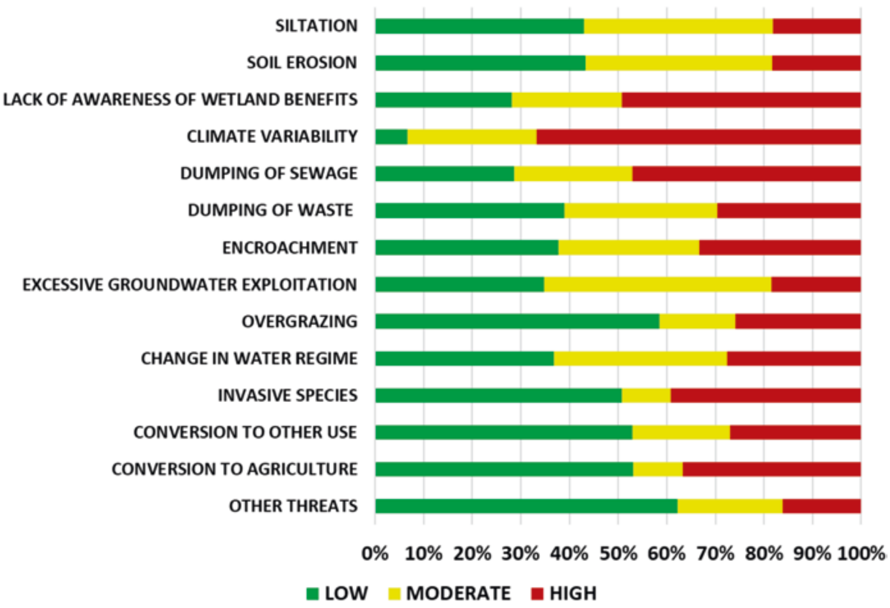


Fig. 8.10 Community perception of threats to wetland

The impact of wetland degradation and impact on communities surrounding were assessed. The respondents attributed the impact of increased instances of waterlogging to affect the entire village; the increase in invasive species would affect all households. Loss of cultural values and reduced landscape aesthetics would be impacting the entire village. The respondents further reported that the impacts of reduced freshwater availability would affect the whole village the most followed by pastoralists, all households and farmer groups. The impact of wetland degradation and high exposure to droughts as per the respondents would impact the pastoralists the most, this response can be attributed to increasing dependency on service infrastructure for water demands for the other occupation groups (Fig. 8.11).

11 Results of Drought Assessment of Kachchh (Bhachau) from 1950 to 2020 Using SPEI

In the time scales SPEI 1–6, there is the high frequency of drought with very wet periods prevalent till the 1980s. In the longer time scales, the severity of dry periods increases with longer durations but lower frequency of drought. From the period between 1984 to 2006 (with the exceptions of 1997) a prolonged period of drought with severely dry conditions is observed. The relation of drought conditions and the current hydrological setup across the different time scales from the SPEI help shed light on the hydrological systems. The interactions of wetlands, rainwater water

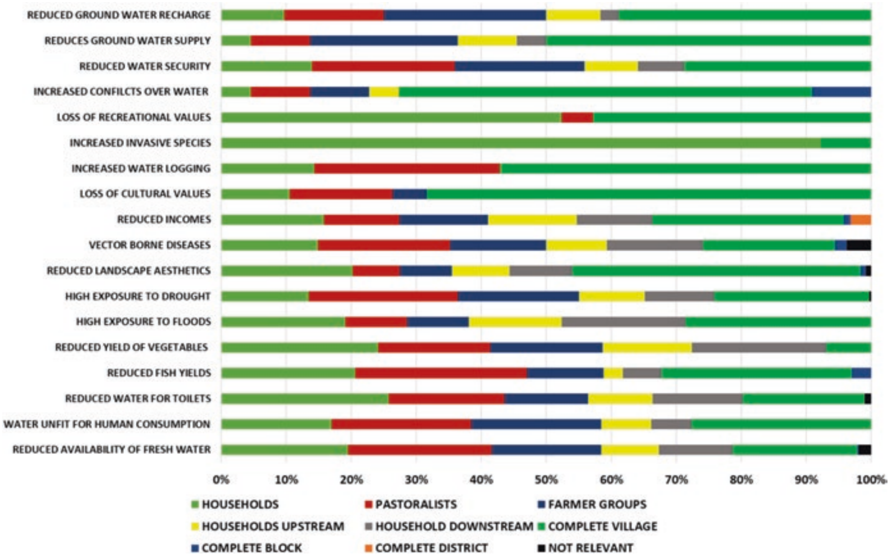


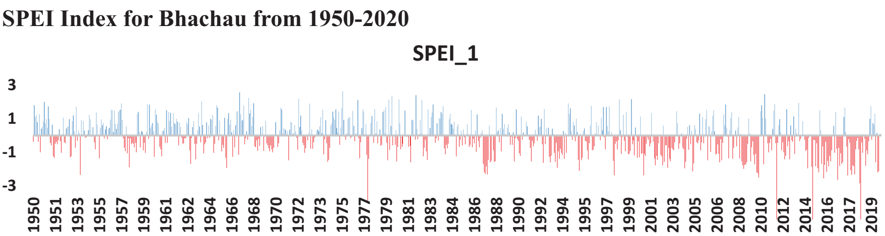
Fig. 8.11 Community perception of perceived impacts of wetland degradation on different groups

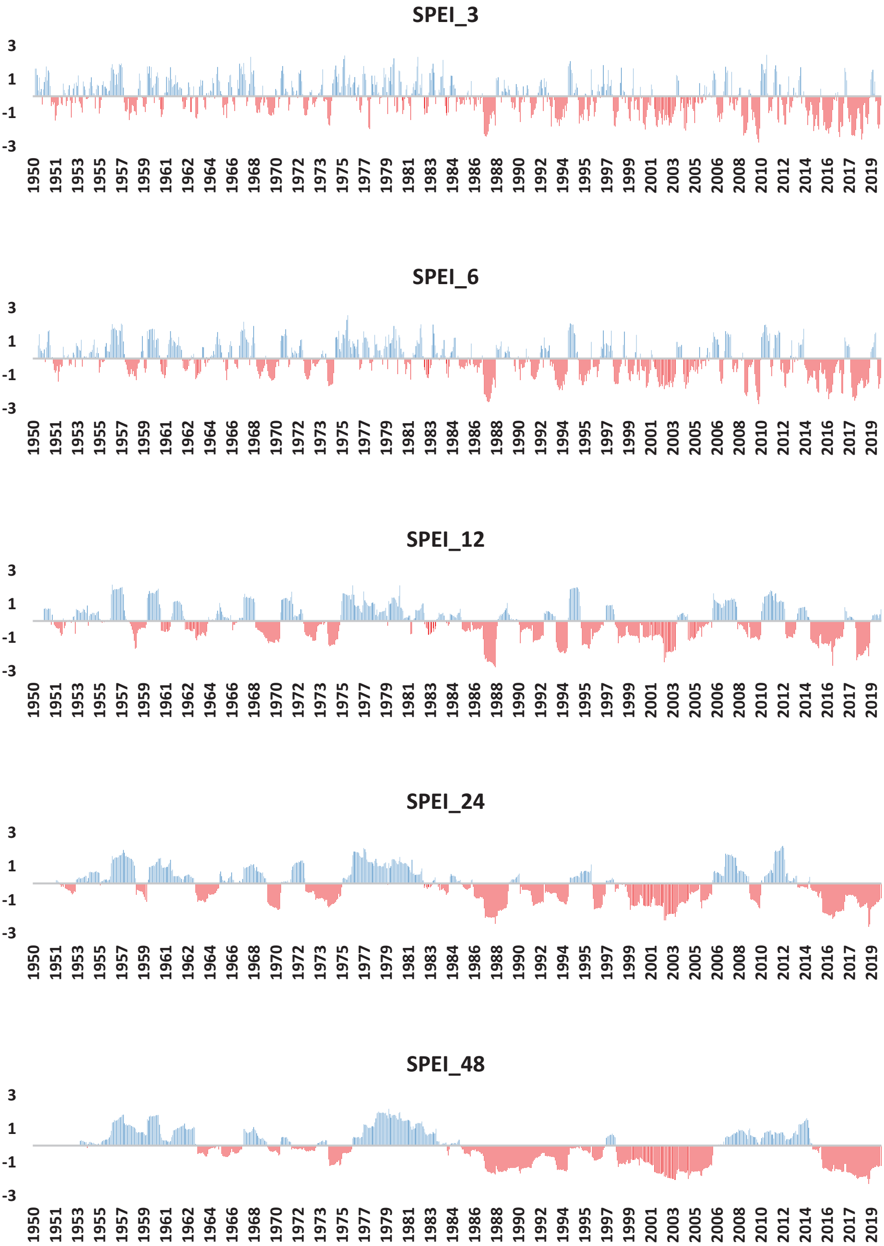
runoff and groundwater all indicate that over the years, the ecological resilience of the landscape is rapidly reducing. In the future, the prolonged droughts with dry condition could be much more prevalent.

The SPEI index is based on the moisture categories as follows.

Moisture category	SPEI
Extremely wet	2.00 and above
Very wet	1.50–1.99
Moderately wet	1.00–1.49
Near normal	−0.99 to 0.99
Moderately wet	−1.00 to −1.49
Severely dry	−1.50 to −1.99
Extremely dry	−2.00 and less

SPEI Index for Bhachau from 1950 to 2020





12 Discussion

The profile of ecosystem services of the wetlands mapped by the questionnaire reflects the extent to which their societal well-being role is identified by the respondents. The communities have a good understanding of the threats and use of wetland ecosystem services but the diminishing use of wetlands can point to reasons for degradation and limited ownership for management. Limited awareness of the values of wetlands for their regulating and supporting role also points out to the need for the greater efforts towards raising awareness and education on the wetland values. This lack of awareness may contribute to the degradation of wetlands. The pattern of ecosystem services as well as that of community rights and privileges may help define sectoral convergence needs and priorities. The reduced connectivity as a major reason for degradation indicates that the past interventions for development have adversely impacted wetlands. Any future development interventions need to ensure connectivity of wetlands.

Ownership of wetlands by PRI's further indicates the opportunity to include the wetland conservation within the developmental planning instruments such as the Gram Panchayat Development Plans (GPDP), for their role in mitigation and buffering droughts, and to ensure that wetland health is maintained.

The pastoralist group of stakeholders remains the most vulnerable due to changing climate as their dependency on natural resources for fodder remains higher compared to the farmer and other occupation groups that are currently using canal water for sustaining their livelihoods. The spread of invasive species (Prosopis Juliflora), locally known as Gando bawad, Jhar-beri/Chanibor and Kair/Kerdo remains another major challenge.

As the SPEI indicates the growing drought periods which could be attributed to over a reliance on service infrastructure for meeting the current water demands which have and will continue to effect the wetland ecosystems and the resilience they offer as the water is not retained in the landscape systems. As wetlands can be sustained and rejuvenated by rainfall projected under the different climate change scenarios which indicate the shorter rainfall trends and greater temperatures, remains a major challenge in the future.

The assessment is not intended to create a comprehensive picture of wetlands in the region. The results are derived from a select set of wetlands only, which is not representative of the entire wetlands distribution. Being a pilot study, the focus was on understanding the role of wetlands in relation to the drought and demonstrating integration of wetlands within developmental planning. But as the education, awareness and training on wetlands management remain limited, along with the absence of local governance of wetlands, a majority of these wetlands face a grave future. It is important to rehabilitate the degraded wetlands as well as monitor the ecological status of wetlands. Wetlands could be a cost-effective, community-driven, bottoms-up approach in mitigating the drought disaster risks if properly managed and restored to reduce the future risks. The PfR case example, esp. award winning district, can be and already is used as inspirational examples.

13 Water Governance Discourse in India and Risk Informed Development Planning

To explore how wetlands could be a cost-effective, community-driven, bottoms-up approach in mitigating drought disaster risks, an understanding of the water governance in India is needed. The Jal Shakti Ministry (merged into the water resources ministry) and its recently launched Jal Shakti Mission has its foundations of public management of water resources in the National Drinking Water Mission, 1986. The main objective of this mission was to improve the performance and cost-effectiveness of the on-going programmes in the field of rural drinking water supply and to ensure the availability of an adequate quantity of drinking water of the acceptable quality on a long-term basis (Dept. of Rural Dev., 1990). This was taken a step ahead with the *Swajaldhara* Program,[2] supported by the World Bank in 2002, with a focus on community-based management of rural water supply. The program did focus on people's participation. However, there was no clarity with regard to the water governance. It stated that the Panchayat needed to plan, implement and maintain all the water supply and sanitation schemes. Throughout this, the main focus, however, was still on water supply rather than water management. Initially, WASMO (Water and Sanitation Management Organisation) was created after the 73rd Amendment to the Constitution in 1993 and a resolution was released for the formation of a '*Pani Samiti*',[3] with the Sarpanch appointed as its chairperson. In a study conducted with WASMO, it was found out that the location of the water structures does not promote water security. It is important to recognize the importance of management of water at the gram panchayat level.

The discourse around governance as a whole in India has experienced a shift since 2015. The Gram Panchayat Development Plan (GPDP) conceived by the Ministry of Panchayati Raj (MoPR) for the effective implementation of financial devolution under the 14th Finance Commission (FFC); at present the 15th Finance Commission is all ready to roll out. Article 243G of the Constitution of India acknowledges Panchayats as institutions of local self-government and mandates them to prepare plans for economic development and social justice. As local government, Gram Panchayats (GPs) are responsible for delivery of basic services to local citizens and address the vulnerabilities of poor and marginalized ones. This can only be achieved through implementation of well-thought-out plans through efficient and responsible utilization of available resources. The Finance Commission therefore has provided a great support to the Panchayati Raj Institutions (PRIs) in terms of their ownership, leadership and monitoring control over village level activities and most importantly, strengthening decentralized governance. Taking up the issue of water, the various government schemes and programs may be utilized for the same.

The PRIs can make use of government programmes using schemes like the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) to undertake the restoration work of wetlands making it a part of the development plans. The National Disaster Management Plan (2019) of India, the District Disaster Management Plan (2018) of Kachchh district and the Manual of Drought Management (2009) by the Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India are important documents for understanding the risk due to the impact of droughts and the related complexities with it.

[2] Community based rural water supply scheme.

[3] Community water management institutes.

The complexity of drought risks is growing due to the growing climate variability, siloed approaches and dependency on hard engineering solutions is rendering the mismanagement of wetlands. These risks therefore need to be acknowledged and incorporated into development planning at all levels and most importantly at the local levels through the GPDPs.

14 Conclusion

The Kachchh DDMP recommends the implementation of a range of structural and non-structural measures which can enable systemic disaster risk reduction. However, the Gram Panchayat Development Plans (GPDPs) remain the key instruments through which the aforementioned measures are implemented on the ground but still remain infrastructure centric. The available GPDPs do not take into account the local water context while planning for disaster risk reduction measures. Thus, on-the-ground impact of disaster planning remains very limited. The results of the community surveys, and the experiences from drought risk reduction, as presented as part of the case of PfR program, resonate and demonstrate the tremendous possibility of reducing drought risk through community managed interventions.

Broadly, the main tenets of Community Managed Drought Risk Reduction are the following:

- Community-based partnerships and institutes for water management;
- Conservation and management of wetlands by inclusion with GPDPs;
- Participatory and inclusive water resources management by Panchayati Raj Institutions (PRIs) and.
- Increased ownership over water infrastructure and resources by vulnerable households (Unnati, 2011).

This approach offers a good opportunity to mainstream restoration and management of natural resources for disaster risk reduction. It can be upscaled by developing the catchment and landscape level restoration plans of wetlands, offering cost-effective solutions as ecosystem-based disaster risk reduction measures. As the case of the PfR program presented in this article has shown, with GPDP for Kanthkot in Bhachau being awarded as model for replication Gujarat for integrating DRR within the village development plans. The ecosystem-based approach to reduce disaster risk and adapt to climate change has continued to receive much international attention in the recent years (Davies et al. 2016; Renaud et al., 2013), the GPDP documents remain key for integrating the approach within developmental planning. Convergence of restoration activities with government programmes by integration with GPDPs can also mobilize community efforts towards conservation and management of wetlands based on simple assessments, therefore, consequently contributing towards building community resilience against droughts and its mitigation.

Further for Bhachau and other drought-prone landscapes, inducing behaviour change and increasing awareness of wetland benefits can lead to a greater ownership by communities and management of the wetlands.

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Chapter 9
Building Socio-Hydrological Resilience for Inclusion: Experience of Co-operatives in Tanzania

Neema Penance Kumburu and Vincent Sebastian Pande

Abstract This chapter portrays that co-operatives be it agricultural or financial are instrument in building socio-hydrological resilience. This is due to the fact that co-operatives are deep rooted to solve societal problems in an inclusive way. The co-operatives are built under social responsibility and caring values which support them in the provision of strong social security to its members. This helps co-operatives to lessen adverse impact on the most disadvantaged groups, and this in turn promotes disaster risk reduction. Likewise, unity as another value of co-operatives enables them to play a philanthropic role after the occurrence of disaster. Co-operatives, being among strong institutions and very close to the communities, are positioned to create awareness for disaster response. Building social hydrological resilience in a more effective and sustainable manner requires comprehensive and all-inclusive approaches which in the one hand are among the pillars inherent in a co-operative ideology. It is also important to note that this does not mean other approaches of dealing with resilience such as engineering resilience and ecological resiliencies are less important. The two approaches are equally important but their success and sustainability will depend on socio-hydrological approach. Thus, it can be concluded that if co-operatives become more adaptive and sustainable mainly as a result of strong management, solid market advantageous, strong venture capital and good governance, they are likely to be resilient not only on financial aspects but also in many other aspects including socio-hydrological matters. This can be demonstrated by their abilities to have self-mobilisation and be able to fulfil the needs of their stakeholders.

Keywords Socio-hydrological · Resilience · Co-operatives · Floods · Tanzania

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1 Introduction

Globally, it has been seen that in the situation of social insecurity co-operatives have been considered as alternative organisations capable of providing employment and ensure economic stability to people as an individual or group. Various literatures are of opinion that co-operatives can be considered as among the resilient institutions as they have capacities to ensure economic revamp during times of economic instability. However, there is still a gap on how co-operative can become resilient to the socio-hydrological changes. This study, therefore, attempts to explore the degree to which the co-operatives can become resistant institutions during times of socio-hydrological changes (Jaramillo, Stone, Benson, & Eslamian, 2021).

Co-operative is defined as a member-owned organisation which is independent and democratic where people have joined together voluntarily in order to fulfil their common socio-economic goals and expectations (Bwana and Mwakujonga, 2013). They differ from the other private firms due to their close relationship with the community and their ideologies of being an independent and democratic institution. Co-operative being a democratic organisation enables active and full participation of members and transparency in the way of operation and this in turn establishes a less exploitative relation with stakeholders. This leads to the reduction of information asymmetric and enhances a more innovative community.

Experiences show that during economic shocks, co-operatives have been playing a major role to lessen the problem and continue to meet the needs of their members. Co-operative connected in a dense of network of individuals, management and co-operative itself has an impact on co-operative resilience. They are seen as resilient in nature when they are able to satisfy the majority of stakeholders and build clear mechanisms that ensure pellucidity in their operations. In addition, they are regarded as resilient form of organisations probably because they are low risk taker in investment as the focus is on the achievement of long term objectives and not short ones (Allen and Maghimbi, 2009).

Resilience as a concept has been perceived differently by various scholars. Folke (2016) defines the resilience as ability to endure in new changes and continue to grow as per changing environment. Previously, resilience as a concept was very famous in other fields of studies such as biology, engineering and development studies as well as other issues related to natural hazards (Eslamian et al., 2019). Currently, its context has been extended to other disciplines including hydrological, ecological, community, disasters, urban and other hazardous issues (Mao et al., 2017; Reyhani et al., 2017). Despite the fact that the contextual applicability of resilience has been extended, still issues related to socio-hydrological dynamics have not been explained fully particularly in the aspect of floods which face humans (Mao et al., 2017).

The extent to which societies can act and overcome social resilience can be demonstrated by ability of the societies to prepare coping strategies, apply them and address any instantaneous dangers (ability to handle), taking previous lessons and use them to discourse current and future challenges (accommodative abilities), and societies' capacity to design and develop organisations that promote individual and society welfare development even during the difficulties times (ability to change) (Wurl et al., 2018). In regard to socio-hydrological matters, resilience can also be explained as the way societies can be able to absorb, adapt and transform themselves to ensure their survival and sustainability (Mao et al., 2017).

Eslamian, Reyhani, and Syme (2019) defined socio-hydrological resilience as the ability of a society to cope and overcome any biophysical and hydrological occurrences and continue to survive in the changing environments. In Tanzania hydrological effects are manifested through floods. Floods are climatological occurrences as a result of number of factors including climatic changes such as rainfall variations in terms of strength, interval and volume and watershed characteristics (Kimambo, Chikoore, & Gumbo, 2019). Similarly, Bushesha and Mbura (2015) noted that floods can occur due to overflow of water from water bodies such as lakes, rivers and dams due to breaking of river or lake or dam banks causing water to escape its usual boundaries. River floods normally occur when running water surpasses the ability of the river banks, predominantly at corners which are normally associated with slow water movement. Floods are intense when water bodies intrude and endanger the area of land which is normally used by people. It can be in a farm, town or other inhabited area. Flash floods are ranked the high among natural disasters worldwide and Tanzania in particular. Studies show that globally about half of the area experiences flooding but the intensity differs from region to region and the occurrence is locally unpredictable. For example, in East Africa, floods are considered to be the leading hydro-climatological disaster. It has been observed that the unpredicted climatic changes are the major causes of floods in the region and that instigate many towns and cities to be highly susceptible to floods.

Mafuru and Guirong (2018) observed that in some areas in Tanzania, floods have been caused by prolonged rainfall and in most occasions have overtime caused the substantial damages socially, economically and emotionally. In Tanzania, flood prone areas were found to be in Tanga, Dar es Salaam, Coast, Morogoro, Arusah, Rukwa, Iringa, Kigoma, Mbeya and Lindi regions (Bushesha & Mbura, 2015), which in other aspects of the economy, these regions are the leading in the economic activities particularly agriculture and it is where many co-operatives are found. Of recent years, a number of floods have been plaguing Tanzania. In 2020 a number of floods occurred in some regions where thousands of people were affected. In the northern regions of Tanzania, for example, occurrence of floods accompanied by mudslides destroyed more than 3200 homes; 2700 were households in Kilimanjaro and 50 were households in Arusha. In addition, floods destroyed road network particularly Arusha-Moshi road, causing destruction of normal business routine such as private and business trips and hence people were emotionally, economically and socially disturbed. In coast region about 3500 homes and 6600 hectares of land were destroyed by floods. In Lindi, Mwanza, Morogoro, Manyara and Iringa regions about 1750 houses were made homeless, 15,000 people were affected and 40 fatalities have occurred as a result of floods. This shows the magnitude of the problem for the period of 1 year in Tanzania. The impact of floods is often disastrous and is a result of both natural and human factors. Table 9.1 shows the socio-economic impact of flood which might occur in any country.

Since floods have been recognized as potential hazards, the Tanzanian Government designed and implemented the policies and programmes as well as establishing institutions to manage the situation and create mechanisms to mitigate the occurrence of disasters caused by floods. Among the efforts made were training candidates on disaster management, establishing a department under the Prime Minister's Office responsible for disaster management, which has committees from the level of region to village, developing Disaster Management Act of 2015 which details the legitimacy of disaster risk management and established Tanzania Disaster Management Agency (TDMA), which is responsible for coordinating disaster risk management in Tanzania.

By understanding the importance of disaster risk reduction, a number of research works have been conducted in Tanzania. Msilanga (2018), for example, assessed community mapping for the flood resilience in Dar es Salaam and concluded that when the communities understand that vulnerabilities in their living environment increase the resilience to floods. Pavlova (2016) assessed the strategies for city resilience to riverine floods in Msimbazi River in Dar es Salaam and noted that the existing mitigation measures could be strengthened in order to avoid the potential risks and harmful consequences of flood hazard and therefore ensure the sustainable progress of towns. Shemdoe (2016) also examined and recommended the potential

Table 9.1 The negative impact of floods

Group of impacts	Negative impacts
Environmental	• Environmental pollution and degradation (soil erosion, land reclamation, etc.) • Animal and floral injuries, diseases and mortality • Water stagnation • Saltwater intrusion
Economical	• High cost of living due to repair and maintenance of properties • Low income earning due to shifting to other areas • Impediment for networking and businesses
Social	• Hindrance for outdoor activities (householding, playing for children, etc.) • Inaccessibility to information and disruption in communication
Infrastructural	• Infrastructure losses (inaccessibility to energy, water, emergency and other facilities and services) • Destruction of infrastructures (if not total destruction but due to moisture wicking materials warping and cupping, surface stains, risk of rust and corrosion, mould) • Overflow of sewage and drainage systems
Agricultural	Destruction of agricultural fields, crop failure
Health	• Injuries and deaths of people • Spread od water-borne diseases • Contamination of drinking water sources • Psychological impacts—Continuing stress

Source: Authors construction (2020)

measures on minimising risks for people residing in areas prone to floods. Many of these studies focused on the impact of floods and strategies for resilience to floods but none of these findings has assessed the role of community organisations in socio-hydrological resilience. Since the occurrence of disaster affects a mass of people, collective measures are important to reduce risks in disaster prone areas. Co-operative embedded with the value of solidarity, humanitarians' response, social obligation and love for others enables the members to organise and improve their conditions collectively. Thus, in practice it shows that co-operatives have the potential in disaster management compared to other private enterprises. In particular, the aspects of co-operatives as instrument for building socio-hydrological resilience have not been recognised if not rarely mentioned in a few research works. It is for this reason that this chapter will document and share knowledge on building socio-hydrological resilience for inclusion, experience of co-operatives in Tanzania.

This chapter was focused on theoretical and historical perspectives. To ensure a comprehensive study, a number of literature were consulted. The study used a case study design where the experiences of various co-operatives in Tanzania on resilience aspects were explored.

2 Theoretical Framework

The concept of resilience is made under three theoretical perspectives: engineering, ecological and social or adaptive resilience. Engineering resilience is the capacity to sustain damage without much loss and is aiming at designing, maintaining and refurbishing infrastructures and the communities in general (Wied, Oehmen, & Welo, 2020). It is usually applied during structural and architectural designing to ensure proper adaptation of technology that minimises hazardous effect during floods and to enable floods tolerance and reduction of recovery time when flood occurs (Zevenbergen, Gersonius, & Radhakrishan, 2020). A comprehensive engineering resilience model was given by Laboy and Fannon (2016) who modified the 4R model (robustness, redundancy, resourcefulness and rapidity) developed by Bruneau et al. (2003) into 6R model. This model details the applicability of engineering resilience into architectural design and its usefulness in flood risk management by taking on board two aspects: risk avoidance and recovery. The 6R model explains how engineering resilience can be employed to prevent occurrence of disaster from early stages of planning, preparedness before occurrence of disaster and the recovering processes (Mayunga, 2007; Zevenbergen et al., 2020). Engineering resilience describes the robustness of the performance of technological systems in order to have a stable function while ecological resilience is used to describe techniques for recognising the dynamics of complex and dynamic natural systems. In regard to this emerging perception, ecological resilience is considered as a process in which the post-traumatic condition may be different from the pre-traumatic condition, but the whole process of recovery is resilient (Linkov et al., 2014; Zevenbergen et al., 2020).

In the setting of flood risk management, ecological resilience is considered as the capacity of a system to withstand/absorb turbulences (such as storm currents and flood clouds) and to remain active under a widespread of flood currents or storm forces. This implies enduring a flood (resistance) or speedy recovery with little impact after being affected by floodwaters (e.g. due to failure of the flood protection system (Gersonius, Van Buuren, Zethof, & Kelder, 2016) aiming at preventing side effects that are very difficult to recover).

The understanding of artificial systems and ecology is exposed to rapidly changing stimuli and shocks and thus that the domain of resilience is changing has called for adherence to the temporal element of resilience. The acceptance of this approach has led to the rise of a system of social and ecological resilience, which identifies nonlinear dynamics, thresholds, how gradual change intervals interact with rapid transition periods and also how to deal with scepticism (e.g. Folke, 2016; Gersonius et al., 2016; Zevenbergen et al., 2020). Social-ecological resilience has been defined as the ability of interlinking social and ecological systems to engross periodic disruptions such as flooding to maintain key structures, processes and responses (Folke, 2016). Furthermore, socio-ecological resilience also demonstrates the extent to which complex systems can adjust themselves and that these systems can build capacity to learn and adapt (Zevenbergen et al., 2020). This is the comprehensive concept of resilience which has been assumed in the sphere of climatic change variation in order to tackle two things: steady, disturbing changes and shockwaves as a result of climatic change and unpredictability (Linkov et al., 2014). In this context, a flexible, resilient strategy does not depend on static conditions, but explicitly focuses on unpredictable changes—such as climate change. In the context of climatic change, adaptation often refers to feedbacks that intend to create awareness on the impact of climatic change. The word adaptive means the revision of a plan or strategy that follows new knowledge (Zevenbergen et al., 2020).

Socio-ecological approach best explains Socio-Hydrological Resilience for inclusion, this is so because as Eslamian et al. (2019) put it that it is the ability of society to adapt to biological and hydrological changes and continue to thrive as per continuing-changing environment. The social hydrological resilience is based on the assumptions that management of water problems should not be primarily taken as technical issues rather policy issues with the involvement of various stakeholders and institutions (Paul et al., 2017). Growth which is sustainable normally goes together with cultural and material needs satisfaction that is necessary for all people living with self-respect that everyone deserves. Zevenbergen et al. (2020) have established the role of human beings in the sphere of water by developing a socio-hydrology as a way to recognise broader techniques in the management of hydrological resources aimed at building resilience.

3 Empirical Literature

This area presents the results of previous studies as per the subject matter. These studies provide a broader view of the knowledge of the resilience in aspect to socio-hydrological systems as well as identifying a gap. Wurl, Gámez, Ivanova, Imaz Lamadrid, & Hernández-Morales, 2018) presented the prominent knowledge in analysing the hydrological resilience of an arid aquatic ecological system beneath forthcoming extraction conditions and alteration of climate change. The scrutiny shows the suitable basis for recognising the relationship between social and hydrological systems. To envisage the water course under diverse human situation or context, different gauges are modelled to establish the real impact of human–water systems. This particular information assists in understanding the matter concerning participation of different people in decision-making in turn around the negative effects of present water management and climatic change. This piece of writing assists to comprehend the issues in relation to participation of various indigenous patrons and policymakers in turn round the negative effects of contemporary water management and climate change. Xu, Gober, Wheater, and Kajikawa (2018) examined the trends in socio-hydrological resilience by means of mixed methods. The study found that the domain is still inhabited by hydrologists, with little, and of course insufficient contribution, from social scientists. Three topics were suggested to constitute themes focusing in hydrological matters. The first is systemic risk and natural hazards, the second is sustainable science and third is about the adaptive governance. Thus, the use of multifunctional approaches is apparent when dealing with natural hazards.

Zevenbergen et al. (2020) offered a comprehensive description of the thoughtful and appreciation of challenges of flood disaster management and significant adaptable measures in arid urban areas through a social and hydrological system. The study found that weak institutional capacity, poor governance, inadequate resources and bad urban planning are the main issues challenging disaster management. Improving awareness and engagement of civil society in dealing with the hazard was among the approach recommended to reduce risks. Veettil, Konapala, Mishra, and Li (2018), on the other hand, presented a modelling system using a machine learning technique to forecast the hydrological ratio for water bodies situated in the USA using a set of climate, soil, vegetation and geographical changes. The study used nonlinear elasticity to determine the potential influence of hydrological balance estimates on various drought characteristics (resilience, vulnerability and proximity) to the river. It was found that a machine learning technique based on random forest algorithm could economically estimate the atmospheric ratio of hydrogen balance sufficiently observed and the data needed to be manageable.

Sharma and Goyal (2018) provided useful knowledge in assessing the resilience of land ecological system in India for water climatic turbulences in the district (i.e. the administrative unit). This article found significant atmospheric differences in Ecological Water Use (WUE) at the region level, which was complex in the Himalayan regions compared to other countries. Resistance was measured by the

WUE ratio under drought conditions and the WUE average, which shows the capacity to take in the disturbances of the hydro-climate disturbance. The findings from this study outlined the need for appropriate policies of ecosystem management in India and provided an analysis of how this process could continue.

Conversely, Hough, Pavao-Zuckerman, and Scott (2018) proposed a social-ecohydrological thresholds (SEHT) framework that integrated the social hydrological, trait-based ecological and ecosystem services concepts. San Pedro riparian corridor in Arizona was a case under investigation, the SEHT framework was utilised as analytical framework to identify key drivers and thresholds in the social-ecohydrological system. Their results showed that the use of the SEHT system facilitates the identification of several key catalysts of possible thresholds in ecosystem services derived from the natural or social components of the entire system.

Based on the above empirical studies, it is clear that the studies on hydrological resilience have been conducted worldwide. Yet, little research has examined how co-operative societies can build a social hydrological resilience, particularly the extent to which co-operatives promote "Socio-Hydrological Resilience" for inclusion in Tanzania context. Therefore, it is against this fact that this study aimed to fill the existing gap by documenting and share experience on "Building Socio-Hydrological Resilience" for inclusion experience of co-operatives in Tanzania.

4 Co-operatives as Instrument for Socio-inclusion: A Conceptual Framework

The co-operatives are businesses owned by members. The easiest way to recognise co-operatives is that they encompass the market power of people whom by themselves could have achieved little or no success and in so doing provided the means to escape poverty and incapacity (Birchall and Ketilson 2009). The well-known definition of co-operatives as per the United Nations Guidelines and ILO R.193 (2002) and the International Co-operative Union (ICA) is that co-operatives are an independent association of people willingly joined together to satisfy their common economic, social and cultural needs and aspirations, through a mutually owned and constitutionally organised firm.

Co-operatives are governed by seven key principles: voluntary and open membership; control; democracy; economic participation of members; freedom and liberty; education, training and information; cooperation between co-operatives and caring for the community (Rwekaza & Muhihi, 2016). Voluntary and open membership, control, democracy and economic participation of members are the basic principles which give co-operative its identity. They give power for members to control, own and benefit from the firm. Other principles such as education is an obligation for membership to ensure members seriousness and is therefore a prerequisite for democratic control, while cooperation between co-operatives is in fact a business strategy to ensure economic sustainability of co-operative. The final principle, caring for others, differentiates co-operative from other businesses as co-operative is there to ensure the particular community grows in terms of social and economic. In many cases, one of the goals of a co-operative is to satisfy the needs of the broader community and for that case, co-operatives are regarded as social and economic business organisations. Conversely, in co-operatives a sense of inclusion is given priority as all people get chance to members without considering their differences in terms of income, ethnicity and the like (Vieta & Lionais, 2015). Being an inclusive society means management of all aspects that can create discriminations among members such as racial, gender, class, genealogy and location and ensures that all members get equal chance to participate, have opportunity and ability to determine an acceptable set of social institutions which regulates their social collaboration. These elements make co-operatives to be different from other business ventures and become very effective tool in handling unforeseen events such as disasters and therefore become very important in guaranteeing sustainable social and economic development. This is because co-operatives adhere to the good governance pillars of transparency, democracy, rule of law, respect for human rights and accountability. In addition, co-operatives are built under social policies of ensuring equal opportunities to all members and thus form a society that is flexible and resilient. In order to create and develop an inclusive society, it is important that all members of the community be able and encouraged to participate in all matters relating to social, culture, economic and politics, at national and international levels. Rwekaza and Muhihi (2016)noted that a society which best adheres to the principles of inclusiveness is the one that ensures its members have equal chances to participate in decision-making, getting their basic needs and all members feel recognised in their doings.

5 The Role of Co-operatives in Building Socio-Hydrological Resilience for Inclusion: Experience of Tanzania

It is believed that socio-hydrological resilience built under equality and empowerment will last longer since development ought to be for all members who are directly or indirectly affected by it. Thus, the problem of hydrological events including flood worldwide and Tanzania inclusive can be solved through co-operative processes from agriculture to finance. By understanding this great role of co-operatives, UN General assembly through Resolution No. 62/128 calls upon the Government and other agencies of UN as well as other stakeholders to seat together and appreciate the role of co-operatives in representing a large group of people in a community compared to other civil (Rwekaza & Muhihi, 2016). This is in line with Tanzania Co-operative Development Policy of 2002 which also gives emphasis on the role of co-operatives in bringing equality in socio-economic development.

The International Co-operative Alliance (ICA) and its members have shown a good example in delivering resources and extending unity and in the same manner co-operatives are very essential in disaster risk reduction and management if encouraged and supported by the government and other organisations as partners in joint efforts. Co-operatives can mobilise resources to assist during occurrence of disaster and restoration as a way of reviving the local economy. Since co-operatives are important in the socio-economic development of a country, they can be considered as backup in the global problems of food insecurity and economic instability. In this regard, the participatory financial system signifies the footsteps of equality in hydrological resilience. Hydrological resilience for inclusion will be sustainable and have far reaching impact if there is empowerment and fairness. Therefore, worldwide, the co-operative processes from agricultural to financial can assist to address the problem associated with hydrological phenomena of unfairness and poverty.

An agricultural marketing association is a group of farmers who willingly work together to integrate their produce for sale. That joint production is sold and circulated through co-operatives that are owned and organised by the farmers themselves. All over the world, farmers are more and more motivated to join market co-operatives. Statistically, the market share of agricultural produce circulation from production site to end-users is largely held by the co-operatives (Tchami, 2007; Zevenbergen et al., 2020). Conversely, the financial co-operatives popularly known as Savings and Credit Co-operative Societies (SACCOS) are associations which like other forms of co-operatives members are willing to join together and put together their funds and consequently can get loans that they can use for different purposes (Bwana & Mwakujonga, 2013). The primary aim of these societies involves the mobilisation of resources from which individual co-operators may benefit. That is, to promote savings and make credits available to the members (Mwakajumlo, 2011; Kumburu, Pande, & Buberwa, 2014).

6 Experience of Co-operatives in Tanzania

In Tanzania, there are some evidences that show the growth of co-operatives in terms of number and finance. Apart from other actors in socio-economic development in Tanzania, co-operatives are also very important. Presently, in Tanzania there are different forms of co-operatives including financial, agricultural marketing, fisheries, livestock, mining, irrigation, housing and industrial co-operatives (Table 9.2).

Statistics indicate that in 2018, there were 41,835,042 registered co-operatives in Tanzania, with a membership of 2,489,376; share capital of Tsh 325, 590, 252, 019.46. (Kumburu et al., 2014). The financial co-operatives, mostly SACCOS are the main co-operatives in Tanzania and account for 56% of all members followed by Agricultural Marketing Co-operatives (AMCOS) (36%) and the rest accounts for 8%. Financial co-operatives in Tanzania include SACCOs and co-operative banks. It is estimated that out of five households in Tanzania, there are almost eight million people who benefit from co-operative services taking the current estimated population of 50 million people. Furthermore, not only members who benefit but also other non-members and it is estimated that around 2.5 million people benefit from

Table 9.2 The status of co-operatives in Tanzania by December, 2018

Sn	Coop type	Male	Female	Groups	Institutions	Total	Shares (Tshs)
1	SACCOS	785,017	316,560	14,735	1879	1,118,191	163,617,260,840.85
2	AMCOS	780,452	314,719	14,649	1868	1,111,688	156,438,168,399.76
3	Consumer	8478	3419	159	20	12,076	767,202,378.85
4	Irrigation	17,174	6926	322	41	24,463	772,714,252.00
5	Livestock	32,827	13,237	616	79	46,759	648,887,421.00
6	Industrial	8044	3244	151	19	11,458	496,254,533.00
7	Housing	3478	1403	65	8	4954	906,450,874.00
8	Mining	22,392	9030	420	54	31,896	224,340,300.00
9	Fisheries	13,696	5523	257	33	19,509	103,525,000.00
10	Others	76,089	30,683	1428	182	108,382	1,615,448,020.00
	Total	**1,747,648**	**704,742**	**32,803**	**4183**	**2,489,376**	**325,590,252,019.46**

Source: Tanzania Co-operative Development Commission (TCDC) (2020)

co-operative services. This implies that over ten million people (account for almost 20% of the total population) benefit from co-operative services. The data quantify that the co-operatives sector was making huge business and members benefited out of it. This show how useful the co-operatives are. It is apparent that if co-operatives are engaged in socio-hydrological issues can play a big role in managing hydrological problems.

6.1 Co-operative and Environmental Resilience

Hydrological disaster has a negative impact to environment such as environmental pollution and degradation (soil erosion, land reclamation, etc.), animal and floral injuries, diseases and mortality, water stagnation and saltwater intrusion. This impact requires the joint efforts and collective responsibility. The sense of joint efforts and collective responsibility is also shown in co-operatives through one of the core values, solidarity. This value enables co-operatives to play a philanthropic role during post-disaster. For example, Moshi rural SACCOS located in Kilimanjaro, Kitunda SACCOS located in Dar es salaam and Ilulu SACCOS located in Lindi regions in Tanzania showed a sense of solidarity when members or people came together to help one another in clearing farms and street after 2020 floods in the areas (Figs. 9.1 and 9.2).

Co-operatives absorb the costs of flood damage and try to protect the members so that in later days they are not affected. For example, in unplanned residence number of actions has been taken to avert flood damage. Common methods include the use of sandbags, tree logs. Furthermore, on the aspect of sanitation co-operatives do provide soft loans to members so that they can rehabilitate toilet facilities by raising pit latrines and doorsteps as well as the provision of water outlet pipe. On the aspect

Fig. 9.1 Co-operatives members cleaning streets

of water in the house co-operatives offer seasonal displacement to members affected for free as well as education on water boiling and treatment.

6.2 Co-operative and Economic Resilience

Economic shocks emanating from hydrological disasters cannot be ignored, this is because of the impact brought by such disasters including increased living expenses, reduction of earnings, loss of valuable assets and impediment for communication and businesses. Using the values of social responsibility and caring for others enable co-operatives to provide a solid social protection that mitigates the crises impact on the most vulnerable groups. For example, Mruwia agriculture marketing co-operatives had to encourage members to donate some amount of money so as to help those in need. It was also found that the less affected members had to accommodate most affected members until their houses were rebuilt and rehabilitated. SACCOS being near to communities and being member-based kind of organisation have mechanism that is used to cope with shocks due to its availability and timeliness. Co-operative decreases vulnerability of the members by distributing risk among individuals. Financial co-operatives, such as SACCOs can offer loans to members so as to enable them to help cover meet costs of shocks in household

Fig. 9.2 Sandbags to prevent floods

budgets, re-establish their closed business as well as re-purchase of destroyed household assets. This is because the financial resource and education can be accessed quickly compared to other forms of organisations. In addition, some SACCOS have established disaster basket fund which together with the ideology of cooperation becomes important in disaster risk reduction in the community. Thus, it can be said that co-operative being reliable, effective may prevent a family from being worse off and in turn they become instrumental in building hydrological resilience than other form of organisation (Figs. 9.3 and 9.4).

Financial co-operatives in Tanzania (SACCOS) methods of ownership and capitalisation are critical component forming the difference in the pecuniary points of credit unions and banks and present advantages them. However, they are not subjected to risks compared to other forms of financial organisations. Since SACCOS are member-driven and self-help to a large extent do not impose risk to borrowers or members. Their governance structure ensures the patronage, accountability and transparency in a way that members who obtained loan to cope with disaster or floods know in one way or another that money is another member's money.

SACCOS are independent from capital markets for funding, because they are guided by savings first and credit later, and that major source of funding is from member deposits and savings. Member's satisfaction is their main motive rather than profit, this makes them escape from unnecessary risks. In view of that, SACCOS are most ideal in building hydrological resilience because of the principles underlying SACCOS operations.

Fig. 9.3 Reconstruction of houses after floods

6.3 Co-operative and Social Resilience

Hydrological disasters have affected the social matters negatively as such there was hindrance for the outdoor activities (house holding, playing for children and missed days of schooling,) as well as inaccessibility to information and disruption in communication. One of the core principles of co-operatives is concern for the community. Co-operatives to a large extent played this role through provision of counselling services to affected members so as to cope with isolation emanating from lack of outdoor activities. At the same time, less affected members had to accommodate most affected members until their houses were rebuilt and rehabilitated. Various assistance and aids in forms of money and school uniforms are donated to affected family so as to enable the affected children resume to their study as well as information concerning availability of outdoor activities, access to credit, market access as well as information on the various resilience techniques. The combined effect of these positive results of co-operatives has greatly affected the hydrological resilience of the members (Figs. 9.5 and 9.6).

Fig. 9.4 Loss of household assets

Fig. 9.5 Students in uniforms and balls donated by co-operatives

Fig. 9.6 Commination break down between Kilimanjaro and Tanga region

6.4 Co-operative and Infrastructure Resilience

Hydrological disaster has a negative impact to infrastructure such as the infrastructure losses (inaccessibility to energy, water, emergency and other facilities and services) or destruction of infrastructures (if not total destruction but due to moisture wicking materials warping and cupping, surface stains, risk of rust and corrosion, mould) and overflow of sewage and drainage systems. Co-operatives had to intervene in 2019 floods by offering emergence loans to members so that they can restore the damaged infrastructures such as water and electricity which was severe damaged but again through its corporate social responsibility co-operative donated about 50,000,000 Tsh equivalent to 21,000 $ so that road infrastructures in rural areas can be rehabilitated (Figs. 9.7 and 9.8).

6.5 Co-operative and Agricultural Resilience

Hydrological disaster affects the agriculture activities and production negatively as such it leads to destruction of agricultural fields, crop failure. Co-operative structure reduces individual risk by sharing risks between groups of individuals. Co-operatives are also pro-poor organisations. Financial co-operatives, SACCOS inclusive are very important in serving members interests during the time of shocks or emergence in terms of loans, advance salary or emergence fund. In addition, they can assist members to meet their business requirements throughout the business cycle. They can be farmers, fisheries, livestock keepers or miners. For example, Mruwia agriculture marketing co-operatives had to encourage members to donate some amount of money so as to help those in need. It was also found that the less affected members

Fig. 9.7 Electricity infrastructures covered by water

Fig. 9.8 Road infrastructures affected by floods

had to accommodate most affected members until their houses were rebuilt and rehabilitated. SACCOS being near to communities and being member-based kind of organisation have mechanism that is used to cope with shocks due to its availability

Fig. 9.9 Co-operative food donation during floods

and timeliness. This is because the financial resource and education can be accessed quickly compared to other forms of organisations. In addition, some SACCOS have established the disaster basket fund which together with the ideology of cooperation becomes important in disaster risk reduction in the community. Thus, it can be said that co-operative being reliable, effective may prevent a family from being worse off and in turn they become instrumental in building the hydrological resilience than other form of organisations.

In overall, because of their values, extensiveness and diverse presence in various sectors, co-operatives are well positioned to strengthen human security in all its aspects. Agricultural co-operatives focus on food security problems, while financial co-operatives promote financial inclusion and are resilient financially, economically and in natural disaster. 2020 flood in Tanzania left more than 8500 houses and 9600 hectares of farms destroyed, these people and household left with no food. But agriculture marketing co-operatives and SACCOS such as Hai Rural Teachers SACCOS, Same Kaya SACCOS, ELCT, ND SACCOS, Mruwia AMCOS and Mamsera donate food, organise training among members on how to store the foods during floods and other calamities (Figs. 9.9, 9.10, and 9.11).

SACCOS are independent from capital markets for funding, because they are guided by savings first and credit later and that major source of funding is from member deposits and savings. Member's satisfaction is their main motive rather than profit, this makes them escape from unnecessary risks. In view of that, SACCOS are most ideal in building hydrological resilience because they do not seize crediting operation, loan interest rate does not change at a high cost and is usually more stable due to the different capitalisation and lending practices.

Fig. 9.10 Reconstruction of houses after floods

Fig. 9.11 Food items donation after floods

7 Conclusion

The Role of Co-operatives in Building "Socio-Hydrological Resilience" for inclusion Experience of Tanzania has been presented in this chapter. Literature revealed that the floods are among the highly ranked natural disasters worldwide. It has also observed that there are three theoretical frameworks of resilience which are engineering resilience, ecological resilience and socio-ecological or adaptive resilience. These frameworks can be employed to explain how co-operatives can be regarded as adaptive resilient. The proposition of this study is that the co-operatives are found to be best explained in the context of socio-ecological or social hydrological resilience. This is so due to their role of ensuring community inclusiveness and joining together people of diverse socio-economic traits. Thus, this makes the co-operatives unique and very effective instrument in managing risk and disaster also ensuring the sustainable socio-economic development. Although there are little or no researches which vividly explain how co-operatives can build socio-hydrological resilience, it can be established that if the co-operatives are built in more adaptive and sustainable manner, they may become more socio-hydrological resilient. The chapter, therefore, has shown that the co-operatives either agricultural or financial are instrument in direct selling.

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Chapter 10
Strengthening Climate Resilience and Disaster Risk Reduction: Case Study of the Sahel Adaptive Social Protection

S. A. Igbatayo, Saeid Eslamian, O. O. Babalola, and A. A. Makanju

Abstract Climate change has emerged in the recent times as, perhaps, the most challenging development issue that poses an existential threat to both humanity and ecosystems. The manifestation of climate change and variability includes rising atmospheric temperatures, erratic rainfall patterns, rising sea levels, accompanied by the extreme weather events. Spawned largely by anthropogenic forces, comprising, among other things, demographic explosion, rapid urbanization, deforestation, over-grazing, agricultural intensification and extensification; the distribution of climate change impacts are rather uneven across the world. While Africa contributes the least emissions of carbon compounds blamed for global warming; the region has suffered some of the most severe impacts of the phenomenon. Over the past several decades, the global climate change has unleashed natural disasters around the world, triggering considerable loss and damage to people's lives and property. It has also fueled humanitarian crises, particularly in developing countries, which depend largely on rain-fed agriculture for their livelihoods. Crop failure, often associated with drought, and driven by climate variability, has devastated several low-income countries, with grave implications for food and nutrition insecurity. Increasing hazards, associated with the global climate change spurred the international development community to establish Disaster Risk Reduction frameworks as instruments to tackle climate-related risks and foster resilience, particularly among the poor and vulnerable segments of the population in the most affected countries around the world. Consequently, the World Bank, in 2014, established the Adapted Social Protection Program (ASPP) in the Sahel, covering Burkina Faso, Niger, Chad, Mali, Mauritania, Niger, and Senegal. With donor funding, the World Bank has supported the six countries with US75 million for the initiative, comprising cash transfers, as well as cash-for-work projects. In a progress report on the ASPP in 2017, the World

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Bank reveals the considerable success associated with the initiative, which drives the innovative social protection systems in the Sahel along a path of resilience, improved livelihoods and prosperity among the poorest and most vulnerable elements of the population.

Keywords Climate change · Sahel · Disaster · Resilience · Social protection · Risk reduction

1 Introduction

1.1 Preamble

Climate change has emerged as, perhaps, the most troubling development issue confronting humanity and the environment in contemporary times. Driven by largely rising atmospheric temperatures and increasingly unpredictable rainfall patterns, climate change and variability have triggered recurrent weather events that have unleashed considerable shocks through hurricanes, wildfires, droughts, and floods, among others, accompanied by considerable loss and damage to people's lives and property. Scientists largely agree that the contemporary global climate change emerged at the dawn of the industrial revolution (i.e. 1750), when humans began to pollute the environment with increasing emission of greenhouse gases (GHGs) and aerosols, as well as through changes in land use that fuel a rise in global atmospheric temperatures. Therefore, human-induced activities, otherwise known as anthropogenic forces, largely account for the emergence of global climate change.

With increasing industrialization, first, in advanced market economies and, then, in the emerging market economies, the global community has witnessed a heightened emission of GHGs, which are blamed for climate warming. In a paradox, the African continent, which accounts for the least emission of carbon compounds among the world's major regions, is suffering from some of the highest impacts of global climate change. Increasing atmospheric temperatures and erratic rainfall in Africa over the past several decades rank among the highest in the world. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (2014) reveals strong evidence that atmospheric temperatures had increased considerably across Africa over the previous 50–100 years, with estimates ranging from 0.5 to 2 °C, accompanied by a rapid frequency of such extreme weather events as droughts, wildfires, and flooding. This development has undermined people's livelihoods, particularly farmers, who rely mainly on rain-fed agriculture. Recurrent droughts, especially since the 1960s, have rendered several African countries, particularly in the Sahel vulnerable to food and nutrition insecurity. Extreme weather events, manifesting in form of droughts and floods in the early 2000s, were accompanied by rising food prices that triggered disaster shocks across the Sahel in 2005, 2008, 2010, and 2012, with grave humanitarian consequences. The negative trend prompted national governments across Sahel, often in partnership with the international development community, to create Disaster Risk Reduction (DRR) frameworks to foster climate resilience, with the aim of reducing vulnerability against food and nutrition insecurity in the most affected households (Igbatayo and Babalola, 2018).

The major objective of this chapter is to strengthen climate resilience and disaster risk reduction, drawing lessons from the Sahel adaptive social protection. The data used in the study are sourced from journal papers, monographs, and other periodicals, as well as the various publications from such international development agencies as the World Bank, United Nations, and other multi-lateral and bi-lateral agencies. Findings reveal the Sahel features fragile ecosystems vulnerable to global climate change. The region is undermined by dwindling the natural resources, spawned by such anthropogenic forces as rapid population growth, increasing urbanization, deforestation, over-grazing, as well as agricultural intensification and extensification. These developments exacerbate the disaster shocks across the Sahel, leaving a significant proportion of the population vulnerable to food and nutrition insecurity. The adaptive social protection in the Sahel, driven by the World Bank, in partnership with national governments, emerged in 2014 to foster disaster risk reduction, with national programs in Burkina Faso, Chad, Mali, Mauritania, Niger, and Senegal.

The paper is structured into four sections: Section 1 introduces the global climate change and strategies designed to combat the phenomenon. Section 2 examines the disaster risk reduction frameworks, as well as the resilience aimed at overcoming the shocks that often accompany disasters, while Sect. 3 elaborates the Sahel Adaptive Social Protection Program. Section 4 ends the paper with summary and conclusion.

1.2 An Overview of Global Climate Change

Climate change has emerged as the defining issue of contemporary times that holds grave implications for both human and ecological well-being. While the phenomenon has risen to the top of the international development agenda in the past few decades, there is hardly a unanimous agreement among climatologists on the definition of climate, let alone climate change. While UC Davis (Science and Climate) (2019) defined climate change as “significant change in temperature, precipitation, wind patterns and other measures of climate that occur over several decades or longer”; the Intergovernmental Panel on Climate Change (IPCC) (2014) defined the phenomenon as “ a change in the state of climate that can be identified (e.g. by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer.”

The aforementioned definitions differ from that of the United Nations Framework Convention on Climate Change (UNFCCC), which defined that climate change as “a change of climate, which is attributable directly or indirectly to the human activity that alters the composition of the global atmosphere and which is in addition to the natural climate variability observed over comparable time periods." Thus, the lack of precision in definitional terms of climate change lies at the heart of the controversy that has accompanied the phenomenon in recent times. However, despite the lack of consensus on the specific definition of climate change, there is considerable agreement among global scientists that the change in the climate system is a reality (USGCRP, 2017). While the UC Davis (Science and Climate) study, as well as the IPCC report associates climate change with the long-term trends, the UNFCCC draws a distinction between climate change attributable to human activities affecting the atmospheric composition, and climate variability attributable to natural causes (GWPF, 2011).

The IPCC, in its fifth report, acknowledges the human activities as the major causes of global climate change, with the rapid increase in anthropogenic greenhouse gas emissions since the pre-industrial era, driven largely by economic and demographic forces. Industrial development, which is associated with fossil fuel consumption, had led to atmospheric concentrations of carbon dioxide, methane, and nitrous oxide that are unprecedented at least, in the last 800,000 years, according to the IPCC report. The cumulative effects of the emissions have been detected throughout the climate system, which are extremely likely to have been the dominant cause of global warning since the mid-twentieth century.

Global warming, an element of global climate change, refers to the gradual increase in the average atmospheric temperature and its oceans, a change scientists believe to be permanently altering the earth's climate. Live Science (2019), in a report on global climate change, reveals that the planet is warming. According to the report, the scientific consensus on climate changes related to the global warming is that the average temperature of the Earth has risen between 0.4 and 0.8 °C over the last 100 years; driven by the increased emission of greenhouse gases released by the burning fossil fuels, land clearing, agriculture, and other human activities. These forces are blamed for global warming, with projections through the climate models revealing that average global temperatures could rise between 1.4 and 5.8 °C by the year 2100, according to the Live Science (2019) report.

In another study on global climate change, Adedeji, Reuben, and Olatoye (2014) acknowledge that while both natural and human-induced forces can fuel climate change; the current phenomenon is largely attributed to human activities, in a development of the study blames on the burning of fossil fuels.

The United States Environmental Protection Agency (EPA) (2017), in a study that examines the causes of the climate change, reveals that the earth's temperature is a balancing act between energy entering and leaving the planet's system. The study reveals that when incoming energy from the sun is absorbed by the Earth System, Earth warms; however, when the sun's energy is reflected back into space, Earth avoids warming. And when the absorbed energy is released back into space, Earth cools. Consequently, a combination of factors, both natural and artificial can fuel the changes in Earth's energy balance, including: (i) variations in the sun's energy reaching the earth; (ii) changes in the reflectivity of both the earth's atmosphere and its surface; and (iii) changes in the greenhouse effect, which impacts the amount of heat retained by the Earth's atmosphere, according to the EPA study (2017). Figure 10.1 reveals the contributions of both natural and human factors to climate change from 1900 to 2000.

As revealed in Fig. 10.1, human factors largely account for rising atmospheric temperatures over the twentieth century. According to the EPA (2017) study, the climate models that account only for the effects of natural processes cannot explain the warming observed over the century. Also, the models that account for the greenhouse gases emitted by humans are able to explain the warming trend. The EPA study further reveals that over the last several hundred thousand years, carbon dioxide (CO_2) levels varied in line with the glacial cycles. For example, during warm "interglacial" periods, the CO_2 levels were higher and lower during the cool "glacial" periods. Consequently, the heating or cooling of the Earth's surface and oceans can affect changes in the natural sources and sinks of these gases, changing the greenhouse gas concentrations in the atmosphere. Figure 10.2 reveals the trend in estimates of the Earth's changing CO_2 concentration and Antarctic temperatures based on analysis of ice core data extending back 800,000 years.

Figure 10.2 reveals that until the past century, the natural factors accounted for atmospheric concentrations of CO_2, varying within about 180–300 parts per million volumes (ppmv), with the warmer periods coinciding with the periods of relatively high CO_2 concentrations.

Reporting on the effects of climate change, Climate and Weather (2019) revealed that changes in weather pose grave consequences to agriculture. Changes in the

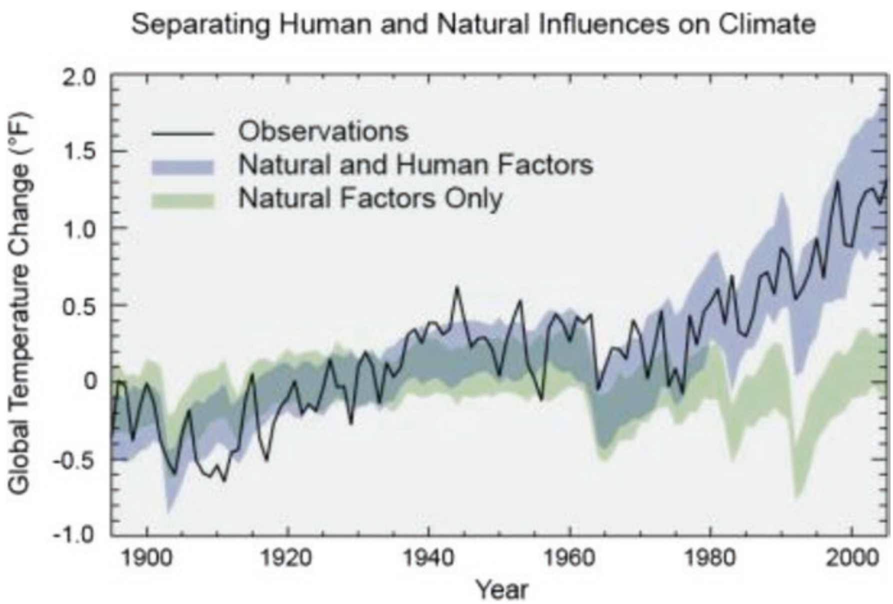


Fig. 10.1 Contributions of natural and human-induced factors to climate change, 1900–2000. Source: EPA (2017)

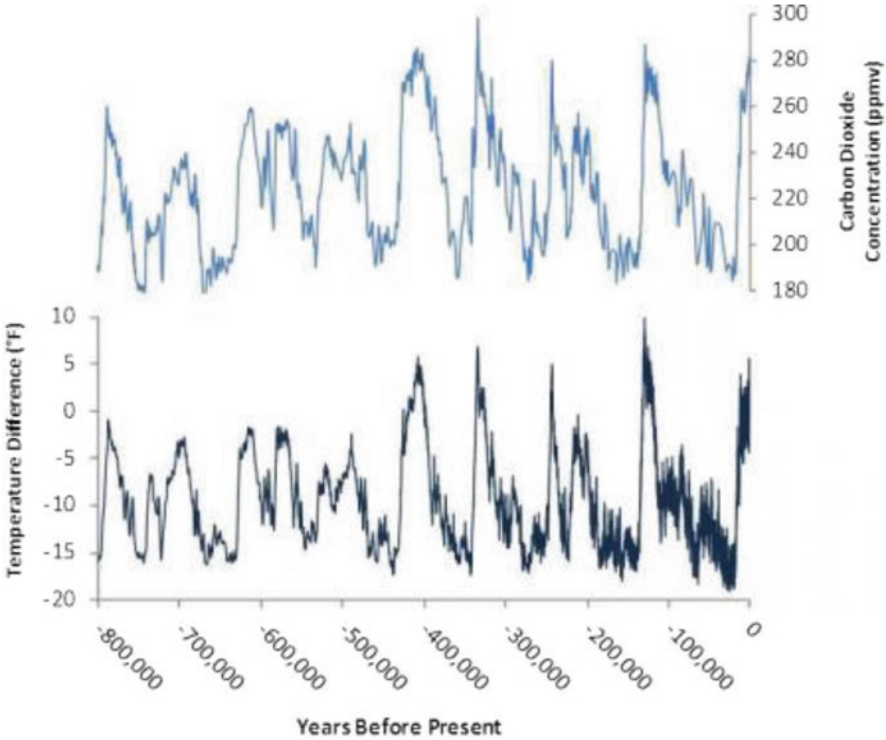


Fig. 10.2 Relationship of carbon dioxide concentrations and temperature levels in Antarctica estimated over the past 800,000 years. Source: EPA (2017)

rainfall patterns already affect the productivity of crops around the world. The report revealed that the impact of climate change on plant growth may lead to food insecurity in several countries, including Brazil, parts of Africa, South-east Asia, and China and exposing millions to hunger. The report also reveals that the emergent global climate change is poised to exacerbate the water scarcity in parts of the world, with increasing water demand in many regions.

A major worrisome trend associated with global climate change is its impact on human health. The United States Center for Disease Control (CDC) (2014) revealed that climate change poses several risks to human health, as some of its impacts are felt throughout the world. The report further revealed that climate change, along with the other natural and human-induced health stressors, influences human health and diseases in a range of ways. Some existing health threats are set to intensify, while new health challenges will emerge, driven by the emergent global climate change. The health effects of the phenomenon include increased respiratory and cardio-vascular diseases, injuries, and premature deaths relating to extreme weather events, changes in the prevalence and geographical spread of food and water-borne illness, as well as the other infectious diseases and threats to the mental health. Fig. 10.3 illustrates the impacts of climate change on human health.

In a study of the economic effects of climate change, Tol (2009) acknowledged that while developed economies largely account for carbon emissions blamed for climate warming, some of the most severe impacts of the phenomenon are prevalent in the poorest countries in the world. Indeed, the impact estimates for Sub-Saharan Africa reveal a welfare loss equivalent to a quarter of income. The study further reveals that the low-income countries tend to be located in tropical zones closer to the equator, where the climate is already hotter and their output already suffers from the high temperature in such vulnerable sectors like agriculture. Also, the low-income countries are largely less able to adapt to climate change, owing to both lack of resources and less capable institutions.

2 The Nexus of Disaster Risk Reduction and Resilience

2.1 Disaster Risk Reduction and the 2030 Agenda for Sustainable Development

Natural disasters are assuming increasing dimensions around the world, with grave consequences. Over the past decade alone, more than 1.5 billion people have been affected by disasters, with an estimated cost of at least US$1.3 billion. Indications are that climate change, weak governance, as well as increasing concentration of

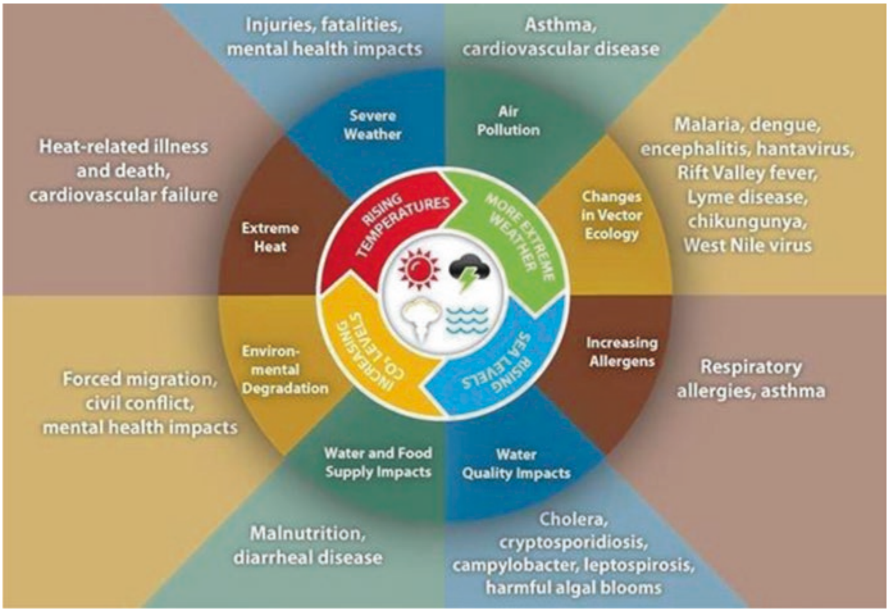


Fig. 10.3 Impact of Climate Change on Health. Source: CDC (2014)

people along paths exposed to natural hazards, are driving up the disaster risks, particularly in low-income and fragile countries. This development poses a threat to the global community, spurring the inclusion of DRR on the agenda of the 2030 Sustainable Development Goals (SDGs) (UNDP, 2019). For example, the UNDP's disaster risk reduction efforts aim to risk-inform development in tandem with the goals and targets of the SDGs, as well as the Sendai Framework for Disaster Risk Reduction.

The 2019 Global Assessment Report (GAR) on Disaster Risk Reduction (DRR) explores the interactions between the Sendai Framework for DRR, the Paris Agreement on Climate Change, the New Urban agenda (NUA), the Agenda for Humanity, and the 2030 Agenda for Sustainable Development. Acknowledging that the 2030 Agenda recognizes the central role risk reduction and resilience play in the sustainable development policy, the report promotes the adoption of strategies to manage risk and prevent a slowing or reversal of progress toward achieving the SDGs and highlights the disaster-related targets, for which the United Nations Office for Disaster Risk Reduction (UNDRR) is the custodian agency under SDGs1 (no poverty) 11 (sustainable cities and communities) and 13 (climate action) (Mead, 2019).

The 2019 GAR further reveals that integrated monitoring and reporting on Sendai Framework and SDGs reduce the duplication of data-collection efforts and the reporting challenges for countries. Among other things, the 2019 GAR outlines the current practices in developing the national and local plans to enhance the risk reduction capacity and integrating DRR with development planning and climate change adaptation. It reveals the lessons drawn in using a system-based approach to risk reduction at national and local levels. The GAR has also introduced the Global Risk Assessment Framework, which aims to improve the understanding and management of current and future risks to better mitigate uncertainties and mobilize people, innovation, and finance.

The International Science Council (2019), in a report on achieving risk reduction across Sendai Framework, Paris global climate agreement, and the SDGs reveals the synergies and coherence embedded in these global instruments in respect to the systemic and cascading risks. The report acknowledges the global trend associated with increasingly frequent and severe emergencies and disasters, driven largely by the demographic shifts and urbanization patterns, the impacts of climate change, increasing the exposure and vulnerabilities to hazards, and the rising global interdependence of systems to combat the scourge.

2.2 The Evolution of Disaster Risk Reduction Frameworks

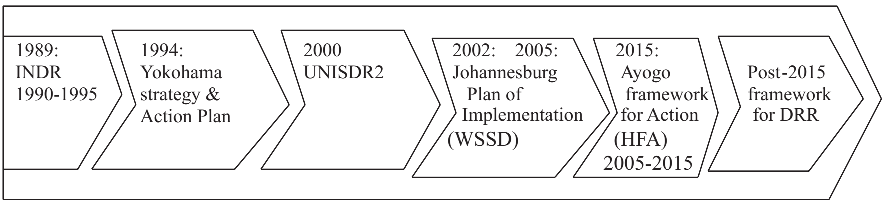
The concept of Disaster Risk Reduction (DRR) has evolved over the past few decades, with its origin traceable to the adoption of 1989 as the International Decade for Natural Disaster Reduction. Over the past decades, the UN International Decade for Natural Disaster, the Yokohama Conference (1994), and the 2004 World

Conference on Disaster Risk Reduction (WCDR) have all assisted in elaborating a shift in the understanding of disaster management toward a more holistic appreciation of the underlying causes of hazards and vulnerability, as well as toward the development of a forward-looking and longer term strategy for anticipating and managing risk. The evolution of DRR is illustrated in Fig. 10.4.

The Yokohama Strategy and Plan of Action for a safer world emerged in 1994 as a framework for Disaster Risk Reduction, adopted following the United Nations World Conference on Natural Disaster Risk Reduction at Yokohama, Japan. The document is the first providing the guidelines at the international level on preparation for and prevention, as well as mitigation of disaster impacts (Poteric and Baudoin, 2015). A product of the International Decade for National Disaster Reduction (1990–2000), the Yokohama strategy was also the result of the 1994 World Conference on Natural Disaster Reduction. The two global events acknowledged the imperatives of community participation in DRR, as reflected in the Yokohama Strategy (IDNDR, 1994):

> Active participation should be encouraged in order to gain greater insight into the individual and collective perception of development and risk, and to have a clear understanding of the cultural and organizational characteristics of each society, as well as of its behavior and interactions with the physical and natural environment.

The document offers guiding principles to leverage the DDR for risk mitigation, particularly as they relate to community participation. The Yokohama strategy also focused on improving coping mechanisms in order to better adapt to and recover from disaster impacts. In order to enable easy and fast recovery process, the strategy



Promoting of disaster reduction, main focus on technical and scientific aspects (IDNDR – International Decade for National Disaster Reduction)	Revision of IDNDR, first blueprint for disaster reduction policy guidance (social & community orientation)	Increate public commitment to sustainable development enlarged networking and partnership	Includes new section of "An Integrated, multi hazard, inclusive approach to address vulnerability, risk assessment and disaster management"	Building the resilience of nations and communities towards disasters	Review and improvement of the HFA (update on monitoring system and periodic review processes, voluntary commitment of stakeholders, political declaration

Fig. 10.4 Evolution of the DRR Framework

acknowledges knowledge and experience in managing emergencies existing at the local and community levels.

The evolution of DRR was notched forward with the Hyogo Framework for Action, 2005–2015. The framework was popular with the world conference for Disaster Risk Reduction, held in Kobe, Hyogo, Japan in mid-January, 2005. The event, which took place in the aftermath of the 2004 tsunami in the Indian Ocean, devastated millions of lives in the region. It however brought into sharp focus the impacts of natural disasters, as well as their risks (UNISDR, 2005).

The implementation of and follow up to the strategic goals and priorities of action set out in the Hyogo framework for Action is aimed at different stakeholders in a multi-sectoral approach, including the development sector. States and regional, as well as international organizations including the United Nations and international financial institutions are called upon to integrate the disaster risk reduction efforts into their sustainable development policy, planning, and programming at all levels, according to the IDNDR (1994) report.

They Hyogo Framework of Action (HFA), a DRR instrument, evolved over a period of 10 years, 2005–2015. During this period, the global community continued to witness natural disasters, with increasing human, economic, infrastructure, and ecological losses, particularly in the most vulnerable, low-income countries (Nicholson, 2015).

Upon its expiration, the HFA was succeeded by the Sendai Framework for Disaster Risk Reduction (SFDRR) 2005–2030. In a reflection of the global community's commitment to DRR, the SFDDR was concluded in Sendai, Japan, in March 2015. The emergent framework is built on lessons drawn from the implementation of the HFA over the previous decade.

Adopted at the third World War Conference on Disaster Risk Reduction in Sendai, Japan in 2015, the Sendai Framework is focused on building the resilience of nations and communities to disasters; it offers the countries a unique opportunity to: adopt a concise, focused, forward-looking and action-oriented post-2015 framework for the disaster risk reduction; complete the assessment and reviewing of the implementation of the Hyogo Framework for Action 2005–2015; building the resilience of the nations and communities to disaster; considering the experience gained through the regional and national strategies/institutions and the plans for disaster risk reduction and their recommendations, as well as the relevant regional agreements for the implementation of the Hyogo Framework of Action; intensify the modalities of cooperation based on commitments to implement a post-2015 framework for the disaster risk reduction; and determine the modalities for the periodic review of the implementation of a post-2015 framework for disaster risk reduction.

The Sendai Framework of action comprises four priorities:

- Priority 1: Understanding disaster risk.
- Priority 2: Strengthening disaster risk governance to manage disaster risk.
- Priority 3: Investing in disaster risk reduction for resilience.
- Priority 4: Enhancing disaster preparedness for resilience response.

A common feature of recent frameworks for disaster risk reduction is resilience. Prevention Web (2015) defined the resilience as "ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including the preservation and restoration of its essential basic structures and functions through risk management."

Indeed, resilience is about anticipating, planning, and reducing disaster risk to effectively protect persons, communities, and countries, together with their livelihoods, health, cultural heritage, socio-economic assets, and systems. The Prevention Web (2015) report revealed that resilience is driven by "capacity" and "coping capacity" accompanied by the following related issues:

1. Resilience: the ability to flourish in the face of disaster risk;
2. Capacity: strengthening ability and resources available to anticipate, cope with, resist, and recover from disasters; and
3. Coping capacity: the ability to face and manage disaster.

The Partners for Resilience Alliance (PIR) (2019) revealed the critical nature of resilience as an instrument for disaster risk reduction. It advocates robust partnerships by the international development community to implement the Sendai Framework (Fjäder and Eslamian, 2021). Among other things, the third priority of the Sendai Framework advocates the public and private investment in disaster risk prevention and reduction through the structural and non-structural measures critical for enhancing the economic, social, health, and cultural resilience of persons, communities, countries and their assets, as well environment. In the opinion of experts, these are the drivers of innovation, growth, and job creation, which are largely cost-effective and critical to saving lives, preventing and reducing losses, as well as ensuring effective recovery and rehabilitation.

3 The World Bank and Sahel's Adaptive Social Protection Program: A Multi-Country Study of Burkina Faso, Niger, Chad, Mali, Mauritania, and Senegal

3.1 The Sahel Social Adaptive Protection Program (ASPP)

Concerned by the recurrent shocks that have been unleashed through natural and human-induced disasters across the region, the World Bank, in 2014, established the Sahel Adaptive Social Protection Program (ASPP). The initiative is conceived beyond the traditional responses to shocks and disasters, through humanitarian aid and emergency assistance; to embrace the new approaches that assist the poor to build long-term resilience to the climate-related shocks and other risks, reducing endemic poverty, while contributing to shared prosperity. Thus, the ASPP has emerged as a novel approach that draws on and integrated the tools and techniques of social protection, climate change adaptation, as well as disaster risk reduction (World Bank, 2016). Managed by the World Bank, the ASPP is a multi-donor Trust Fund (MDTF) into which the UK Department for International Development committed about US$75 million over an initial period of 4 years, 2014–2018, with more donors showing commitment during project implementation. The ASPP is targeted at vulnerable populations in Burkina Faso, Chad, Mali, Mauritania, Niger, and Senegal. Under the initiative, the program provides technical assistance, together with finance to develop, operationalize, and implement the robust systems that will enable these countries to provide the cost-effective, adaptive social protection in the long run.

The ASPP is an integral part of the World Bank's global Social Protection and Labor Strategy to assist the developing countries to develop more harmonized systems for social protection and labor; it is also anchored in the Africa Social Protection Systems in order to reduce vulnerability and poverty by assisting people to (World Bank, 2016): (i) managing the risk and responding to shocks; (ii) building their productive assets and increasing their access to basic services; and (iii) engaging in productive income-earning opportunities.

Table 10.1 shows the profile of social safety net programs associated with ASPP in the Sahel.

Table 10.1 reveals the profile of social safety net programs, an element of ASPP in the Sahel. The initiative targets the vulnerable populations in Burkina Faso, Chad, Mali, Mauritania, Niger, and Senegal. The value of the cash transfer ranges between 10,000 FCFA in Niger and 30,000 in Burkina Faso and Mali, during a period ranging between 2 and 5 years, with coverage of households mostly ranging between 56,000 in Burkina Faso and 300,000 in Senegal.

As part of the ASPP, six countries in the Sahel have embarked upon social protection strategies that prioritize an investment in the long-term, as well as the comprehensive, adaptive systems. Among other things, each country's targeted program of investments has been created in close consultation with the World Bank Country Team to complement and leverage the current International Development Association (IDA) support, according to the World Bank (2016) report. The country programs in Burkina Faso, Chad, Mali, Mauritania, Niger, and Senegal are expected to contribute toward achieving long-term impact in helping the poor and vulnerable

Table 10.1 Profile of social safety net programs in the Sahel

Country	Payment amount	Duration	Coverage
Burkina Faso	30,000 FCFA/3 months	2 or 3 years	56,000HH
Mali	30,000 FCFA/3 months	3 years	62,000HH
Mauritania	15,000 MRO/3 months	5 years	100,000HH
Niger	10,000 FCFA/3 months	2 years	100,000HH
Senegal	25,000 FCFA/3 months	5 years	300,000HH
Chad	30,000 FCFA/3 months	4 years	6200HH

Source: USAID (2017)

people to become capable of anticipating, absorbing, and recovering from the climate shocks and stresses, as illustrated in Fig. 10.5.

Figure 10.5 reveals the theoretical framework behind the ASPP, showing its elements: input, output, outcome, and impact over its projected course, spanning a period of 10–15 years. At the end of the initiative, the poor and vulnerable people in the six countries across the Sahel are expected to acquire the capacity of anticipating, absorbing, and recovering from climate shocks and stresses.

In a progress report on the ASPP, the World Bank (2017) reveals that during the first year of implementation (FY15), the World Bank task teams finalized and began the implementation phase of the Bank-executed work program. This embraces preparation of recipient-executed program, which began with recipient-executed activities approved for Mauritania in May 2015. The World Bank (2017) report also revealed that during the second year, the ASPP advanced in its implementation of both country-level and regional programmatic activities, as well as launching the innovation window. Country-specific research and knowledge activities were initiated, while some products were completed. The country work programs focused on advancing the design and implementation of recipient-executed activities.

During the ASPP's third year (FY17), the World Bank (2017) report revealed the considerable progress was recorded on the implementation phase of recipient-executed activities, which are now in place in all of the six countries. Indeed, the initiatives undertaken in the previous 2 years, especially through the bank-executive activities and the regional programmatic activities, provided the foundation for building adaptive social protection systems in the Sahel. It is also noteworthy that the activities under the innovation window have been advanced, according to the World Bank report (2017).

3.2 The Sahel Adaptive Social Protection Program: A Multi-Country Analyses of Burkina Faso, Chad, Mali, Mauritania, Niger, and Senegal

3.2.1 Burkina Faso

A low-income country, with Gross National Income (GNI) per Capita of US$620 in 2016, Burkina Faso is home to some of the world's most impoverished people. The country is also listed alongside the World's Least Developed Countries (UNCTAD, 2019). Its profile as a deeply impoverished country, together with its location in the Sahel has rendered Burkina Faso particularly vulnerable to both economic and environmental shocks. The ASPP team has worked closely with the country management unit to plan and identify the activities that laid a foundation for a comprehensive social protection program. Key activities are in place, enabling a robust analysis of the country's fragility and vulnerability, while a better understanding of how safety nets can contribute to improve the response to shocks in place (World Bank, 2016).

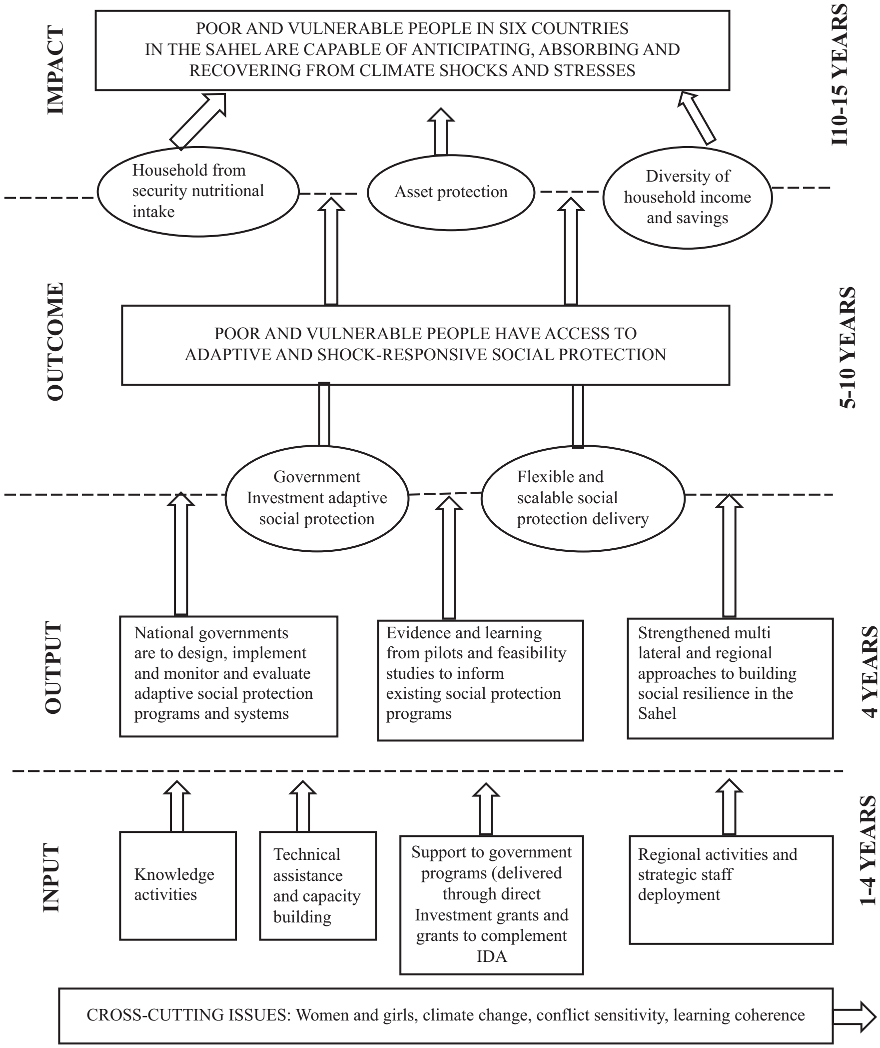


Fig. 10.5 ASPP Theory of Change. Source: World Bank (2017)

In its progress assessment on the ASPP, the World Bank (2017) report revealed that Burkina Faso received US$8 million to drive the recipient-executed activities involving financing for existing safety nets project, with the aim of ensuring that the country's safety net system can be rapidly scaled up to respond to crises that can foster resilience of the poorest households. The country's safety net program currently covers 80,000 people with cash transfers and awareness programs on health, nutrition, women's empowerment, as well as early childhood development. In addition, a climate response transfer for 30,000 people has been included in FY18. The initiative aims at covering 225,000 people by 2020, while a further expansion is being initiated by the government. The World Bank (2017) report further revealed that the beneficiary and local community feedback suggests the project is making progress toward the following objectives: (i) "Households no longer have to sell their food reserve to finance kids' school equipment. Until recently, some women found it hard to buy as much as a pen; now that is no longer a worry for us"; (ii) "The project has in fact increased understanding in households. One husband who was going to take over the entire transfer after his wife had been paid turned round and agreed to buy some sheep jointly with her—three actually—which they are now managing together"; and (iii) "Women did not know they could just take the initiative and declare the birth of a child; they would wait for their husband. Now they know."

Complementing the recipient-executed activities are the Bank-executed activities, which are being implemented as planned. Several have been finalized, including a study on possible update of the proxy means test formula and an analysis of the alternative quantitative targeting approaches for reaching the poor and vulnerable households, a feasibility study and productivity, as well as the technical assistance to start linking data from the country's existing early warning system to establish trigger mechanisms for recipient-executed shock-responsive pilot, the World Bank (2017) report reveals.

3.2.2 Chad

Chad is a low-income country, with GNI per capita estimated at US$740.00 (World Bank, 2018b). The country's socio-economic profile is characterized by high levels of impoverishment. While the nation's poverty rate fell from 55% to 47% between 2003 and 2011, the absolute number of poor is projected to rise from 4.7 million to 6.3million between 2012 and 2019, according to the World Bank report. Chad's consistent low ranking on the United Nations Development Program (UNDP) Human Development Index (HDI) is testimony to the nation's multi-faceted development challenges. While the nation's HDI ranking has improved steadily from 0.299 in 2000 to 0.404 in 2017, it remains in low human development category and ranks 186 of 189 countries and territories in 2017 (2018).

Endemic poverty in Chad has rendered a significant segment of the population vulnerable to economic and environmental shocks. The vulnerability of the poor to the disaster shocks in Chad prompted the nation's inclusion in the ASPP, which was established in 2014. In Chad, the initiative aims to update the existing social protection strategy to further integrate the disaster risk management and climate resilience while strengthening the existing early warning system to better anticipate the impact and occurrence of the hazards on the most impoverished segments of the population. It also aims at strengthening the monitoring and evaluation mechanisms of efforts to prevent and respond to recurrent food crises. In addition, the indications are that policy and analytical work undertaken to date has been integrated to Chad's endeavor in its social protection strategy. It has also informed the World Bank's strategy in Chad, shedding light on critical elements and priorities in social protection, adaptive safety nets, increased resilience, as well as improved livelihoods (World Bank, 2016).

In a progress report on ASPP in Chad, the World Bank (2017) revealed its US$5million in support of recipient-executed activities involving piloting cash transfers and cash-for-work interventions targeting the poor, which laid the foundations for an adaptive safety net system. Conversely, the Bank-executed program in Chad embraces a vulnerability and safety assessment and supports implementation of a pilot project introducing adaptive social protection to the country. During FY17, according to the World Bank report, recipient-executed activities focused on the establishment of a social safety nets unit, ***Cellule Filets Sociaux*** (CFS), driven by its core nine-team members. An independent government unit, the CFS is attached to the Ministry of Economics and Development Planning, serving as the project implementation unit for the cash transfer, as well as cash-for-work projects supported by the ASPP. The profile of CFS is shown in Table 10.2.

Table 10.2 revealed the profile of social safety net project in Chad, comprising cash transfers and cash-for-work project. While disbursement conditions were met in July 2017, disbursement of funds commenced in early August for participants in the pilot project.

3.2.3 Mali

A low-income country, Mali is characterized by high levels of poverty and exacerbated by endemic conflict. It is home to some of the most impoverished people in the world and ranked alongside the Least Developed Countries (UNCTAD, 2019). While Mali's poverty rate fell from 55.6% in 2001 to 43.6% in 2010, the trend relapsed to 45% in 2013, against the backdrop of armed conflict in 2012, as well as series of droughts (World Bank, 2018a). With a GNI per capita estimated at US$770.00 in 2017, Mali is classified as a low-income country. The country's development challenges are brought into sharp focus with its persistently low rankings on the annual United Nations Human Development Index (HDI). For example, in the 2018 assessment, Mali ranked 182nd of 188 countries and territories (World Bank, 2019). Climate variability has unleashed the natural disasters in Mali, accompanied by extreme weather events, particularly droughts and flooding, which undermine the livelihoods of an already impoverished population. This development informed Mali's inclusion, in 2014, on the ASPP. Social protection, a key element of the ASPP, has also emerged as a major component of Mali's poverty reduction strategy. Thus, the major objective of ASPP in Mali is to expand the current endeavor on social safety nets toward developing adaptive social protection programs to increase the coverage, resilience, and livelihoods of the poor and vulnerable (World Bank, 2016). The ASPP team is conducting the various analytical activities, particularly the monitoring system, together with an assessment of basic needs, institutional arrangements, as well as public work activities that could be integrated into the ASPP. In 2016, the technical activities to develop the adaptive social protection

Table 10.2 An overview of safety net project in Chad

Name	Project Pilote de Filets Sociaux
Total budge	US$10 million
Number of beneficiaries and geographic targeting	Cash transfer beneficiaries Logone occidental region: 4650 households Bahr el Gazal: 1550 households Cash-for-work beneficiaries N'djamena: 9000 individuals
Safety net transfer	Cash transfer: CFAF 15,000 (US$26) per month per beneficiary for 3 years Cash-for-work: CFAF 1200 (US$2) per day for 80 days (one cycle) per beneficiary
Frequency of payments	Quarterly for cash transfer program Every 20 days for cash-for-work program
Payment modalities	Cash through a payment agency for cash transfers, proposed that payments be made through local banks to be cashed with a beneficiary card at ATMs

Source: World Bank (2017)

systems were consolidated, along with laying the groundwork for the country-implemented work program, according to the World Bank (2016) report.

In a progress report on the ASPP in Mali, the World Bank (2017) report revealed that the country received US$11.25 million in support of the recipient-executed activities to provide an additional funding for the country's already existing cash transfer program, with the aim of further strengthening its current social safety net system, making it more adaptable, while increasing the resilience of the poor and vulnerable households. In order to complement these activities, Bank-executed activities leveraged the geographic information system (GIS) to consolidate the local statistics on poverty, vulnerability, climate change, disaster, and human capital. At the same time, the Bank is supporting the development of a national social protection strategy, together with the design and implementation of adaptive social protection tools.

The World Bank (2017) report further revealed that Mali's recipient-executed activities have focused on implementation of labor-intensive public works, as well as income-generating activities to complement and expand the ongoing safety net project. Activities include the geographic targeting of the 40 beneficiary districts for the labor-intensive public works that have been completed. Also, targeting 20 communities for income-generating activities was finalized, while selecting of beneficiaries is ongoing. In total, 10,000 people will benefit from income-generating activities.

3.2.4 Mauritania

Mauritania is a lower, middle-income country, with a GNII per capita estimated at US$3900.00 in 2017. Despite the nation's relatively high income status in comparison with other countries in the Sahel, its poverty profile remains challenging, with impoverishment rate estimated at 33% in 2014, down from 44.5% in 2008 (World Bank, 2019). In line with improving living standards, Mauritania's inequality profile, measured by the Gini Index, declined from 35.3 in 2008 to 31.9 in 2014. However, the nation's location, largely confined within the Sahara Desert, has rendered Mauritania's poor segments of the population vulnerable to both economic and environmental shocks. The increasing prospects for the natural disasters in the country promoted the World Bank, in 2014, to include Mauritania in the ASPP. The World Bank's initiative in Mauritania is linked to its regional agenda on pastoralism, since the service associated with the initiative provides the pastoralist population, an opportunity to quickly enroll in the social registry in case of emergencies. The ASPP also finances the establishment of key building blocks of the national safety net system, including adaptable social protection tools. The ASPP, in addition, creates the design and implementation modules to promote the household resilience to shocks, as well as adaptation among conditional cash transfer program beneficiaries. Technical support is also provided on vulnerability analysis, adaptation of early warning system to trigger the social protection responses to crises, while defining mechanisms and measures to respond to shocks and promote resilience are also in place (World Bank, 2016).

In a progress report on the ASPP in Mauritania, the World Bank (2017) revealed that the country received US$5.25 million in support of recipient-executed activities focusing on supporting the creation of key building blocks of the national social safety net system, particularly a national registry of poor and vulnerable households, a management information system (MIS), which can be adapted and adopted by other permanent or temporary programs. It also includes a functional coordination mechanism with the disaster response mechanism system. In order to complement these activities, the Bank-executed activities include the vulnerability analysis, adaptation of the early warning system to trigger the social protection responses to crises, as well as defining mechanisms and measures to respond to shocks and promote resilience.

The World Bank (2017) report also revealed that under the recipient-executed activities, the major components of Mauritania's safety net system were established in FY17, including the social registry, which completed the first household round of data collection in September 2016, while the first national safety net payment was made in December 2016/January 2017. In addition, the nation began a rollout of these components throughout the country. Furthermore, principles and modalities for implementing the program were defined in the first quarter of 2017.

3.2.5 Niger

Niger is a low-income country with GNI per capita estimated at US$420 in 2007 (World Bank, 2017). The nation is faced with multiple development challenges that undermine its economy and environment. With a poverty rate of 44.1%, Niger is one of the poorest countries in the world listed alongside the Least Developed Countries (UNCTAD, 2019). The severity of the nation's development challenges is highlighted by the nation's consistently low rankings on the annual UNDP's HDI. For example, the 2018 HDI ranks Niger at the bottom (189th position).

The nation's high rate of impoverishment, together with its location mostly within the confines of the Sahara desert, renders it vulnerable to both economic and environmental shocks. The emergent global climate change has exacerbated the nation's vulnerability through increasing weather events. These developments prompted the World Bank, in 2014, to include Niger in the ASPP. The initiative provides support for poverty mapping, particularly climate risks; a review of the existing social protection strategy to ensure that climate-related vulnerabilities and mitigating measures to enhance the resilience within communities are addressed; and a capacity needs assessment to facilitate the effective delivery of the revised social protection strategy. Support and technical assistance are also being provided for the design of tools to promote resilience in social protection intervention (World Bank, 2016).

In a progress report on the ASPP in Niger, the World Bank (2017) revealed that Niger received US$11million in support of the recipient-executed program, including support for additional financing to the original safety nets interventions to crisis on resilience of the poorest households. According to the World Bank report, key elements of the bank-executed programs embrace the improving diagnosis on vulnerability, developing the new tools and instruments for resilience, and impact evaluations, as well as targeting assessments. Several activities were undertaken under the recipients-executed programs with a focus on social registry, the payment system, and the cash transfer component and the cash-for-work elements. A clear road map and a detailed action plan were also provided for implementation of the social registry over the next 2 years. In order to facilitate the identification and payment of beneficiaries, a smart card payment system was created and field-tested in a village in 2016. In addition, an emergency cash transfer system was first tested in Diffa region. The additional financing on the cash transfer project is to be extended to new regions, including Agadez, Diffa, and Niamey. A total of 8521 households, including 2381 households in Agadez, 3872 in Diffa, and 2268 household in Niamey were registered into the project.

According to the World Bank (2017) progress report, the first transfer to the beneficiary was made in June 2017. In order to enhance the monitoring and evaluation of the cash-for-work activities at the national level and facilitate implementation of the productive accompanying measures, the initiative supported geo-referencing of all cash-for-work worksites; which will enable the government to provide an overview of all such worksites supported by a range of development partners.

A shock-responsive safety net system was also set up by the ASPP and successfully tested in the Diffa region of Niger, which has been highly impacted by the Boko Haram insurgency. The region has experienced a lot of refugees and returnees from Northern Nigeria, who have been displaced and fleeing insecurity attributed to the emergency. By August 2017, a total of 2456 households received the emergency cash transfer in Diffa. The distribution of the beneficiaries is as follows: 54% for internally displaced people, 37% for host populations, and 9% for returnees.

The success attributed to these activities has prompted the government to request for an extension of the emergency cash transfer to the region of Agadez, with a new ware of 2500 additional households.

3.2.6 Senegal

Senegal is a lower, middle-income country, with a GNI per capita estimated at US$1240. While the World Bank (2019) report projected a decline in poverty rates from 34% in 2017 to 31.2% in 2020; the poverty levels in Senegal remain a development challenge. For example, the Senegal's HDI value for 2017 is 0.505, which puts the country in the Low Human Development category and ranking it at 164 of 189 countries and territories (UNDP, 2018). The country's Low Human Development profile, together with its location largely in the Sahel, renders it vulnerable to both economic and environmental shocks. In a development compounded by the emergent climate change, Senegal has suffered the natural disasters unleashed by increasing weather events, particularly droughts and floods. The negative trend associated with rising natural disasters in Senegal prompted the World Bank in 2014 to enlist the country under the ASPP.

In Senegal, the ASPP supports the capacity to implement the adaptive social assistance programs and build resilience of the most vulnerable households, complementing ongoing and planned World Bank assistance in the country. Program activities are shaped to complement Senegal Country Partnership Strategy and with government plans, as well as the National Strategy for Social Development. The ASPP also supports the design of adaptive safety net mechanisms, including frameworks for existing programs to address the crises, as well as the additional measures to promote resilience and new programs, including public works to respond to the shocks. This is particularly critical to broadening the country's early warning systems to trigger social protection responses to shocks; expansion of the national registry of vulnerable households to include those vulnerable to shocks; and implementation of adaptive social assistance programs that assist to prevent shocks or mitigate their impacts (World Bank, 2016).

The World Bank (2017) progress report on ASPP revealed that Senegal received US$13 million in support of recipient-executed activities aimed at scaling up the existing safety net project and strengthening the foundations created for social protection system through a national registry, as well as national conditional cash transfer program accessible to all localities while introducing adaptive components in the social protection system to make the poor households more resilient to shocks.

Among other things, the objective of the bank-executed activities is to contribute to the development of frameworks that can make Senegal's safety net system more adaptive, efficient, and responsive to enable the ability of the poor and vulnerable households to respond to shocks and build resilience.

According to the World Bank (2017) reports, the indications are that implementation of the recipient-executed activities is progressing well. For example, the two pilot programs were implemented in 2017 in response to the shocks associated with drought and its impact on food security, as well as flooding and fire (and their impact on household assets).

4 Conclusion

The Sahel has witnessed a variety of disasters in recent times, largely attributed to the fragility of the region's ecosystems, as well as the emergent global climate change (Igbatayo, 2018). Climate variability and change have unleashed severe weather events, triggering droughts, floods, wildfires, and rising sea levels. The trend is accompanied by increasing shocks associated with natural and human-induced disasters, with grave humanitarian consequences. Recurrent droughts have fuelled crop failure and triggered food and nutrition insecurity across the Sahel, in a development that has prompted the international development community to respond with resources to mitigate the recurring disasters unleashed across the region in recent times.

Increasing disasters are indeed a global phenomenon, which has galvanized the international community to respond with disaster risk reduction and management strategies. Among other things, two major instruments were developed recently by the global community to foster Disaster Risk Reduction and build resilience against both natural and human-induced disasters: the Hyogo Framework of action, 2005–2015, and the Sendai Framework, a post-2015 instrument to fostering disaster risk reduction.

The imperatives to address the rising disaster shocks in the Sahel with innovation prompted the World Bank to embrace adaptive social protection framework as an instrument, not just to mitigate disasters in the Sahel, but also to increase the capacity of the poor and vulnerable segments of the population to anticipate, prepare for, and confront disasters while building resilience critical to livelihood sustainability and prosperity. Therefore, the World Bank, in 2014, established the Adaptive Social Protection Program (ASPP) in the Sahel, covering Burkina Faso, Chad, Mali, Mauritania, Niger, and Senegal. The ASPP is sustained by donor funding and managed by the World Bank. It comprises both recipient-executed activities and Bank-executed activities. Through the ASPP, the six countries have received assistance to establish adaptive social protection mechanisms aimed at strengthening poor and vulnerable households to foster the disaster risk reduction measures critical to supporting their livelihoods.

The adaptive social protection programs in the six countries comprise mainly of conditional cash transfers to support consumption in poor and vulnerable households. This is also complemented by cash-for-work programs designed to provide livelihoods for the poor and vulnerable segments of the population. The World Bank is also assisting with capacity building to create the frameworks for selection of participants for cash transfer, as well as the training of beneficiaries for disaster risk reduction.

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Chapter 11
Effect of Climate Change on Water Availability and Quality: An Assessment of Socio-Resilience in Nigeria

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Abstract Freshwater is crucial to human society, not just for domestic uses such as drinking and washing, but also for agricultural productivity and many other activities. Water is expected to become increasingly scarce in the future; this is partly obvious in many African countries, due to climate change. In recent years, there is high confidence that climate change might have increasing impacts on the quantity and quality of water. In this study, therefore, the impacts of climate change on water availability for drinking, agricultural activities and domestic uses were examined. Based on communities' assessment in Nigeria, socio-resilience implications of climate change on water availability were examined. The study focuses on the impacts of climate change on the quantity and quality of water in selected communities. The study approach was a mixed-method, involving the use of both qualitative and quantitative data. The results show that the majority of local people in the study area engage in rainwater harvesting. This may be due to the point that rainwater harvesting is easy to use and much more available during the rainy season of the year. The

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rate of the use of rainwater harvesting, as adaptation option in the rural community, is very high compared to other adaptation measures. The study concludes that as climate change is leading to scarcity of water to meet the rising demand for food, this is expected to be 60% higher in Africa by 2030, this spikes food prices and worsens food scarcity. Thus, there is a need for more local-scale assessment of water availability and distribution patterns as influenced by climate change.

Keywords Climate change · Adaptation · Water availability · Socio-hydrological · Nigeria · Resilience

1 Introduction

Water is one of the most invaluable natural resources which is vital to the existence of life, as it sustains the life of man and other living organisms. The availability of quality drinking water is a powerful environmental health determinant (WHO, 2011). Safe drinking water is essential to humans and other life forms even though it provides no organic nutrients. Accessibility to drinking water has been a major challenge to rural communities in developing countries, with nearly 2.5 billion lacking access to adequate sanitation (World Health Organization, 2014; Adams et al., 2016; Pichel et al., 2019). Freshwater is indispensable for all forms of life and is needed in large quantities, in almost all of the human activities, not only for drinking, but also for farming, washing and many other activities. Approximately 70% of the freshwater used by humans goes to agriculture, Thus, freshwater is crucial to human society, not only for drinking, but also for farming, washing and many other activities. Climate change has caused a shift in the seasons of weather, thus a shift in the normal length and timing of wet and dry seasons and increase in the seasonal changes of the water bodies (Pimentel et al., 2004; Gheewala et al., 2018; Ricart et al., 2020; Wasko et al., 2020). This has led to inadequacy of water for the use of the man and animals, thereby creating unhealthy competition for water between the farmers and large ruminants (like cattle) which are herded mainly for grazing fresh pasture and water at the disadvantage of smallholder farmers especially in Sub-Saharan Africa (Ayanlade & Ojebisi, 2019).

Thus, hydrological resources such as ponds, rivers and streams that are mainly rain-fed are adversely affected by climate change. Many people, especially in the rural communities in Nigeria, depend on rivers, streams and rainfall harvest for their water supply in the face of infrastructure challenges. It is not farfetched to say that climate variability has a drastic effect on water quantity and water quality. High temperatures and decreased rainfall have led to climatic extremities such as drought. For instance, in many Nigeria rural communities, water supply infrastructures are still at the developmental stage or are completely absent. Especially in the Sudano-Sahelian region which extensively includes the large parts of Northern Nigeria, these climatic anomalies have led to the Shrinking of lakes (e.g. Lake Chad in the Nook of Northeast Nigeria) and decrease in the river and stream water level. Scarcity of water also hinders food production, health and industrial development, efforts should be made at providing the quality of the water and ensuring food security by expanding irrigation areas, management and recycling of wastewater, mitigating the effects of desertification, flood and drought in Nigeria and sub-Sahara Africa as a whole (Ngoran et al., 2015; Nonki et al., 2019; Shiru et al., 2019).

It is worthwhile to note, though, that the climate change has some benefits as regards the water availability in some areas. Some areas are projected to have increased runoff and increase in water supply, but such rare scenarios are outweighed and counterbalanced with its disadvantages as the most areas will be negatively affected by climate change. Even in areas of increased runoff, there will be cases of flooding and runoff shifts in the water supply. In the Sub-Saharan part of Africa, for example, due to the backlash effects of climate change resulting to drought in some parts, as well as flooding in other parts, quality water is a rare commodity in many rural communities. Thus, there is a need for the structured policies and procedures to ensure the quality of water. The major benefit of this study is to assist the major stakeholders in many water affected sectors, such as the agricultural sector, to make the up-to-date decisions on measures of control/availability and water resource management for sustainable food security in Nigeria and sub-Saharan countries of Africa at large. These, therefore, necessitate this study, the need for more local-scale assessment of water availability and distribution patterns as influenced by climate change. It is believed that such efforts will assist different sectors in Nigeria, especially the agro-ecological communities, in their adaptive options at relevant and appropriate scales alongside the country's future agricultural development efforts.

2 Climate Change Impacts on Water Availability and the Implications on Different Sectors

On a global scale, the observed warming over the decades has resulted in enormous changes in the hydrological cycle. This has led to weather extreme events, changing precipitation patterns, extreme episodes of weather conditions, melting of polar ice, drought and flooding. Due to such changes, the projections have been made as to the effects on the water quality and quantity. Such projections include water pollution by sediments, pathogens, dissolved organic matter, pesticides, salts. These will, without doubt, have negative impacts on the health of people. Sea level is also projected to rise (Cazenave & Cozannet, 2014; Ablain et al., 2015; Agboola & Ayanlade, 2016), therefore extending salinization to areas with freshwater as well as the percolation of saline water into groundwater. This will affect the quality of freshwater which is the main source of potable and drinkable water for the world's population.

Water demand and supply to crop plants will be modified to the detriment of crop yield as global warming progress. Soil moisture which aids the crop growth and development through photosynthetic processes is being controlled by rainfall, and conversely, the growing season is determined by the availability of rainfall to meet the crop water requirements (Guo & Shen, 2016; Gondim et al., 2017). With the same level of perceptible water, a higher temperature will reduce the relative humidity and increase the sink strength of the atmosphere. As a consequence, more water will be withdrawn from the soil through evaporation and less water will be available to be absorbed by the plants. Higher atmospheric sink strength will also increase the rate at which the water passes through the crop plants from the root hairs to the leaf surfaces. In any healthy plant, water is pulled through tabular columns by the tension created by transpiration and the leaf surface. Water keeps the living cells turgid, a condition required for optimum functioning (Turner, 1981). The amount of water and the rate at which it passes through the plants is determined by the evaporative power of the atmosphere, which can be enhanced by higher atmospheric temperature. Thus a higher temperature will not only reduce the water supply, but it will also increase the water demands by crop plants. The result is a higher level of moisture stress, which can be harmful to most crops during flowering, pollination and grain filling. Cattle cannot adapt to the water restriction. The feed intake of cattle will greatly decrease if the water is restricted. Water availability and quality can become a major challenge during a drought. Water consumption in cattle is influenced by some factors, which include the moisture and protein level of the feed, salt intake, relative humidity, temperature and type of feed and the breed of cattle (Willms et al., 2002; Miglierina et al., 2018; Malan et al., 2020). Any time there are high moisture, intake of water by cattle reduced and feeds such as fresh forages are used at such situation. Because of the need to excrete more urine, high level of salt or protein in the feed increases water needs.

An estimated 15–20 million pastoralists whose livelihood is based on raising and herding the livestock in the semi-arid and arid zones of the Horn of Africa are displaced due to increasing drought impacts, especially during dry seasons when in search for water and grazing land (Herrero et al., 2010). With fluctuating rainfall patterns, increasing temperature and changes in water availability, climate change adaptation should be a major priority because of the region's vulnerability (Feenstra, 1998; Mortimore & Adams, 2001; O'Brien et al., 2009; Azuwike & Enwerem, 2010).

In Sub-Saharan African countries, climate change's impact on water availability, thus impedes the food production, as nearly 75% of the population are devoted to agriculture. The food prices are expected to rise by 77% by 2080 as a result of climate change, compared to other parts of the worldwide. Without enough water to meet the rising demand for food, expected to be 60% higher than today by 2030, this spikes food prices and worsens food scarcity. Climate impacts on water availability and water quality in West Africa have been reported in the literature (Kunstmann & Jung, 2005; Karambiri et al., 2011; de Hipt et al., 2019). Indeed, the region's major watercourses (Niger, Senegal, Gambia, Lake Chad hydrographical network) have their sources in high rainfall areas, before flowing through the Sahelian zone, which experiences chronic rainfall deficits. Hence, these watercourses serve as interzonal transfer mean of freshwater movement from wet to arid parts of the region. These transfers create a high level of water interdependency among West African countries. Though, the 17 countries of the region share 25 trans-boundary rivers. The Niger river basin is shared by 11 countries, but 8, 6 and 4 countries, respectively, for the Lake Chad Basin, the Volta River and Senegal, respectively. Studies have shown that, if the trends in climate contexts that took place over the last three decades continue to prevail, West Africa may experience decrease in freshwater availability. Compared to the previous decades, it is observed that since the early 1970s, the mean annual rainfall has decreased by 10% in the wet tropical zone. This sharp decrease in water availability has been combined with the greater uncertainty in the spatial and temporal distribution of rainfall and surface water resources (Oyebande et al., 2002; Niasse et al., 2004).

3 Climate Variability/Change Implications on Water Availability: Nigeria Case Study

3.1 Materials and Methods

The general rainfall seasonality in Nigeria is such that locations south of 10°N are characterized by double rainfall peaks (occurring in June/July and September/October), while locations north of this latitude have a single rainfall season occurring in August (Bello, 1998; Odjugo, 2010). Studies have reported that this general pattern has been influenced as recent evidence of climate change. For example, the northeast region of Nigeria is increasingly becoming an arid environment at a very fast rate per year occasioned by the fast reduction in the amount of surface water, flora resources (Obioha, 2009; Ayinde et al., 2011). Thus, facing the threat of desert encroachment while the southern area of Nigeria largely known for high rainfall is currently confronted by irregularity in the rainfall thereby posing threat to food security in Nigeria (Bello et al., 2012; Ogunrotimi & Kayode, 2018). This climatic fluctuation is putting Nigeria's agriculture system under serious threat and stress and the study of the effects of the variability on agricultural productivity is critical given its impact in changing livelihood patterns in the country (Enete & Amusa, 2010).

In this study, the case of climate variability/change impacts on water availability is presented in some farming communities of southwestern Nigeria: Ilora, Origbo communities and some communities in Ife Centre Local Government. Ilora is a community located in the Guniea Savahan ecological zone, part Afijio Local Government area (LGA) of Oyo state. Origbo communities are an agglomeration of seven communities, in rainforest ecological zones, in Ife-North LGA while the other communities are located in Ife Central LGA of Osun State. Study approach was a mixed-method, involving the use of both qualitative and quantitative data. The descriptive statistical methods were used, including the mean, deviation values as well as the coefficient of variation of temperature and rainfall using the Statistical

Package for Social Scientist Software, combined with Microsoft Excel Spreadsheet in the Word Processing Package.

For the qualitative data, 38 key informants were systematically selected (based on 5 by 5 m gridding of the study area) for the household in the region. A female (wife or the eldest) in the selected household was preferred because of the belief that they hold better information on family feeding and water supply. Also in terms of water quality, a 2-litre polyethylene bottle was used to obtain samples of drinking water from available water (drinking) source at every household where the questionnaire was administered. While pH was determined on-site, the remaining water samples were taken to the laboratory for determination of the selected physio-chemical, heavy metals and coliform (*E. coli*) count in each of the 38 samples, following the appropriate protocol and precautions. The heads of families in the study area (respondents) were mostly (84.2%) adults (aged at least 41 years) and have acquired at least the primary education (Table 11.1). Majority of the respondents are rural farmers, public office holders—either as teacher/lecturers or health workers or civil servants, and only 28.9% were self-employed. Greater than half of the people

Table 11.1 Attributes of respondents during the social data collection

Socio-demographic characteristics	Categories	Percentage
Age of head of the family	18–30	5.3
	31–40	10.5
	41–60	57.9
	61 and above	26.3
Level of education of head of the family	No formal education	0
	Primary	5.3
	Secondary	21.1
	Tertiary	73.7
Occupation of head of the family	Teaching: secondary/primary schools	5.3
	Teaching: Tertiary level	13.2
	Health worker	2.6
	Transport worker	10.5
	Self-employed	28.9
	Private organization; including banks	13.2
	Other public services	23.7
	Student	2.6
Monthly income of head of the family	Below ₦ 15,000	0
	₦ 15,001–₦ 30,000	13.2
	₦ 30,001–₦ 50,000	15.8
	₦ 50,001–₦ 100,000	18.4
	Above ₦ 100,000	52.6
Length of stay in the present location	Less than 1 year	2.6
	1–5 years	21.1
	At least 5 years	73.7
	Indifferent	2.6

(52.6%) earned above one hundred thousand Naira (₦100,000) in a month and the rest earned below the dollar equivalent. All of the respondents have lived in the area for at least 1 year before the interview (Table 11.1). Besides, the study area was categorized into low, medium and high population densities and the majority (60.5%) lived in the medium population density area; most of which are within the growth pole influence of the communities.

4 Results

4.1 Climate Change Impacts on Water Availability and Adaptation Options in the Study Communities

Figure 11.1 presents the adaptation options implementation to address the climate change impacts on water availability in the study communities. Out of all the major adaptation options, wastewater reuse, rainwater harvesting and changing regulation practices have a higher rate of use and are easy to implement as the adaptation

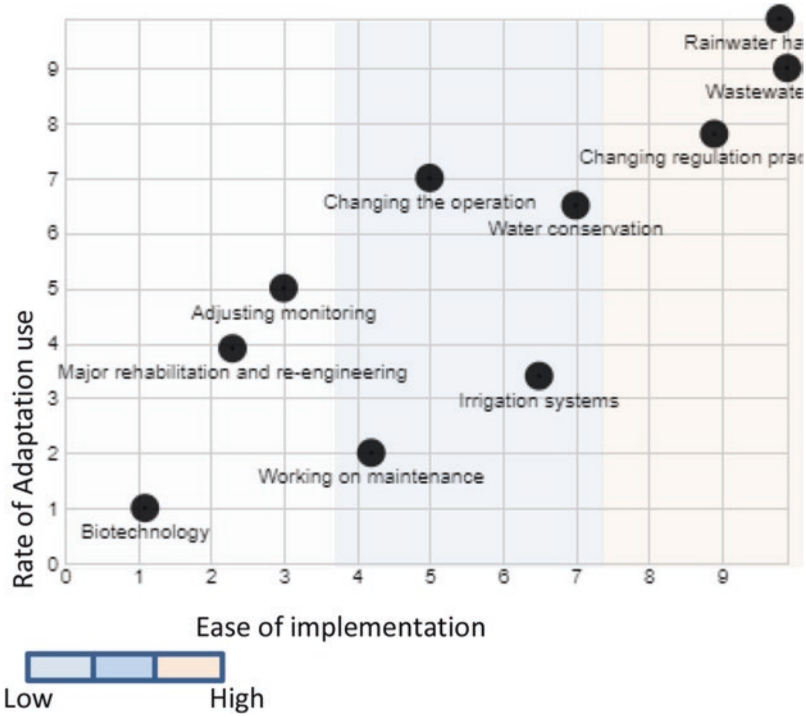

Fig. 11.1 Adaptation options implementation to address the climate change impacts on water availability in the study area

Fig. 11.2 Water-related technology for irrigation

measure to cope with the impact of climate change on the water availability in the study communities (Figs. 11.2 and 11.3). What is obvious from Fig. 11.1 is that the majority of local people in the study area engage in rainwater harvesting. This may be due to the point that rainwater harvesting is easy to use and much more available during the raining season of the year. The rate of the use of rainwater harvesting, as adaptation options in the rural community, is very high compared to other adaptation measures (Fig. 11.1). In terms of ease of implementation and rate of use, the biotechnology adaptation options appear very low. This implies that many rural communities do not make use of biotechnology as an adaptation measure for climate change impacts on the water availability. What is not yet clear, from this study is either the rural farmers were not aware of this technology or they do not have financial support to implement it (Table 11.2), or that they are willing to adopt this adaptation option. In crop farming, it is only the area with a perennial source of water that can turn to irrigation. So irrigation is used in small-scale farming especially the vegetable in such area (Fig. 11.2).

During the interview and focus group discussion, the participants clearly stated that lack of financial support is a major barrier to the implementation of many of these adaptation options. This is affecting both the herdsman and crop farmers in the study communities. The results show that the lower the income level the higher the degree of impacts of climate change in terms of the water availability in the household with the rural communities in the study region (Table 11.2). For example, the Fulani herdsman who engage majorly in rearing cattle complained majorly about

Fig. 11.3 Sample of rural water use for palm oil processing

the reduction of grazing grass and water for their cattle. The Fulani herdsmen usually move the cattle around, in searching for pasture and to the location where they could find water (Ayanlade & Ojebisi, 2020). Moreover, when there are inadequate grazing grass and water for the cattle, the herdsmen do not mind moving the herd along the riversides where they could get the sufficient water for the cattle to drink. Also, the cattle are moved towards the south where they would be enough grasses for their animals to graze. Although sometimes clashes occur between the herdsmen and crop farmers because somehow the cattle sometimes wander into farms when there is no proper supervision. Many stated that:

> Since we find ourselves in this part of the world and no other place to go and nothing to do the occurrence of climate change; the farmer has device number of steps in ameliorating the effects of climate change which include waiting for the time when rainfall will be much before planting (changing of planting time), watering as in case of small farm particularly vegetable, mulching—that is covering of heaps with leaves after planting yam, which will cool the withering yam when it germinates

Furthermore, poultry farmers whose major business was egg sales also could not watch themselves lose continually but found a way to cope with the changing climate. For instance, a farmer put the palm fronds around the wire mesh in his farm so that whenever there is heat, it will help to cushion the effect of the heat on the animals. Also, sometimes plants like plantain are grown close to the pen to help with cool air. Another issue was that when the heat is warm the drinking water of the

Table 11.2 Average monthly income and degree of impacts of climate change

	Little impact	Moderate impact	High impact	Total
	Delay in onset			
Average monthly income <20,000	8	10	50	68
20,000–50,000	6	14	47	67
50,000–100,000	2	2	14	18
>100,000	2	4	10	16
Not sure	0	4	13	17
Total	18	34	134	186
	Early stop			
Average monthly income <20,000	12	20	38	70
20,000–50,000	10	22	40	72
50,000–100,000	4	3	11	18
>100,000	3	5	6	14
Not sure	2	3	7	12
Total	31	53	102	186
	High variability			
Average monthly income <20,000	10	30	22	62
20,000–50,000	11	41	23	75
50,000–100,000	8	5	8	21
>100,000	0	1	13	14
Not sure	8	1	5	14
Total	37	78	71	186

chicken will be hot and they also started removing the hot water and replacing it with cool water instead. This increases the workload of the workers because they will have to change the water from time to time to avoid the water for the chicken to be raised above normal temperature. It also breeds disease. Many poultry farmers are now experiencing heat-related losses.

Thus, in livestock farming, turning to the other sources of water is the major adaptation strategies, such as borehole, to supply adequate water to the farm. During extreme temperature, farmer also makes use of palm front and other leave to cover their pens to reduce the amount of solar radiation, to regulate the temperature of the pens. Keeping drinking water cool, using medicines and supplements to help hens cope with rising heat, and keeping the building cool and boosting ventilation are the key adaptation measures used by poultry farmers to adjust to climate change.

4.2 Water Supply and Quality Condition

Water supply in the study tends to reveal the topographic influences. Most (64.3% and 66.7%) households in medium (100–300 m) and low topography (below 100 m) possessed machine-drilled, covered and protected wells, while only 47.1% of the households in high (higher than 300 m) possessed same (machine-drilled, covered and protected wells) water source (Table 11.3). Furthermore, the majority (>80%) of the households did not agree to be suffering from any water-related diseases at

Table 11.3 Type, condition of water sources perception and health implication

Elevation		Lowlands (<268 m)		Middle area (268–346 m)		Highlands (>346 m)	
		Freq.	%	Freq.	%	Freq.	%
Condition of the well	Machine-drilled, covered and protected	4	66.7	9	64.3	8	47.1
	Hand-dug, covered, often locked, and users are only members of the hose	2	33.3	4	28.6	5	29.4
	Hand-dug, cover not in good condition, and users are not only members of the house	0	0	0	0	3	17.6
	No well	0	0	1	7.1	1	5.9
Family member suffering from any water-based diseases	Yes	1	16.7	2	14.3	2	11.8
	No	5	83.3	12	85.7	15	88.2
Prevalent water-related disease	Cholera	0	0	0	0	2	11.8
	Typhoid fever	0	0	2	14.3	7	41.2
	Hepatitis	0	0	0	0	0	0
	Schistosomiasis	0	0	0	0	0	0
	Dysentery	1	16.7	1	7.1	0	0
	Diarrhoea	0	0	1	7.1	0	0
	None	5	83.3	10	71.4	8	47.1
Quality of potable water supply	Excellent	2	33.3	1	7.1	2	11.8
	Good	3	50	11	78.6	10	58.8
	Fair	1	16.7	1	7.1	3	17.6
	Poor	0	0	1	7.1	2	11.8
Perception about water quality	Excellent	2	33.3	1	7.1	2	11.8
	Very good	0	0	1	7.1	0	0
	Good	2	33.3	6	42.9	4	23.5
	Fair	2	33.3	4	28.6	9	52.9
	Poor	0	0	2	14.3	2	11.8
	Water quality is fair, with little treatment, it is good for domestic and cooking purposes	0	0	0	0	0	0

the time of the study. The few proportions that suffered from water-related diseases reported dysentery, typhoid fever and cholera as prominent water-related diseases. In all, majority of the respondents rated the domestic water sources as 'excellent' to 'good', except at the high altitude where 52.9% perceived the quality of water they consume as of 'fair'; quality (Table 11.3). Based on the perception of the domestic water as relatively pristine, only 47.4% of the respondents treat their water before consumption in the study area, and they do so without the use of alum and chlorine before drinking (Table 11.4).

The results of laboratory analysis of the selected toxic metals, physicochemical parameters and *E. coli* reveal that the water samples that were obtained from systematically selected water sources suggest that the water bodies are contaminated (Table 11.5). Specifically, the waterbodies were generally alkaline, beyond the World Health Organization (2016)'s recommended limit, and the contained manganese ion of more than 0.4 ppm as well as the abnormally high concentration of *E. coli*. The studies have shown that whereas slightly high pH as observed in the study may not possess significant effect (de Joode et al., 2016). Abnormally high E. coli in drinking water is also associated with chorea and typhoid.

5 Discussion and Conclusion

Rain-fed agriculture is the primary consumer of water, it accounts for nearly 75% of total water use in Nigeria. As rainfall determines the growing season in developing countries like Nigeria where agriculture is predominantly rain-fed, its seasonal

Table 11.4 Perception of households on water quality and treatment options

		Freq.	%
Treatment of water before use	Yes	18	47.4
	No	20	52.6
Water treatment before consumption	Addition of alum	4	10.5
	Addition of chlorine	7	18.4
	None of A or B	18	47.4
	Both A and B	6	15.8
	We purchase already treated water (packaged)	1	2.6
	Boiling	2	5.3
Preferred water source for drinking	Borehole	12	31.6
	Table water	7	18.4
	Sachet water	7	18.4
	Well water	0	0
	None	12	31.6
	Tap water	0	0
	Not applicable	0	0

Table 11.5 Comparison of water samples with the World Health Organization (2017) limit guidelines for drinking water

Variables	W.H.O. Standard	Low density (Mean ± SD)	Medium density (Mean ± SD)	High density (Mean ± SD)	Remarks
pH (no unit)	6–8	8.5 ± 0.8	8.5 ± 0.9	8.2 ± 0.8	Polluted
Total dissolved solids (mg/l)	<600	512.5 ± 520.0	420.7 ± 397	537.6 ± 767.2	Acceptable
Conductivity (uS/cm)	Not stated	26.9 ± 1.3	36.8 ± 51.9	26.6 ± 0.9	Unknown
Lead (μg/l)	10	0.01 ± 0.004	0.01 ± 0.002	0.01 ± 0.003	Acceptable
Arsenic (ppm)	0.01	0.01 ± 0.01	0.01 ± 0.003	0.01 ± 0.003	Acceptable
Cadmium (ppm)	0.003	0.01 ± 0.01	0.01 ± 0.01	0.01 ± 0.01	Acceptable
Manganese (ppm)	0.4	0.03 ± 0.01	0.03 ± 0.01	0.02 ± 0.01	Polluted
E. coli (/100 ml)	0.00	13,703 ± 2618	440,271 ± 2,083,986	3993 ± 9054	Polluted

variability impacts the livelihood outcomes of farmers and landless labourers who depend on such system of agricultural production (Olayide et al., 2016). Pasture, which serves as a major food source for livestock has progressively reduced as its growth and spread are determined by water availability from the rainfall. Low amount and intensity of rainfall during the growing seasons of June/July and August/September (JJAS) common to both the southern and northern part of the country will trigger food insecurity (Alli et al., 2012; Ayanlade et al., 2018a). The forced migration of herdsmen to relative areas of grassland, civil and environmental unrest will hamper national growth and development (Fasona & Omojola, 2005; Ayuba, 2007; Ayanlade & Ojebisi, 2020). Adejuwon and Odekunle (2006) in their study opined that the length of rainy days appears to be more relatively more important than the amount with respect to water required by vegetation. There studies have concluded that climate change is likely to have considerable impacts on Nigerian agriculture. As a result of the limited rainfall and rising temperature, farm yields may be low.

As reported in the previous studies, the rainfall trends over some parts of Nigeria have shown a general decline of dry season contribution to the annual rainfall, implying that dry period is getting drier (Nicholson et al., 1998; Olaniran, 2002; Oguntunde et al., 2011). Assessment of rainfall distribution and its changes across climatic zones in Nigeria showed that there were observed barriers with no skewness in the average zonal rainfall distribution between 1910 and 1999 with the established variability and erratic rainfall pattern in the zonal rainfall received in Nigeria (Ogungbenro & Morakinyo, 2014). Improving water-management approaches in agricultural conservation is likely to be the centre of adaptation strategies in dry-land agriculture (Rabbinge, 2009). Sustainable agricultural practices also include the practices for conservation of water quality and quantity (Wall &

Smit, 2005; Ainsworth et al., 2008). The increasing temperature and decreasing precipitation in drought conditions lead to a decrease in water resources and water volume in irrigation systems (Wall & Smit, 2006; Ati et al., 2009). Technologies in harvesting, transporting and using water are applied in low precipitation and decreasing precipitation trend area (Howden et al., 2007; Ainsworth et al., 2008; Ati et al., 2009). In India (Shaw et al., 2008) and Philippines (Ainsworth et al., 2008), for example, local communities and government improved the water source through 'watershed development program' as long-term adaptation strategies to increasing drought condition. The farmers in drought-prone districts in Indonesia were trained in technologies in rain harvesting to absorb the surplus water from irrigation and precipitation (Ainsworth et al., 2008). In Vietnam, the government planned for the extension of small-scale irrigation schemes in Ninh Thuan drought-prone province. Besides, traditional knowledge and indigenous technologies in water harvesting of farmers contribute significantly to the water preservation (Ati et al., 2009).

Early cessation of the raining season shortens the growth period of crops and their physiological maturity. Delay in the onset of the rainy season will delay the date of planting crops, thereby extending their growing period into the dry season. (Stern & Roche, 2012; Ayanlade et al., 2017). The other studies have reported a progressive early retreat of rainfall over Nigeria up to half a century now and consistent with this pattern is the decline in the frequency of rainfall, a result of noticeable changes in the onset and cessation of raining season in recent times (EKPE, Adesoye, 2010). Several strategies have been put in place to cope with the water stress which results from the climatic variability/change. The adaptation strategies include the social reengineering, expansion of irrigation infrastructure, adoption of drought-tolerant seeds, recharging of wetlands, extraction of underground water through hand-dug well and borehole and among others (Ayanlade et al., 2018b). The kind of coping strategy is determined by the local area preference, and this is invariably a function of what best suits the area. An important variable of interest is water management and distribution in a developing country like Nigeria. Due to the water stress which results from climate variability, an effective and efficient strategy should be put in place to meet the insatiable need for good and quality water. To tackle this problem, several legislations, policies and procedures have been developed. Such policies should include effective and sustainable supports for local adaptation efforts to climate change and water stress. Climate change mitigation policies should encourage not just increased capacity and collaboration among stakeholders, but also increased financial resources.

In order to increase the moisture retention in more frequent drought-prone areas, there are many specific water management innovations including the central pivot irrigation, dormant season irrigation, drip irrigation, pipe irrigation and sprinkler irrigation (Smit & Skinner, 2002). When dry-land areas increased and the lack of water for cropping, farmers apply drip irrigation techniques to save water (Smit & Skinner, 2002; Adejuwon, 2004). These can be used to establish pasture for cattle as well. The dam can also be built in some rangeland in the Guinea Savannah. However, these technical innovations have not been sufficient on their own because these conditions and their capacity still have many limitations, especially in coastal and sandy soil areas where the rate of the poor household is still high and because their capacity for investment in technical innovations has not been enough. Therefore, to apply these new techniques, adaptation strategies in agricultural policies should be considered and supported to improve awareness (Ayanlade et al., 2020) and enhance their capacity as well as to take full advantages of traditional or indigenous knowledge from local people.

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Part III
Flood Detection, Risk and Adaptation

Chapter 12
A Risk-Based Approach to Development Planning

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Abstract Beyond the normative definitions of an all-encompassing development as a goal to achieve, exploring the diverse, complex, and sometimes contradictory relationships between development and risk leads to question both concepts, each one through the lens of the other. The present chapter represents a contribution to the so-called "risk-informed," or "risk-based" development decision-making, policy and planning. The authors attempt to unveil the complex relationship between risk and development on one side, and risk mitigation and development planning on the other: what risks, by whom, for whom. How do risks (re)generate, how are they transferred and (re)distributed through development and development planning? How the latter can become a risk mitigation process for those more at risk, even at the expense of development gains? The chapter gives evidence of the necessity for risk-based development planning and investigates its scope and objectives, the appropriate planning paradigm, governance process, tools and scales involved. The chapter embraces the broad range of hazards covered by the Sendai Framework for DRR 2015–2030, i.e., natural, manmade, environmental, biological and technological as well as multi-hazard conditions. In geographical terms, the examples and case studies offered illustrate situations from the developed and developing world, urban and rural regions, coastal and inland, and a wide range of scales, from supra-national to local.

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1 Introduction

Risks and disasters are not exogenous to development. Not only disasters jeopardize the development gains and prospects, but there are the specific development paths producing the risks and paving the way for disasters. Examples include the rapid urbanization and unplanned spatial development; poverty and social inequalities in terms of access to the resources; financial and socio-political crises and armed conflicts; privatization of public services and reduction of the state's capacity to provide social safety nets; expansion of the real estate market in hazardous or sensitive ecosystems and unbounded building construction activity; unwise exploitation of resources (e.g., water, land) and pressures on limited reserves; even conceptualizations of quality of life based on Western world visions of dominating nature with the help of technology (Sapountzaki, 2016).

Careful consideration of the above-mentioned risk causing processes reveals their long-term implementation and hold, the diversity of spatial scales involved in these processes (from global to the local), as well as their link with each determinant of risk and disaster (hazard, exposure, vulnerability, and coping capacity). Regarding the historical dimension of the development-driven risk-producing processes, it has been eloquently suggested that present-day disasters have been "planned" because of decisions taken in the past and that the future disasters will be the result of choice made or not made today (Tierney, 2014). Moreover, the development processes around the world are uneven and contribute to either creating—increasing—or reducing the disaster risk. Some people, organizations, places, or activities take full advantage of the development processes, while others bear the burden and face the correlative risk conditions.

In so far as development processes and risk situations are sensitive to the heterogeneity of the social contexts and interests, special attention must be paid to what "development" (and "risk") stand for, for which stakeholder, at which scale.

Among the various definitions of development, consensual ones exist, like the one proposed by Overseas Development Institute (ODI), United Nations Development Programme (UNDP), and Swiss Agency for Development and Cooperation (SDC) (2019): "*the past and present social, economic, political, cultural and technological pathways and trends and how these change processes create, interact with and are shaped by environmental change.*" The definition considers a broad scope of aspects of development and development planning, favors its long-term nature and historicity, the multiplicity of the scales involved, and the underlying human–environment interactions. However, beyond the normative definitions of an all-encompassing development as a goal to achieve, exploring the diverse, complex, and sometimes contradictory relationship between the development processes and risk leads to address and question the actual contents of both the ideas of development, and risks. While the development for all is a legitimate goal to achieve, the processes involved, contents, implementation, and results come true unevenly. A key challenge lies in the ability to tackle the failing "one-view-fits-all" development processes creating risk.

The development planning follows collective visions but results in "winners" and "losers"; it is inherently a decision-making process involving communities, NGOs, national governments, and international organizations Therefore, it is a collective decision-making and policy formulation, i.e., a governance process, where the participants aspire to visions of a better quality of life for the groups they represent. All in all, the development planning is concerned with *territorial processes of change* (socio-demographic, urbanization, economic activity restructuring and re-allocation, resource accessibility redistribution, etc.), with *political stakes of progress, life quality improvements and sustainability* (involving justice, redistribution, regulation, preservation, etc.), and *institutional structures and instruments to govern the process.*

In line with the Sendai Framework for Action (SFA), the authors understand the risk-based development planning as planning that favors the transformative changes to the advantage of the most at risk and utilizes the corrective and prospective strategies, actions, and measures to both reduce the level of existing risk and prevent the new risk creation. The present chapter represents a contribution to so-called "risk-informed," or "risk-based" development decision-making, policy and planning, which aims to simultaneously serve the 2030 Agenda and Goals for Sustainable Development (SDGs) and the Sendai Framework for Action (SFA), 2015–2030.

The authors consider as a comprehensive approach to risk-based development planning the process that:

(a) Enables the understanding and reasonable perception of the multiple, concurrent threats and complex risks attached to territorial changes, political stakes, and development decisions. Relevant contributions are Sects. 2.1 (on hazard transformation by incremental societal/territorial changes), 2.2 (on hazards emerging from socio-economic and political crises), 3.1 (on rapid urbanization affecting exposure and livelihood vulnerability), and 3.2 (on political doctrines favoring unconstrained building development).
(b) It is embedded in a supportive institutional and governance environment bridging/coupling/trading-off, on the one hand, responsibilities and issues for development and, on the other hand, risk reduction. The relevant contributions are Sects. 3.3 (on risk-blind institutions), 3.2 and 5.
(c) Contextualizes the components of the plan/program, i.e., its scope and objectives, territorial boundaries of reference and involved planning levels/scales, appropriate approaches/methods for both DRR and development, and risk mitigation tools. Relevant contributions are Sects. 4.2 (on scope and objectives), 4.3 (on planning scales and territorial boundaries), 4.4 (on the planning paradigm) and 5 (on risk mitigation tools).

(d) Addresses the interconnections with sustainable development and makes self-adjustment and revisions according to lessons learned and feedback. The crowd of examples offered (in most of the sections) highlights lessons learned and feedback processes.

The chapter embraces the broad range of hazards covered by the SFA, i.e., natural, manmade, environmental, biological and technological as well as multi-hazard conditions. In geographical terms, the examples and case studies offered illustrate situations from the developed and developing world, urban and rural regions, coastal and inland, and a wide range of scales, from supra-national to local.

2 Hazards and Stresses Putting Development at Risk

2.1 Hazards Definition and Classification: Manmade or Natural?

Over the last 20 years, more than 7000 natural disaster events have been recorded worldwide, claiming around 1.23 million lives, and affecting more than four billion people. Moreover, these disasters have resulted in the economic losses of approximately US$ 2.97 trillion (CRED and UNDRR, 2020). UNDRR defines a disaster as a "serious disruption of the functioning of a community or a society at any scale due to the hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to human, material, economic and/or environmental losses and impacts" (UNISDR, 2009; UNDRR, 2020). The overall assessment and the complementary definitions of the different risk components will be discussed later; *hazard* is the first point of attention.

Various types of hazards can be involved in causing a hazardous event, leading or not to a disaster. Historically, there was a tendency to associate the term "hazards" with "natural phenomena." Nowadays, the hazards are defined as "a process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation." It is "characterized by its location, intensity or magnitude, frequency and probability" (UNDRR, 2020). Indeed, a hazard may impact more or less extensive areas, and last varying time periods. For instance, a *small-scale* hazard impacts a limited area (e.g., landslide, avalanche), whereas a *spatially large* hazard (e.g., wildfire, extreme temperature) can reach the scale of one or several countries, or even a continent. Despite the fact that a hazard is only one accountable factor to a disaster, it continues to play a prominent role by supposedly framing the timescale of a disaster. For instance, a *slow-onset* disaster corresponds to an event such as drought, that emerges gradually over time and is hard to discern on a day-to-day basis, whereas a *sudden-onset* disaster is one triggered by a hazardous event that emerges quickly or unexpectedly (e.g., earthquake, volcanic eruption, flash flood) (UNDRR, 2020).

Going further than what is mentioned in the SFA, the hazards have recently been re-classified by UNDRR in eight clusters: biological, hydrometeorological, technological, geohazards, chemical, environmental, extraterrestrial, and societal (UNDRR, 2020). This new classification includes the 302 different hazard types, which may be natural, anthropogenic (i.e., human-induced), or socio-natural, i.e., combining natural and anthropogenic factors (UNDRR, 2020). In other words, socio-natural hazards are the hazards generated because of the actions of the society on nature.

Among those latter, the environmental hazards arise through the dynamics of the natural systems that may be influenced by human activity (UNDRR, 2020). Many of the processes and phenomena that fall into this category, such as soil degradation, deforestation, loss of biodiversity, salinization, and sea-level rise, may be defined as drivers of other hazards. To put it another way, impacts of environmental degradation are often seen most clearly through other hazards. For instance, landslide susceptibility is increased by deforestation; or the intensity and frequency of floods, droughts and heat waves are influenced by changes in the climate and land cover (UNDRR, 2020).

As an example, in various parts of Bukavu city, located in the South Kivu province (Eastern Democratic Republic of Congo), landslides represent a recurrent threat for the dense urban population (Fig. 12.1). In certain areas, such as the Funu

Fig. 12.1 Steep slope of Bukavu, where terraces built to accommodate new houses reinforce the risk of landslides (© HARISSA Citizen Observers network—RMCA, December 2020)

neighborhood, the water distribution and drainage infrastructure are not maintained. More than 15 years ago, the rupture of water network pipes was at the origin of the development of large gullies, which are still constantly evolving by the collapse of their slopes; each rainy season brings the new instability on this slow-moving landslide (Baligamire et al., 2017; Michellier et al., 2020). The rupture of water and sewage pipes also represent a potential major sanitation issue and a potential focus of epidemic. As another example, in the nearby Wesha river basin, significant population growth is associated with deforestation, and reduction of the space devoted to agriculture. Unplanned housing and the wide use of corrugated iron roofs favor water concentration and have negative consequences on soil infiltration capacity. Moreover, this landscape is heavily terraced, resulting in over-steepening slopes, usually designed with no or inappropriate retaining structures, and at the origin of regular, small landslides (Kulimushi Matabaro et al., 2017; Michellier et al., 2020).

In summary, "hazards have become increasingly complex, with triggers or cascading effects that turn what would be considered a hazard in one context into a risk in another" (UNDRR, 2020). Despite reverse argumentation (Michellier et al., 2020) and Beck's assertion (already in 1992) that "not only the risks, but the hazards also are primarily the product of human and social attitude, choice, and action", the conceptualization of hazard as an exogenous to development factor continues to prevail.

2.2 *Hazards and Social-Political Crises*

Crises, whether socio-economic and/or political, have often been considered as (possible) after-effects of disasters. However, the experience shows that crisis itself may result in new or escalating hazards and risks, and reversely that hazards, outside of any emergency period, may lead to socio-economic crises. These causal interrelations have been observed especially in cases of unprecedented hazards (e.g., new pandemics featured by uncertainty), slow-onset hazards related to critical resource scarcity (e.g., drought), technological hazards, or human-transformed natural hazards.

Crisis is a concept with multiple meanings. Some definitions focus on the turning point in the history of a social organization; others give prominence to stress or uncontrollable situations; a few place emphasis on uncertainty, breach of law and ethics. The crises refer to the changes and losses, experienced only by complex systems (e.g., family, society), in several realms: financial, economic, social, community, geopolitical, environmental. Venette (2003) argued that "crisis is a process of transformation when the old system can no longer be maintained."

"*Economic crisis is a situation in which the economy experiences a sudden downturn*" (Business Dictionary). Usually, it is brought on by a financial crisis reflecting situations where the financial assets lose a large part of their nominal value. These are associated with banking panics, stock market crashes or other financial bubbles bursting, currency crises, and sovereign defaults (Kindleberger &

Aliber, 2005). An example is the sovereign debt crisis faced by Greece in the decade 2009–2019. Financial and—the resulting—economic crises tend to deteriorate both economic and social well-being indicators, justifying the term *socio-economic crisis* (Ötker-Robe & Podpiera, 2013). As for a *socio-political crisis*, it is featured by high levels of political, social or military instability, mobilization and/or use of violence.

Socio-economic crises turn up as simultaneous or successive compounds of adverse socio-economic conditions entailing losses for the collective and private agents in the community (e.g., a falling GDP, high deficits and debt ratios, slump in investments, loss of income, assets re-composition, unemployment, poverty, forced migration, homelessness, etc). People and institutions then develop adjustment or mal-adjustment practices causing environmental degradation, expanding exposure to hazards, and bringing to light unprecedented technological, natural, Na-tech or biological hazards and risks. The Greek crisis has highlighted similar harmful practices: avoidance of maintenance costs in the housing, transportation, manufacturing and building sector; promotion of questionable safety foodstuffs in the market; relaxing building and urban planning regulations to attract investments; changing the food consumption and patterns of appealing to medical services, etc. In this way, the crisis conditions trigger social responses that generate hazards and/or increase exposure to hazards.

The reverse is also true. Periods of observable but slow-onset high-level hazards (e.g., drought) or hazards of uncertain consequences raising public concern (e.g., infectious communicable diseases) can be likened to crisis periods in the sense that critical decisions have to be taken then to prevent a likely disaster. These also incubate other forms of crisis (socio-economic, social insecurity, political, etc.). High risk perceptions and political and social struggles for the resilience assets to avoid presumed forthcoming losses lie at the roots of this causal interrelation. An obvious case is the socio-economic and the humanitarian crisis that emerges after meteorological and hydrological drought periods in certain countries, such as the ones in the horn of Africa. Extreme climate conditions result in restricted food availability/accessibility, price increases, insufficient nutrition, fears of famine, disease and epidemics, illegality and corruption and conflicts at the local, national, and supranational level. The example of the volcanic crisis which took place in Goma (Democratic Republic of Congo) in 2002 can also illustrate this relationship between hazards and socio-political crisis. At that time, Goma was in the hands of the dissident movement RCD-Goma, which did not trust the scientists of the Goma Volcano Observatory (GVO), whom they suspected of being under the boot of Kinshasa's central government. As a consequence, the RCD-Goma neither listened to nor transmitted the alerts issued by the GVO. Worse, the messages about the risk of volcanic eruption delivered to the population were confused and contradictory. This created a real panic among the population, who evacuated massively to Rwanda (Fig. 12.2), while they would have had time to move around calmly if the political crisis had not caused communication problems.

All in all, socio-economic and socio-political crises may be either precursors/causes of hazard conditions (and risks) or come up as consequences of the latter.

Fig. 12.2 People fleeing Goma, towards Rwanda, in the front of the advancing lava flow of the Nyiragongo volcano, which destroyed about 10% of the city, on January 17, 2002 (© Goma Volcano Observatory, 2002)

Therefore, the anti-crisis, hazard control, and risk-reduction policies should formulate a comprehensive and integrated policy package.

2.3 Hazards, Exposure, Vulnerability, and Coping Capacity as Equivalent Components of Disaster Risk

Taking into consideration how environmental hazards can be defined and understood (part 2.1), as well as the relationships between crises and hazards (part 2.2) sheds light on the role and place of hazards in the basic risk definition. The traditional definition, still existing today, posits that hazards are the first elements to be considered when trying to define and understand disasters (UNDRR, 2020 and Fig. 12.3).

However, this position is challenged by at least four main understandings of risks and disasters:

(a) Largely considered relevant by UNISDR/UNDRR (2015, 2019), radical thinking endorses that the main risk drivers are less related to the hazard, than to the way human societies are structured prior to the event, allowing or not this event to become a disaster. According to Latin-American researchers, with La Red, every disaster results essentially from social processes associated to political choices. Garcia-Acosta (2005) has named this process the "social construction of risks."
(b) Focusing on hazards is also not consistent with a wide range of definitions concerning risks and disasters. This is the case with EM-DAT, the international disasters database managed by CRED (2020). According to EM-DAT, an event becomes a disaster when it exceeds predefined statistical thresholds of mortality and affected people, and/or exceeds the local capacities to cope with, requir-

Fig. 12.3 The classical risk definition still places hazard first. Even though the definition stresses on interactions, the conceptual model (a graphical representation of the definition) is still linear. (Source: https://www.preventionweb.net/disaster-risk/risk/disaster-risk/ (2020))

ing external assistance. Therefore, the hazard should not be presented first, as is still the case with Fig. 12.3. This presentation conceals the pre-disaster capacities or the lack of such pre-existing coping capacities. Figure 12.4(2) indicates an alternative.

(c) Systemic thinking, which has gained momentum since the beginning of the twenty-first century with the socio-ecological systems (SES) thinking, and a major contribution from Resilience Alliance (Gunderson & Holling, 2002), denies any element of a system to be given the first place. Interactions imply that the hazard should no longer be considered as a factor impacting human systems, but as a factor created by these interactions (Fig. 12.4). Civil engineering works correct hazards in order to protect exposed elements, but, at the same time, create conditions for exposure expansion or hazard transformation, and hazard transfer. As another example, reducing hazard due to atmospheric CO_2 emissions for preventing the climate related disasters is also consistent with the SES approach.

(d) Anthropocene as well as climate change thinking highlight the capacity of the human society to transform the earth (willingly or not) and become the major element of earth system, thus contributing to the modification of the Earth's climates. This understanding allows mitigating hazards—especially the hazards that are related to climate change.

Therefore, it makes sense to reconsider the order attributed to the main components of disaster and risk, in definitions as well as in linear-type conceptual models (Fig. 12.3).

Exposure is defined as the possibility to experience damage, due to location. *Vulnerability* refers to the characteristics of exposed elements which may contribute or not to reduce the intensity of damages (Figs. 12.4 and 12.5). Both may refer to political decisions to take a risk into consideration or not. For example, it is possible to prohibit building development in a flood-prone area—a way of reducing exposure—or alternatively enforce measures reducing the vulnerability of an exposed building (Fig. 12.5).

Exposure and vulnerability are therefore related with *coping capacities*, which include the disaster prevention actions and policies. As such, *coping capacities* should also be explicitly mentioned, a means to take civil engineering works and prevention policies into account in the existing basic risk definitions. As prevention

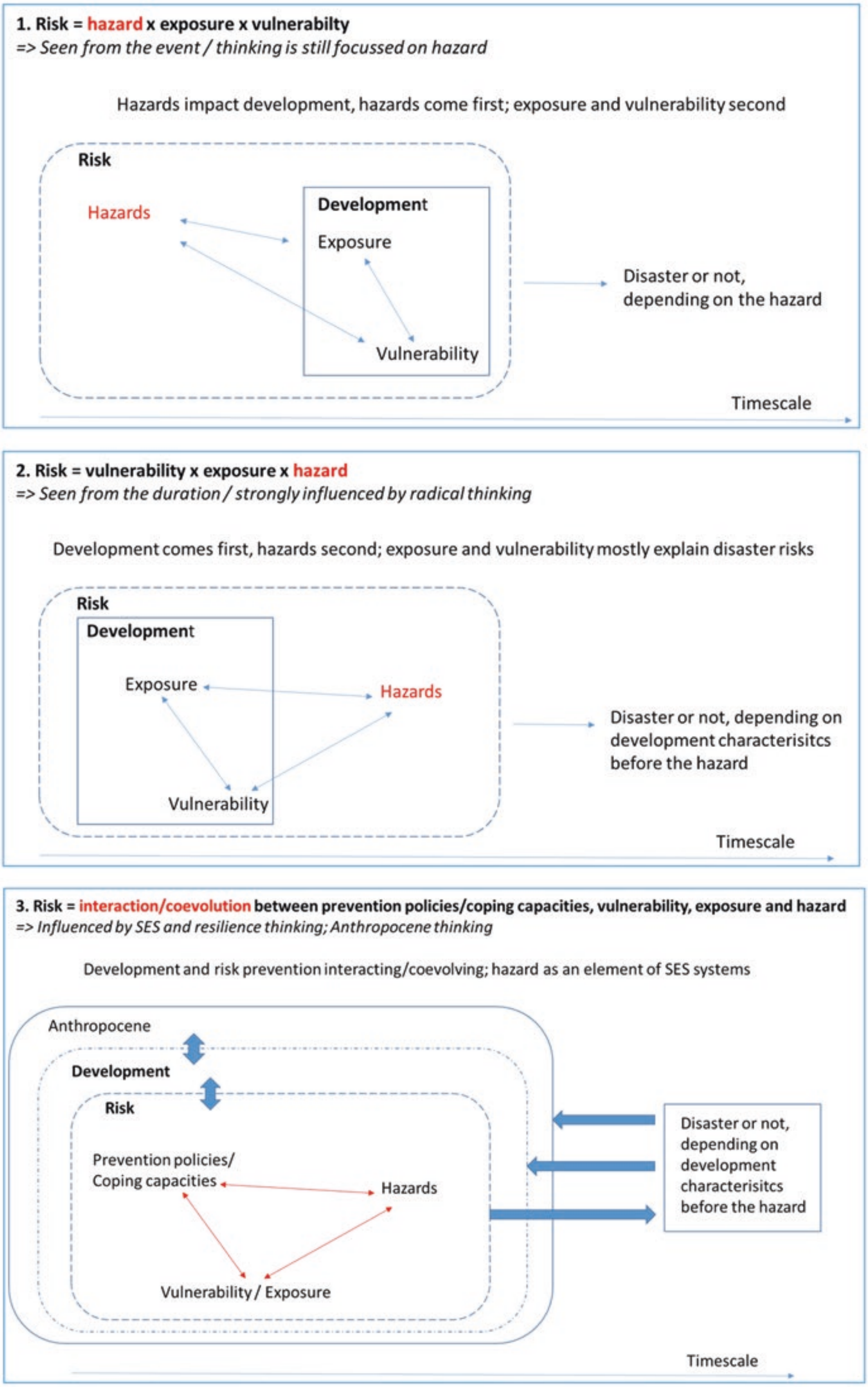

Fig. 12.4 Alternative views on risk definitions (© P. Pigeon and J. Rebotier)

Fig. 12.5 Testing the relevance and the limitations of the classical definition of risk: a French case study. Two buildings (1 and 2 on the photographs) at two different dates (**a**—March 1999 and **b**—February 2020) are equally exposed yet unevenly vulnerable on the Arve River floodplain, Magland Municipality, Northern French Alps. The hazard is related with river Arve floods. Both buildings are exposed to the hazard (1 and 2 in the red circle on the map). But building 2 only takes flood risk prevention measures under consideration (through positioning and extra height), reducing its vulnerability. The classical definition (Fig. 12.3) does not acknowledge policy measures addressing hazard (as dikes—thick black lines on the map), exposure (red zones of the risk prevention plan—see map—forbidding building on flood-prone area), or vulnerability (adaptation of building 2 to flood risk—photographs). Still more, the limitations of flood prevention policies (differences between building 1 and 2) are not explicitly addressed by the classical definition of risk. Uneven policies feedback loops on hazard, exposure, and vulnerability are not addressed by the linear and static basic conceptual model (Fig. 12.3). (Source: Photographs (**a**) and (**b**) by Patrick Pigeon—1999 and 2020; Photograph (**c**) Map from Magland Risk Prevention Plan, 1997)

is a question of choice—and the possibilities for choice—, it is linked to living standards, but also to risk culture and risk perception. While insurance is an option for the most well-off households, the poorest are usually made more vulnerable by their limited capacities (e.g., poverty as reduction of choosing capacities, Sen, 2010). It is also a way of introducing resilience in the basic definitions. Indeed, resilience, which can define the coping and prevention capacities, as well as their limitations, also depends on those economic and cultural conditionings.

To sum up, the authors reconsider the position hazards have in disaster definition and prevention policies: they are influenced by development-related issues as well as they influence them. This evolution calls for a more integrated understanding and management of risks and development.

3 The Role of Development in Producing and Expanding Disaster Risk

3.1 Socio-Economic Processes Increasing Exposure to Hazards and Livelihood Vulnerability

There are different ways of considering the interrelations between socio-economic processes and risk conditions. Since detailing such a complexity is beyond the scope of this chapter, the aim of the section is to present the different paths of socio-economic processes (mainly in Southern countries) that contribute to frame the disaster risk conditions. Emphasis is placed on the experiences of low-developed societies where socio-economic processes seem to be more critical with regard to worsened (but also potentially improved) risk conditions. Yet, there is no doubt that more developed societies (in terms of global development indicators) also cope with the production of socially uneven risk conditions in both time and space.

Intense urbanization contributes to high spatial concentration of assets and people, hence dramatic increase of their exposure. In southern regions, the combination of urbanization and demographic transition processes produces critical urban environment conditions. This took place in most Latin-American countries in the 1950s–1970s: regional urban population grew from 20% in 1900 to about 74% in 1990; growth was even more dramatic in industrial cities, like in Puerto-Ordaz/Ciudad Bolivar (Venezuela), with double digit growth rates for almost 20 years (bearing in mind that, with a growth rate of 7% per year, a city's population doubles in 10 years). In Sub-Saharan Africa, although urbanization processes peaked in the 1970–1990s, the urban population growth rate still held at ≈4% per year. In 2017, population living in cities represented 40% of the total population of the sub-continent, and it is projected to reach about 60% by 2050 (UN-DESA, 2018). In both continents, urbanization mainly results in informal settlements of newcomers to the city who solve their housing problems by themselves, mostly in areas unsuitable for dwelling.

Fig. 12.6 Luxurious villas on the steep and highly gully-prone slopes of Bujumbura (Burundi). (Sources: © C. Michellier, 2012; O. Dewitte, 2013)

Beyond mere accumulation of assets and people, failing land-use planning underpins another relationship between socio-economic processes and risk production. On the one hand, uncontrollable urbanization, guided by the struggle to find a place to settle despite harsh living conditions, inevitably leads to the occupation of hazard-prone areas. This is the case in the Funu neighborhood in Bukavu (Democratic Republic of Congo), where more than 80,000 people are settled on a slowly sliding area (Dille et al., 2020). On the other hand, the weakness of land-use planning or lack of control on land-use, both of which propitiate urban risks, do not concern only the poor people and urbanization processes. For several years, the steep slopes bordering Lake Tanganyika overlooking the city of Bujumbura (Burundi) have been colonized by luxurious villas, whose owners have been more concerned about the view from their terraces, than about the authorizations required to locate their houses in such highly gully-prone areas (Fig. 12.6; Dewitte et al., 2020).

In the mid-1970s, a period of booming oil exportations, every square meter in Caracas (Venezuela) was for sale. Thereafter, the lower parts of the urbanized valley were totally saturated and illicit petrodollars investments began to incorporate steeper lands to the urbanized area. Additionally, in the upper parts of the graded hills, the urban developers expanded the surface to sell illegally by filling the edges with excavated material (Fig. 12.7). Currently, the unstable material of over 30 m high produces the persistent landslide risk situations in the middle-upper class Santa Inés neighborhood. The political economy of urbanization is thus more to blame than the gravity, or the physical quality of the backfills material.

Institutional issues and governance aspects can also affect the risk conditions by making the implementation of the disaster risk prevention policies difficult. Although not specific to Southern countries (Pigeon & Rebotier, 2016), weak

Fig. 12.7 Backfills of excavated material threatening the middle-upper class Santa Inés neighborhood (© J. Rebotier, 2008)

institutions, lack of transparency and accountability, deficient data, and inconsistency of the short- to the long-term risk reduction as well as the development policies which are hardly enforced, stand for significant pitfalls in the risk management in the context of development processes. In Latin America, particularly in Venezuela from the late 1980s onwards, the public institutions have been transformed because of decentralization reforms. In the 1990s and 2000s, the central urban area of Caracas as divided into five different municipalities with a complete autonomy in terms of land-use planning and risk management. In a highly divided national political context, these five municipalities endorsed different political orientations at the local scale, leading to a strong mistrust between technical services. In the 2000s and 2010s, the urban development, risk management, and information collection and organization turned out to be strictly incompatible between municipalities, following political antagonisms (Rebotier, 2008).

Socio-economic processes also play an important role at the scale of groups and individuals, contributing to the spatially and socially uneven distribution of risks within communities. In the case of Caracas, racism and ethnical criteria organize social relations (Marquez, 1999). They also frame the urban segregation in both spatial and social realms. Spatially, western Caracas is associated with poor and black people, and so is the top of the hills called *cerros*. At the opposite, eastern Caracas is associated with a more well-off population of lighter skin. However, the racialized representation of the social urban space of Caracas is more speculative than real. Indeed, wealthy people also live at the top of the hills—the hills are called *colinas* in this case, not *cerros*—and black and poor people live in the far eastern part of the city while remaining marginalized (Rebotier, 2011), a condition that leads to their "invisibilization." It is worth mentioning that, at the beginning of the 2000s, hundreds of thousands of Caracas inhabitants still had no identity document, meaning no right to vote. Moreover, most of the informal housing, mostly in the west and the peripheries, did not even appear in the official urban plans (Baby-Collin, 2000); let alone their non-existence in the risk prevention policies and development strategies.

We know already since a long time that socio-economic processes strongly contribute to risk creation in very different ways (O'Keefe et al., 1976). As shown above, the specific manners such processes influence the risk situations are eminently contextual and deserve consideration of the dynamics of the social world (development issues) as direct—yet uneven—drivers of risk creation but also reduction. Addressing this board range of socio-economic processes (including ethnical, gender, community relations) is a precondition of risk understanding which, in turn, is a precondition for risk-based planning.

3.2 Economic and Spatial Development Doctrines and Culture Ignoring Risks

In their article focusing on community resilience, Cutter et al. (2008) commented on the US societies uncommitted to reduce vulnerability and disaster risk:

> *Despite nearly a half century of concerted research and public policy practice, the US government remains uncommitted to reducing society's vulnerability to hazards. The escalation of disaster losses and the increasing movement of Americans into highly hazardous areas support this assertion… Although there may be recognition of the hazards in many communities, risk reduction is not a salient concern until after the disaster occurs. Residents have other issues that assume priority, and local elected officials do not want to dwell on the hazard vulnerability of their communities as it might heart economic investment and growth.*

This situation prevails in many countries/regions of the developed world. The problem lies in (a) the contradictions between the aspects of sustainable development (social, economic, political, and environmental) and (b) the conceptualizations of quality of life that generate and expand (disaster) risk. Development has been associated with the positive economic expectations, income increase, and improved habitation opportunities. Contrary to this culture, prioritizing the reduction of exposure to hazards and risk implies restrictions to the spatial development which are not welcome by stakeholders (including political institutions) having to curtail their holiday housing and the other building development prospects or land revenue expectations. Therefore, not only the spontaneous spatial development but also the statutory planning follows the social aspirations for development of privileged but sensitive and/or hazardous environments (e.g., coastal zones, foothills of live volcanoes, riverbanks, forest land). This results in the extensive landscapes at risk of flood, forest fire, and other disasters (Fig. 12.8). An instructive example of how risk-scapes proliferate and expand is the case of mixed forest-housing areas exposed and vulnerable to forest fires in the Mediterranean Region. Greece is a prominent case. Historically, the forest land has been the exclusive competence of the Forest Service, i.e., “a black hole” for the spatial planning and development policies. However, the country’s housing policy has been featured by an effort to provide equal opportunities to all landowners to improve living conditions through building development rights on each property (for permanent residence, second home or even financial security through sub-leasing). This policy has long been supported by a specific legal framework: the “Out-of-Plan Building Development” regime and periodical legalization of non-statutory buildings. This has resulted in granting building development rights to every piece of land on Greek territory, with the exception of archeological sites and forest land. Nevertheless, even the prohibition of building on forest land is often breached (through forest land cover changes).

This policy has satisfied the interests of the real estate and construction sector, which has become the driving force of the Greek economy. At the same time it has produced mixed forest-housing areas (see Fig. 12.8) and wildland-urban interface areas (WUI). These areas incubate the causal origins of the forest fires (human negligence and arson), as well as the vulnerability of the human-forest systems to the fires. On the one hand, causes of negligence are associated with the close proximity and interaction of human activities with forest vegetation. On the other hand, motives for elimination of forest land, i.e., causes of arson, find their way in the conflict between forest land protection (represented basically by the Forest Service) and the building development rights acknowledged everywhere outside forests. This conflict converts the forest ecosystems from an environmental common to a factor depriving social groups of individual rights for building development and hence aspirations for a better life.

Queries of social and environmental justice are raised inevitably: How to set priorities between economic growth, safety, and public health under conditions of uncertainty? Should forests be protected for their intrinsic value or in relation to (social and/or environmental) necessities? If so, which “necessities”: Improvement of life quality at the local level or safeguarding climate stability at the global level? Consequently, what is “life quality”: Habitation in the forest or protecting the forest to maintain the micro-climate and thus preserve public health? Is it fair for a state policy to oppose the individual building development plans, especially when certain individuals or more privileged social groups have already built their homes in the most advantageous sites (e.g., inside forests)?

Through the above-presented example highlighting the difficult coexistence risk prevention on the one hand and policy priorities respecting social interests on the other, three recommendations can be made for the risk-based development

Fig. 12.8 High exposure and territorial vulnerability in Mediterranean coastline and mixed forest-residential zones. (1) Part of the French coastline close to St Tropez. (2) Sicily, Piane Vecchie. (3) Nea Makri, a mixed forest-residential area at risk of forest fire disaster in Attica Region, Greece. (4) WUI landscapes in Athens peri-urban zone. (Sources: Images 1–3 from Google Earth, Image 4, © K. Sapountzaki, 2012)

planning: (a) Identification of socio-ecological systems in the region of concern and systemic thinking to embrace the human–environment interactions that generate the hazards and territorial vulnerability; (b) risk communication and education as key policy sectors for changing the people's conceptualizations of "quality of life" and priorities of growth and building development over safety and protection, and (c) a governance structure that facilitates the mutual understanding between the policy agencies responsible for risk prevention on the one hand and building development on the other.

3.3 Challenges to Risk-Transferring "Protective" Infrastructure

The previous section has illustrated how risk prevention can be perceived as a constraint to economic and other development, reducing land-use values. However, as postulated by the radical thinking on the disaster risk (Wisner et al., 2004; Garcia-Acosta, 2005), unconstrained land-use development contributes to construct risk.

When it is hardly possible to build on a hazard-prone area, mostly because of a high hazard frequency or recent damage, civil engineering works are seen as a solution: they are presented as correcting the hazard and protecting the exposed elements at risk. Officially, this solution contributes to economic development while, at the same time, aiming to reduce the risks. Moreover, civil engineering works construction provides labor, a point stressed in Japan (Augendre, 2008), but not only there (Vinet, 2007). Finally, as such, the protective works are widely integrated into the decision-making processes for the risk prevention and land-use management.

However, the following French case study highlights the limitations of such solution. A specific tool—Farmer's curve—helps understanding the benefits and limitations that civil engineering works meet worldwide.

In February 2010, in *La Faute-sur-Mer*, a French municipality, 29 people drowned in the buildings which were supposed to protect them from Xynthia stormsurge. The majority of the casualties were retirees living in low-rise buildings behind supposedly protective dikes. According to academic researches, as well as reports from administrative officials (Anziani, 2010; Verger, 2010), the area had never experienced a similar disaster before, and this latter could not be explained by the stormsurge alone. On the one hand, the disaster came from the municipal decision to allow building low-rise and affordable houses behind dikes (Fig. 12.9). Low-income people considered it as an opportunity to live in the vicinity of a small marina. On the other hand, the weak capacity of the French state to limit this trend also played a role: the risk prevention plan developed in 2007 was hotly opposed locally, and the provided prevention measures, such as building a second floor, were poorly implemented (Fig. 12.9). In line with his electors, the mayor in charge in 2010 considered that the existing dikes did protect the area as they did not break in the past; a claim which was indeed true (Fig. 12.9). Consequently, he consented to continuous building of low-rise houses behind the dikes. To this understanding of the local situation, stopping construction would have strongly reduced the economic and social development of the municipality.

In this case, governance was well established but decisions led to a risk-producing system, with the municipality and the majority of local citizens acting as if they were flood risk blind.

Following the disaster, the French state enforced a significantly revised risk prevention plan, in the face of the human toll and economic losses, which weighted heavily on the insurance companies (Hernu, 2010). This resulted into a golf course in the area, where the 29 people died; the previously existing low-rise buildings were demolished; and the plan strongly reduced the area where the municipality could allow building development, severely limiting local economic development.

Farmer's curve helps representing the various viewpoints on the disaster. At the origin, Farmer's curve comes from a statistical observation made by Mr. Farmer, a civil engineer working in a nuclear plant. He had observed that the statistical population of damages experienced fits an inverse relationship law with the respective causal events: the more frequent the events, the less intense the damages caused.

This observation can be expanded to other types of risks, such as flood risks. Coming back to *La Faute-sur Mer*, point A on Fig. 12.9 depicts the situation in the river Lay estuary: each day, at high tide, the area is flooded. Damages to existing infrastructures happen, yet they are managed locally, because damage intensity is

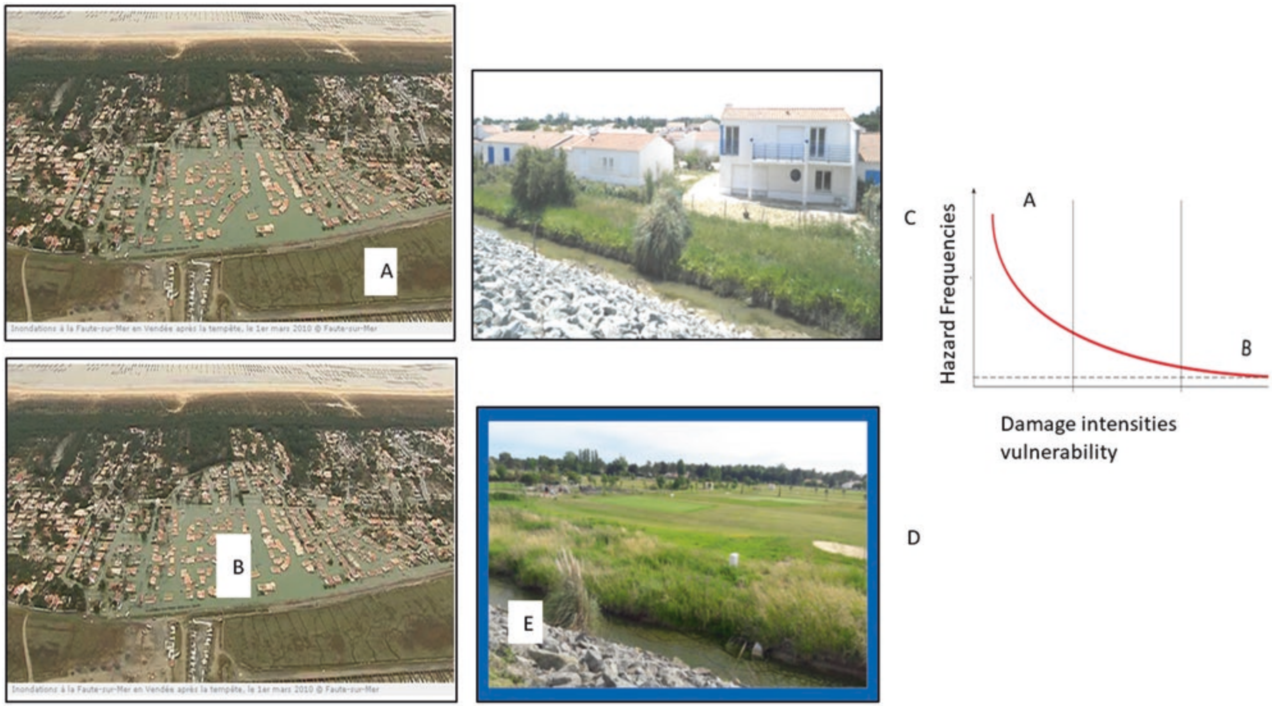

Fig. 12.9 The area of La Faute-sur-Mer affected by stormsurge Xynthia. Without diking, flood happens daily (**a**), but damages intensities are low. As time goes on, building low-rise houses behind a protective dike unwillingly constructs a disaster as here (**b**). Here, the dike did not break: by low tide, water was still at high level behind the dike. Twenty-nine people died drowned in the houses during the disaster. *Very few houses took flood risk prevention plan into consideration. The building on* (c) *had been slightly raised and displayed a second floor allowing people to escape being drowned*. The solution the French State enforced: destruction of the low-rise buildings (**c** and **d**). A golf course (**d**) represented later a kind of trade-off: a means for still using the dikes (**e**) for local development while taking dikes limitations under consideration

low. Without diking, it would be difficult to build low-rise homes in such an area. But diking also contributes to explain the situation we have with point B: the 2010 disaster. The dikes did not protect the area from flooding, and a disaster occurred, mainly because of low-rise buildings not taking into account the transformed flood risk. Water rose behind the dikes coming from the existing water and drainage networks, as well as from other flooded areas of the municipality.

Figure 12.9 demonstrates the ambiguous role played by civil engineering works. In normal times, they prevent flooding and contribute to economic development, through spatial and land-use development. However, ignoring limitations contributes to disaster risk construction. After the 2010 disaster, the solution found for *La Faute-sur-Mer* was a trade-off: dikes were reinforced and they still protect the newly-established golf course. The former most flooded low-rise buildings were destroyed.

To conclude, the case study and Farmer's curve illustrate how disasters are a first-hand result of local and national development policy decisions, as well as the socio-economic and cultural characteristics of the population concerned. Solutions coming from civil engineering measures only should never be considered sufficient, as such protective measures may be the root of disasters.

4 Risk-Based Development Planning: Theoretical Issues

4.1 What Necessity for Risk-Based Development Planning?

Up to the present, development planning and programs have focused basically on the positive aspects of development, those luring the voters of political parties. Yet, development is a coin with two sides.

After authors' reflections and assumptions on the fundamental issue about interrelationships between risk and development (in Sects. 2 and 3 and Fig. 12.4), it has become evident that exposure and vulnerability, as well as the hazards, are socially constructed through (global, national, regional, and local) ongoing development. Economic globalization, impoverishment and inequality, privatization and commercialization of basic resources and commons, unregulated building development are among the development trajectories that undermine disaster risk reduction.

Development is a process of bipolar dilemmas and trade-offs: opportunities versus risks (unequally distributed between different groups and the environment), job creation versus job losses, short-term economic gains versus long-term hazards, formalization of economic activities versus marginalization and vulnerability of people depending on informal markets, resilient versus non-resilient actors. Up to now, the development planning has been concerned, almost unilaterally, with (re) distribution of wealth and opportunities; there is a need for risk-based development planning to pay attention to "(re)distribution of bads," as Beck (1992) suggests (see also Curran, 2013). This means addressing, evaluating and mapping hazards, vulnerabilities, risks and underlying development factors, mapping coping capacities and accessibility to resilience assets, investigating risk transfer and transformation mechanisms and risk mitigation planning strategies, actions and measures to control risk generation and combat uneven distribution of "bads."

A major challenge for risk-based development planning—both for and by a community—is who decides what is considered a risk or an opportunity, and for whom, what is the perceived versus scientific risk level, and how that risk should be addressed to reach an acceptable level (see also ODI, UNDP and SDC, 2019). Answers to these questions are not common to all communities and community groups, and depend on the risk positions and risk knowledge, socio-professional categories and income levels, political and cultural orientations and psychological factors. Prioritizing risk perception and the level of risk tolerance of specific groups is a political and ethical decision depending on the context and a responsibility lying with the planning community.

4.2 Scope and Objectives of Risk-Based Development Planning

Risk-based development planning is founded on three pillars (introduction, p. 4). The **first** refers to understanding and sensitive perception of risk drivers interconnected with the territorial dynamics, socio-political stakes, and governance of risk and development. These preconditions translate into:

– Raising awareness about the historical background of the community of concern regarding hazardous events and disasters. While all types of hazards are relevant (see Sect. 2.1), special attention should be paid however on manmade or human-transformed hazards (environmental, socio-natural), i.e., the long-lived hazard-drivers of development (e.g., deforestation, soil degradation, proximity of incompatible land-uses, etc.).
– Monitoring and anticipating control of exposure- and vulnerability-drivers in development, those reinforcing livelihood vulnerability and eroding coping capacities (see Sect. 3.1). Anticipating development for risk reduction involves acting in the present for the future. Anticipatory is a system containing a visionary and predictive model of itself which allows it to change state in accordance with the model's predictions pertaining to a later instant (Van Niekerk & Terblanche-Greeff, 2017; Rosen, 2012). For a system (e.g., an at-risk community) to be anticipatory, it must be able to envision feasible alternative futures, to arrive at the ideal or preferable future model that is predictive in nature; and able to change.
– Resisting risk-producing (spatial) socio-political stakes and visions based on low risk perceptions or perceptions giving absolute credit to environmental engineering (e.g., unlimited water drillings, unregulated developments behind dikes, etc.) (see Sect. 3.2).
– Addressing the absence or weakness of institutions responsible for regulating and controlling risks in development (institutional vulnerability). In this sense,

critical are spatial (including land-use) planning institutions that are involved in all forms of control of socially constructed hazard, exposure, and vulnerability. Also critical is the coordination of planning institutions with sectoral authorities involved in risk management (e.g., for water, forests, soil stability, coasts and technical infrastructure). However, due to historically fragmented administrations and conflicting objectives or lack of trust between sectoral development or risk management authorities and spatial planning, the latter suffers from risk ignorance and implementation problems (not only in developing countries but also in some developed ones) (see Sects. 3.1 and 3.2).

This issue of weak spatial planning institutions is tightly connected to the second pillar of risk-based development planning: a supportive institutional environment. Accordingly, administrative reforms may be necessary in cases where spatial planning is separated from sectoral development and risk policies and actors or where a vertical coordination (between local, national, and supra-national level) prevails over horizontal linkages. The subordinate hierarchical position of spatial planning in risk management makes risk mitigation increasingly difficult, and engineering works become the only "indisputable" element for prevention despite limitations (see Sect. 3.3). Therefore, administrative reforms should aim to tear down the barriers between spatial planning, sectoral risk mitigation planning, and sectoral development policies so as to make multiple-hazard and risk mitigation a visible objective for all three policies. Removing strict boundaries between the above-mentioned administration compartments is in fact a pre-requisite for the implementation of the SES approach to risk. For instance, this should ease answers to questions such as "is it possible to reduce the forest fire risk independently of the social system with vested interests in these forests?" (Sect. 3.2).

In summary, fostering a leading role for spatial planning and strengthening its implementation are also important for building a reliable database on spatial risk. However, this in turn presupposes a shift in the current prevailing risk cultures, from taking safety for granted towards perceptions of safety as a "contestable human right" (Sapountzaki et al., 2011).

This last issue brings us to the third pillar, i.e., the issue of contextualization of risk-based development plans/programs. Contextualization refers to the act/process of placing information and decisions into context; in other words, making sense of information and decisions from the situation or location they were found. Indeed, the specific processes of hazard, vulnerability, and risk increase/decrease can be interpreted only in context. However, in many contexts, a common trend is that disaster risk will continue increasing until risk-development relationships are transformed. In this sense, Thomalla et al. (2018) understood the transformative planning as the process that questions social values, institutions, and technical practices with the aim to open new development paths reducing the risk through challenging existing systems and paradigms (see also O'Brien (2012) and Pelling (2011).

A transformative outcome may come up as a result of a system crisis (social or SES) (Sect. 2.2), as a result of incremental adaptation, or following intentional change after anticipation thinking (see Thomalla et al., 2018). But, what types of transformation are likely to reduce risks, and at which scales? How can these be put into practice? The SEI Initiative, for Transforming Development and Disaster Risk-2015, identifies three paths with a potential to lead to transformation in the development-risk relationship: (a) establishing trade-offs either between gains and risks (to the benefit or burden of different stakeholders) or between several forms of risk-taking in development decision-making; (b) prioritizing equitable resilience and coping capacities, and (c) transforming (disaster) risk and development governance. Trade-offs are decisions that lead to diminishing or losing one desirable outcome in return of gaining another. They are inherent in cases where multiple objectives and interests, actors and perceptions, spatial scales, and time horizons compete or collide. For instance, the dilemma of relaxing (or not) building and environmental regulations in order to attract investments while raising (or not) risk levels for residents or employees. The difficulty with trade-offs lies with their political and ethical implications, their certain versus uncertain outcomes, and constant change of risk levels/positions due to risk transformation and transfer originating from not only collective/participatory but private trade-offs also. Regarding the prioritization of equitable resilience, this is a matter of fair distribution of resilience assets or resources (see Sect. 5.2, the case study of Messara, Crete).

Finally, transformations in governance structures might be directed by the causal processes of a community/territory's multi-risk profile as it emerges from the systemic and Social-Ecological Systems (SES) approaches.

4.3 The Planning Scale and Boundaries: Planning for Administrative Regions, Communities, or SES?

The systemic approach in disaster prevention has been developed during the twentieth century (e.g., Sorre, 1933; Turner et al., 2003). Yet it has gained more momentum with socio-ecological system (SES) thinking, whether linked to the resilience alliance (Gunderson & Holling, 2002) or not (Renaud et al., 2013). SES calls for a wider understanding of what development could be, without reducing it to economic or social related issues, by introducing more explicitly environment as a basic element interacting with the others. Even though epistemologically challenging, because it posits humankind and earth as equivalent elements of interacting systems, SES thinking is strongly consistent with sustainable development, and the Anthropocene. The latter assumes the capacity of humankind to transform the earth, and also, taking the form of environmental feedback loops, human development (Figure 12.4, point 3) and issues related with the climate change adaptation.

At local scale, a French case study can illustrate why and how SES thinking may improve risk prevention understanding and management, while integrating various aspects of development.

Comparing two French municipalities, *Culoz* and *Chanaz* (Fig. 12.10) drew attention on an unexpected finding: the more flood-prone areas are built and integrated into local development, whereas the less flood-prone areas are not (Pigeon et al., 2018). In both areas, the river embankments allow the full run-off of river Rhône during normal times. However, during flood periods, as the embankments of the *Savoie* side are lower, part of the flood is diverted in the *Chautagne* flood-expansion plain (Fig. 12.10). This situation looks odd: on the one hand, it increases flood risk for the municipality of *Chanaz* downstream, where we find a fluvial yacht harbor and a marina; on the other hand, it reduces flood risk for the municipality of *Culoz*, where a similar development project (construction of a marina) has been cancelled (Fig. 12.10).

Explaining such a challenging contradiction requires clarifying the existing interactions between flood risk management choices and local and national development choices. SES thinking helps to do it (Fig. 12.11).

In the case of *Culoz*, the existing dikes were not considered sufficiently protective for having a yacht harbour and a marina. Indeed, the French state argued the limitations dikes meet. *Culoz* municipality gave up defending the project: the local development plan (PLU) finally focused on a railway station linking *Lyon* and Geneva, far from the *Rhône* banks. The French state, which is responsible for the risk prevention plan, denied any construction of a harbour and a marina by classifying this area as a red zone (Fig. 12.11). This measure prevented a possible disaster and also contributed to protect the economic viability of the existing disaster prevention policy in France. Moreover, the latter, which dates back to 1982, involves insurance companies. They would reconsider supporting the national prevention policy in case of an increase of disasters.

Historically, as much as currently, *Chanaz* is a municipality which strongly depends on river *Rhône* for its development. Diking more *Rhône* embankments in order to produce the hydraulic power gave the opportunity to develop a fluvial yacht harbour and a marina. As local assets are still limited, especially seen from "*Paris,*" the French state representatives agreed to set up a risk prevention plan better taking into account the local development. It classified this area as a blue zone (Fig. 12.11), allowing to have a marina.

The challenging contrast between the two municipalities illustrates resilience seen from the perspective of the SES thinking, as the capacity of various stakeholders interacting at various scales to prevent and transfer risks when it comes to development choices, but which developments and which risks for whom, and at which scale? SES understanding includes the hazard and environmental transformations: flood risk has been transformed if not transferred (Fig. 12.10). However, hazard transformation taken alone cannot explain the local development choices (see Fig. 12.11, point 3).

As SES understanding integrates the context, resources, and cultures, whether local or national, it may lead to a representation (Fig. 12.11) illustrating dynamic trade-offs/interactions between different stakeholders concerned with risk prevention on the one hand and development on the other, as well as environmental management, at various scales. However, clarifying trade-offs between risk prevention and development is still difficult: a major shortcoming SES thinking still meets.

Fig. 12.10 A challenging assessment on flood risk and local development. Because of lower dikes on the Rhône river Savoie embankments (**a**), flood risk is higher in Chanaz (**b**) than in Culoz (**c**). The board warns about it. Marais de Chautagne (**d**) are used as a flood-expansion plain, protecting Culoz and major cities downstream, as with Lyon. However, Culoz risk prevention plan bears red zones (**e**) behind the dikes (**f**), not allowing a fluvial marina to be built here. The plan displays limitations dikes meet, even if managed by a regional/national institution, the CNR (Compagnie nationale du Rhône) mostly producing hydraulic power. Chanaz risk prevention plan bears a blue zone (**g**) allowing the existing marina (**h**). Notwithstanding floods coming from Marais de Chautagne and the limitations diking also meets. Dikes are tended by CNR as well (© P. Pigeon and J. Rebotier)

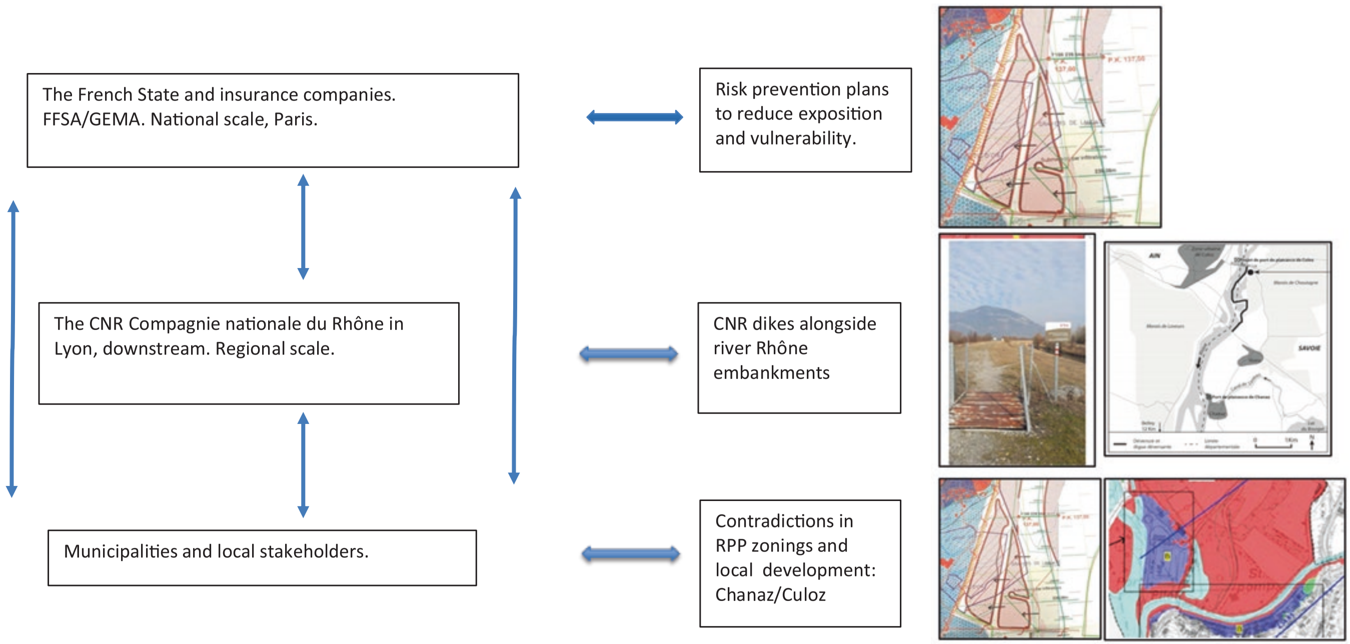

Fig. 12.11 A tentative SES representation of Chanaz and Culoz case study. The representation draws attention on the interactions between three main actors at national/regional/local scales. Here, without the interactions between the national actors, national/regional actor (CNR), and municipalities, it is not possible to understand the contrasting situation between Chanaz and Culoz, about local development and flood risk management. They result from trade-offs between main actors around flood risk and flood risk transfer

A recommendation would be that stakeholders, be they local or national, should make these trade-offs clearer. It would improve the transparency of the decision-making process, in line with the SFA's requirements.

4.4 The Planning Paradigm: Mitigating Vulnerability or Enhancing Resilience?

The previous sections have already explained why and how development processes and outcome not only produce but are also threatened by (disaster) risks. Hence, placing risk mitigation central to the development decisions is gradually acknowledged as the new imperative for development planning. At the global level, the SDGs do not sufficiently support risk-informed development and their achievement could be undermined by multiple threats. Therefore, the SFA and Paris Agreement are becoming critical for providing the core processes for risk reduction in the context of development planning (ODI, UNDP and SDC, 2019). Within the SFA, Murray et al. (2017) have identified some key issues for making development risk-informed and sustainable:

- Capacity building for understanding and acting on risks in development.
- Promoting cultures of risk governance and risk communication in development.
- New financing mechanisms for resilience and risk-informed development.
- Recognition of the mutually supportive roles of disaster risk reduction and climate change adaptation.

In general terms, two major paradigms of the disaster risk reduction are relevant to the development planning context (Table 12.1): (a) Vulnerability (and exposure to hazard) modification with an emphasis on livelihood, socio-economic, territorial and institutional aspects of vulnerability, and (b) resilience building to foster climate change coping and adaptation capacities for social-ecological systems to survive, revive, or "tip" (Adger, 2000). The shift from the former vulnerability paradigm, dating back to the 1960s and 1970s, to the resilience perspective paradigm coincides with the emergence of adaptation in the climate change debate. The resilience perspective has been criticized for the emphasis on coupled social-ecological systems, entailing a significant loss of the idea that it is socio-economic systems themselves that expose people to risks (Cannon & Müller-Mahn, 2010). According to these authors "*the policy requirements of a vulnerability approach are clear: the need to reduce vulnerability through intervention in the economic and political allocation of resources*" (p. 632). By contrast, the resilience approach subsumes politics and economics into the neutral realm of ecosystem management. Accordingly, the vulnerability policy paradigm that targets poverty and powerlessness carries a clear normative content, while resilience defined as a state or inherent capacity (of learning and self-organization for survival) reflects an ontological content. From an opposite point of view, the resilience paradigm presents the

Table 12.1 The basic components of the (disaster) risk reduction policy paradigm in the context of development planning

	The vulnerability (and exposure) modification paradigm	The resilience-building or resilience-enabling policy paradigm
(Geographical) units of reference	• Administrative regions • Planning regions	Systems: • Socio-ecological • Socio-economic • Socio-technical
Targeted hazards/ risks	In case of generic vulnerability: – All hazard-types and multi-hazards – Complex risks In case of hazard-dependent vulnerability single hazards (floods, earthquakes, droughts, etc.)	• General resilience • Specified resilience
Targeted vulnerability aspects	• Livelihood • Social and economic • Institutional • Territorial • Housing and infrastructure • Systemic	• Coping capacity • Adaptive capacity
Main scales/levels of reference	• Micro-level (poor and marginalized groups) • Meso-level (localities, municipalities, administrative regions) • Macro-level (cities and metropolitan regions, cross-border regions, national states, transnational regions)	• Micro (human-environment and other) systems (individuals, rural and urban households, organizations, social groups) • Meso-level (coastal and mountainous communities, mixed forest-residential territories, urban and rural communities, bio-geographical regions etc.)
Policy-making processes	Mostly top-down (originating from state or international organizations)	Mostly bottom-up participatory approaches
Planning tools and approaches	• Livelihood vulnerability analysis (based on socio-demographic, livelihood, health, food, water and social-networking indicators) • Territorial and built environment vulnerability assessments • Social vulnerability profiling methods • Land use and land tenure (public) risk mitigation planning • Housing and lifeline risk and vulnerability mitigation planning • Regulatory frameworks for safety in the industrial, transportation, school education, recreation, hospital care, tourism and other sectors and facilities • Governance and administration reforms to promote the vulnerability mitigation planning priority in all development sectors	• Identification and mapping of adaptive/coping capacities and resilience assets/capitals • Participatory approaches and designation of primary actors • Risk education and risk communication initiatives • Resilience action plans: – Strengthening accessibility of powerless groups to assets/ capitals – Community preparedness plans and school-based preparedness – Voluntarism for resilience – Health and protection plans

(continued)

Table 12.1 (continued)

	The vulnerability (and exposure) modification paradigm	The resilience-building or resilience-enabling policy paradigm
Expected outcomes	Correction of vulnerability imbalances and elimination of vulnerability hotspots	Strengthening of pro-active and re-active coping and adaptation capacities
Effect on (disaster) risk and sustainability	(Disaster) risk reduction and improvement of the prospects of sustainability for the benefit of the most vulnerable groups and communities	Redistribution of risk, resilience assets and sustainability prospects among individuals and social groups; also between the public and private sector

advantages as a more participatory approach: while most of the vulnerability reducing programs are delivered in a top-down manner (from state agencies to local communities) resilience initiatives are bottom-up since they mostly emerge at the individual, organizational, and community level (Kais & Islam, 2016).

Though resilience seems at first glance to lack a normative content, the political issue of access to resources or capitals arises if resilience is considered as a process of becoming (i.e., resilience building). Indeed, transformation for survival versus shocks presumes engagement of assets or capitals (Sapountzaki, 2007, 2012): human (e.g., work skill, education, and health), cultural (e.g., worldviews, values, and norms), financial (e.g., material property, wealth), physical (machinery, shelter, factories, transport, energy), political (political regime, power and power brokers), natural and social (e.g., social networks, trust, reciprocity). However, community capitals are neither equally distributed among community members nor available to a community as a collective entity—often some capitals are under the control/capacity of particular individuals, groups, organizations, etc. This situation results in unequal opportunities for survivability, sustainability, avoidance of and recovery after a disaster. Under these circumstances, only policies that reallocate resilience assets promote justice with regard to coping capacity perspectives.

To use an example, after the 1999 Mount Parnitha earthquake in Athens, Greece, most of the small manufacturing firms in Western Athens, those suffering damage, avoided public support for recovery and "expensive" statutory procedures. Instead, they opted for the resilience solutions that externalized recovery costs by providing time credit for payments, dismissals of employees and/or temporary self-repairs. However, these solutions transferred vulnerability to the other social agents like firms' employees and creditors, and in the future also**.** The example shows that resilience of groups and individuals may function as a catalyst for vulnerability transformation-transfer and redistribution burdening further the already vulnerable (Sapountzaki, 2012). Hence, the public policy paradigm for vulnerability reduction may prove more effective in tackling the vulnerability disparities.

4.5 The Challenging Tangle of Risk and Development Decision-Making Processes

From the international agendas to the local implementation, institutionalization of risk and development policies demonstrates the difficulty to integrate decision-making processes; in other words, the obstacles to mainstream disaster risk reduction into development initiatives are quite resistant.

In 2015, international agendas usually prepared separately have given room to a sort of integration. The SFA (2015–2030), the 2030 Agenda for Sustainable Development, the Paris Agreement on climate and particularly CO_2 emissions, and the New Urban Agenda (in 2016) were adopted almost simultaneously, and were even explicitly interconnected (GAR, 2019). The evolution of risk management strategies, from hazard-based approaches to more integrated views, is expected to promptly settle risk-informed sustainable development, building on the convergence of the different international agendas. There is no doubt that risk management failure undermines development processes (GAR, 2013), and that low-developed contexts worsen risk conditions (Wisner et al., 2004). Yet, the implementation of risk and development governance on the ground still shows a lack of consistency between the two realms:

– On the one hand, the two categories come from two different international threads. The first, on risk, coming from the 1980s onwards; the second, on development, mixing environmental concerns and the improvement of basic livelihoods. The convergence of those sectors is not obvious. For instance, the hazard-centered approaches to risk issues prevailed for a long time, mostly eluding social drivers in risk explanation. But also, international actions (and institutions) must count on limited financial resources as well as political attention. The UN agencies or international organizations struggle for the budgets and advocate for their own priority issues. It is a real challenge to integrate sectorial issues when the agencies and organizations do not share the institutional cultures, make different allies, use a specific vocabulary, promote diverse skills, approaches or frame in very different ways problems which might seem to be close. For conceptual, institutional, political, or economic reasons, risk and development are still hardly thought together.
– On the other hand, both risk and development are analytical, as well as operational categories. The two notions encapsulate competing, and sometimes incompatible, concepts. They allow interpreting reality, as they serve to perform and monitor the results of implementation of public or private initiatives. There is a huge gap between risk as disaster management (still known as *administración de desastre* in Latin America), and risk as lack of development—or risk as underdevelopment (as La Red states in the region and beyond—(https://www.desenredando.org/). There are also strong differences between development as a governance framework (for critics, see Rist, 1996), and development as a political objective to be achieved (enhancing services, improving livelihoods, and better quality of live) beyond normative and regulatory aspects.

In northern Latin-American Andes, institutionalization of disaster risk management is lagging behind the international timeline. It was only after the 1997–1998 El Niño Southern-Oscillation (ENSO) event that a regional initiative strengthened national and institutional capacities for managing risk, coordinating risk reduction, and promoting a culture of risk. The nations of the Andean Community supported PREANDINO (2000–2004) and PREDECAN (2005–2009) programs, which set the ground for current risk management institutions. At the same time, most countries in the region (Venezuela, Ecuador, Brazil, Bolivia) have experienced a sort of re-birth of newly legitimized national and public institutions, as well as a certain degree of autonomy (both political and economic) to reassert their sovereignty and independence vis-à-vis international geopolitics and the globalized economy (Estacio & Bermúdez, 2014). This period corresponded to the opportunity, for those countries, to reappropriate the critical development levers at both national and local scales. The period is simultaneously important regarding the consolidation and implementation of disaster risk-reduction initiatives. From the late 2000 onwards, risk and development decision-making processes have coincidently shaped the public actions and policies in countries like Ecuador.

The national legislation on risk management in Ecuador draws on the 2008 constitutional reform known as the *Revolución Ciudadana*. The return of the State under Correa's mandates corresponds to the institutionalization of risk management, as well as to the consolidation of development policies and land-use planning. In Ecuador, risk regulation has even been stated by some of its promoters as a component of the development strategies and land-use planning. The development of methodologies to root vulnerability assessment into an accurate understanding and control of territories and planning strategies at the municipal scale illustrates such an integrated approach (Estacio, 2014). In this respect, grounding vulnerability assessment starts from identifying strategic and critical assets to take care of instead of knowing better the main characteristics of a natural hazard and framing consequently risk-reduction initiatives. The idea is to turn land-use policies and territorial knowledge into the first step of prevention policies, regardless the kind(s) of hazard at stake. However, as mentioned above, competing visions of risk co-exist, be they obvious in public administration services, in consultancy, or in international cooperation initiatives (Rebotier, 2015). Among the many obstacles to such integration: the national secretary for risk management has been downgraded from a ministry level to the technical secretary level along the 2010s; risk and development management turns to be the place for materializing political competition between national and local scales; and the mainstreaming of risk-reduction initiatives into development policies meets strong limitations as land-use planning capacities are very low in most of the municipalities, officially in charge (Rebotier, 2016).

Structural shortages and limitations, as well as specific conditions, undermine the willingness and attempts to integrate risk regulation into development strategies. Thinking risk and development together depends on the broader political agendas and priorities.

5 Risk Mitigation Tools and Practices in the Context of Spatial and Development Planning: Successes and Failures

The contextual features of risk-based development planning/programming do not leave room for guidance on the tools and practices that could be applied everywhere and always. However, the reader can find in the pages of the present chapter interpretative assumptions and representations of the risk-development interrelationship, as well as proposals for key development paths and preconditions leading to risk mitigation, especially for those more at risk.

Explanatory representations and assumptions, useful for the analytical stage of risk-based development planning, include (Bernal et al., 2021):

- The assumption that hazards, vulnerability/exposure, coping capacities, and mitigation measures all interact within human-environment systems (diagrammatically presented in Fig. 12.4, point 3); this interaction results in risk transformation and the selective transfer of the risk burden to some groups and spatial scales, to the advantage of others.
- The systemic and SES thinking addressing cross-scale effects (in time and space) is probably the most appropriate for identification of the causal processes of risk production, distribution, and transfer.

Key development conditions and paths to support the stage of policy formulation are:

- A transformative safety focused vision shared by the community, e.g., securing equitable accessibility to resilience assets and strengthening coping capacities of the most vulnerable.
- An in-depth knowledge of the decision-making community regarding its territorial risk profile, meaning that risk-education and risk-information dissemination across the community is an important sectoral policy of risk-based development plans and programs.
- A policy package giving a primary role for spatial planning mitigation measures (e.g., zoning prohibiting building development, urban regeneration schemes for enhancing structural and urban safety, expropriations, public control on land commons, etc.) and a subordinate, though sometimes crucial, role for the environmental (protective) engineering works.
- A planning process that involves anticipatory thinking to make the transformative vision a reality (through scenario planning, action learning etc.).
- An identification and an implementation of trade-offs and priorities that are consistent with the risk mitigation vision.

The studies that follow address priorities and trade-offs, as well as risk transfer processes in cases of missing visions for justice, regarding safety and risk distribution. In the first case study (Sect. 5.1), Esmeraldas population and territory—after national level decisions taken in the past—were left to their own in the face of high seismic and seismo-technological hazards and risks, and above all a concealment of seismic hazard information. In the second case study (Sect. 5.2), the open-air farmers of Messara plain, in Crete, were overburdened by the aggregate risk arising from meteorological and hydrological drought in the area.

5.1 A National/Regional Level Case Study: The Triangle of Oil, Risk, and Development in Esmeraldas (Ecuador)

Esmeraldas is the main city of a coastal province of Northern Ecuador, located close to the border with Colombia. This is a relevant case study to illustrate how and why existing policies sometimes poorly address the links between various types of development and risk prevention. Despite recent efforts to mainstream risk prevention into the development policies, the city remains a major risk-prone area.

From Quito, the capital city, Esmeraldas is considered as a rather low-developed city, hosting mainly afro-descendant Ecuadorians, and suffering from high vulnerability levels (Rebotier et al., 2019): (1) Socio-economic indicators characterize a precarious population; (2) the built environment shows deficiency, both in terms of public services and housing conditions; and (3) local institutions face strong constraints, be they related to urban planning, municipal governance and budgetary capacities, or local risk prevention policies.

Yet, the city of Esmeraldas hosts very important oil assets for national sovereignty, security, and independence (Fig. 12.12), such as the biggest oil refinery of the country. Moreover, the only exit point for national crude oil is the port of Esmeraldas, with two oil terminals which ensure exportations: the Balao oil terminal—in the hand of a public entity—and the private OCP oil terminal—assuming a public concession up to 2023.

This is a contrasted and paradoxical—even though classical—situation: a very low-developed territory where strategic facilities are located since the 1970s is worsened by the very high exposure of the urban area (including oil infrastructures) to earthquakes (Fig. 12.12), and associated submersions by tsunami, as well as floods and landslides.

Indeed, traditionally in Ecuador, and particularly in Esmeraldas, local development (both spatial and social) has been separated from the development of oil activities and its strategic interests at the national level. This mismatch, which results from a longstanding lack of recognition of local specificities (cultural, ethnical, institutional) and basic development needs, hampers risk understanding and prevention.

The limited interest for Esmeraldas local development can be illustrated by the uneven level of information on earthquakes, and their related damages, between Quito and the coast (Fig. 12.13). Indeed, the lack of information on earthquakes could be synonymous with the absence of any previous disaster concerning Esmeraldas, before the beginning of the twentieth century: this situation would then

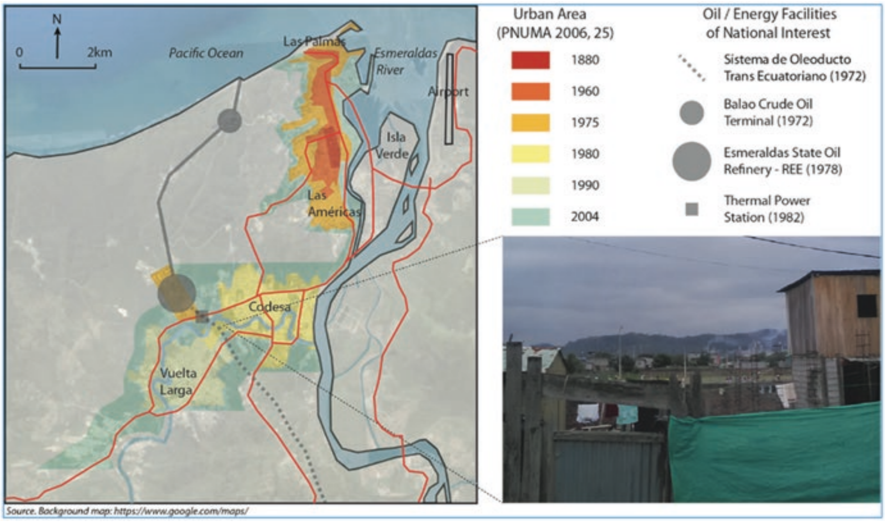

Fig. 12.12 Esmeraldas' waves of urbanization and the oil-related economic sectors. (Source: Rebotier et al. 2019)

reduce the relevance of risk prevention. However, such a statement draws on a lack of consideration for local development and disregard for previous urbanization. Thus, it implies a difficulty to acknowledge local risk characteristics from the viewpoint of the "objective" hazard study perspective! In that case, the underdevelopment tackles the ability to obtain reliable information on risk, and—more objective—on hazards characteristics. In other words, local and contextualized development transforms the types of information on earthquake and disasters, and thus hampers risk prevention, contributing to explain the limitations disaster prevention policies still meet.

This challenging situation illustrates how uneven development processes, between national priorities and local livelihoods, finally lead to more risks for all, and how reconsidering fragmented development strategies could improve overall risk conditions in Esmeraldas.

It is only from 2015 onwards that oil sector institutions appeared concerned about reducing the vulnerability of the whole territory, as a way to guarantee the continuity of their activities, and to lower their own risk (Fig. 12.13). A more integrated approach of risk and development barely begins to emerge, particularly after the 2016 earthquake that struck the Ecuadorian coast (including the Esmeraldas area). At the very same time, the compensatory state position during the Correa's mandates has allowed the country to develop thanks to the significant oil resources of the 2010–2014 years. Yet, on the ground, the "oil-for-development" idea (duly contested, Gudynas, 2012) has not led to "oil-for-risk-reduction." Territorial and social compensations enforced by national laws (2010–2012) did not challenge the structural conditions of underdevelopment (Watts, 2004), while oil compensations invested in the urban territory of Esmeraldas (as a demonstration of correcting the

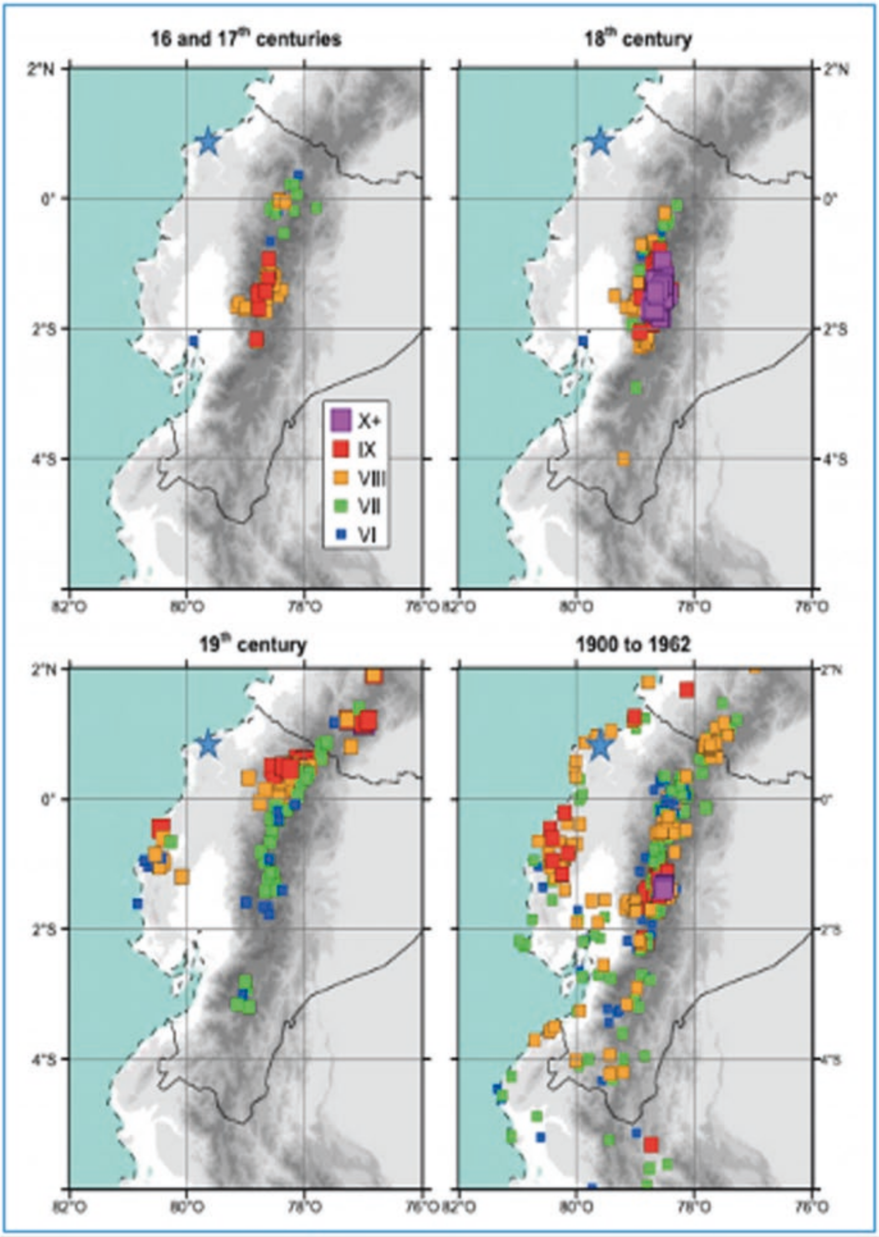

Fig. 12.13 Historical intensity map for Ecuador and uneven distribution of intensity reports. Existing databases do not report any damage nor any earthquake related with Esmeraldas (blue star) before the beginning of the twentieth century. This situation contrasts with the Sierra where ancient as well as present capital cities are located (dark areas). However, the coast is also on an active Pacific-type margin, very earthquake-prone, and Esmeraldas experienced one of the most important earthquakes ever observed worldwide, in 1906. This situation also depicts how the information on damages is captured, who manages it, and why. Local underdevelopment, as seen from a capital city (Quito), does not favor risk-prevention policies. The scale of intensity is MSK. (Source: Rebotier et al., 2019, as it appears in Beauval et al., 2013: 775)

historical debt of underdevelopment) have resulted in increasing assets by building educational infrastructures or consolidating settlements in areas exposed to both natural and technological hazards (Fig. 12.13).

By neglecting the links between risk and development conditions, the policies that are supposed to foster development (though in a highly questionable way) increase the risk conditions. By acknowledging those connections, the next step would be mainstreaming the DRR policies into development policies. In other words, considering the development strategies as the DRR policies for all, based on the territorial interventions.

5.2 A Local Level Case Study: Drought in Messara Rural Locality, Crete

The following study case of Messara rural settlement area addresses/illustrates: (a) mal-development paths increasing exposure to the climate change hazards and disaster risk, (b) social disparities in terms of the livelihood vulnerability to agricultural drought, (c) unfair distribution of resilience capital and mal-adaptations of powerful groups of farmers, (d) prejudiced institutions impacting on livelihood vulnerability, and (e) advantages of the SES approach in integrated analysis of the sustainable development and DRR policies at the local level.

The plain of Messara is located in southern Crete, approximately 80 km away from the capital city of Crete, Heraklion. Through the ages, the fertility of the plain has provided the civilizations that flourished on the island with abundant agricultural products. The area still remains the major agricultural hub of Crete and one of the basic agricultural production sites of Greece. Moreover, it represents more than 30% of the island's total agricultural output. Likewise, sectoral distribution of employment in the area is mostly shared between the primary and the tertiary sector (40% and 50% respectively, Hellenic Statistical Authority, Census, 2011).

The plain is featured hydrologically by the river basin of Geropotamos (Fig. 12.15). The river originates from the foot of Psiloritis Mountain and runs westbound, through the main part of the plain.

In the 1960s, FAO (in recognition of the potential of the region as an agricultural hub) proposed implementation of extensive irrigation schemes, including the construction of dams and diversion of nearby rivers to supplement the water supply. A misleading impression of water abundance was created then, encouraging many farmers to invest heavily in higher value added albeit water demanding cultivations such as tomatoes, cucumbers, and other vegetables. Such investments were fueled by market demand, mainly from central Europe, that resulted in an increase of total agricultural output. As a result, a "sea" of greenhouses has been developed near the town of Tymbaki (Fig. 12.14). Farmers who opted for this solution have gained a significant financial advantage over farmers who continued to practice open-air cultivations entailing high livelihood vulnerability. Consequently, greenhouse cultivations account nowadays for the majority share of the annual agricultural GDP of

Fig. 12.14 The greenhouse cluster of Tymbaki. By being the major agricultural producer in Messara plain, greenhouse farmers have the capacity to leverage political and planning decisions related to drought and water resources allocation (© I. Daskalakis, 2016)

Messara and greenhouse farmers have a significant influence on the political and planning decisions in the area (Sapountzaki & Daskalakis, 2018).

The grandiose irrigation schemes of FAO were fraught with delays and greenhouse farmers have used their financial (resilience) capital to drill private boreholes to supplement their water deficit and support their farms' competitiveness. Farmers without financial capital (i.e., open-air farmers) have continued to rely solely on the unreliable public water supply network, affecting their cultivations' productivity. Consequently, not only the sustainable irrigation practices such as harvesting of rainwater and drip irrigation have lost popularity among farmers, but also financial incentives that could support implementation of sustainable practices have been limited.

Until mid-1980s, the river had perennial flow, since water demand was on par with the hydrological cycle and the prevailing precipitation patterns. Up to then, the plain featured a diverse range of cultivations. Crop rotation and fallow land schemes allowed for the development of sustainable local cultivation patterns.

The individualized, uncoordinated and poorly monitored adaptation practice of borehole drilling in combination with intensive agricultural production has led to the deterioration of the basin's water quality and quantity. Lowering of water tables has led farmers to withdraw the water from ever-deeper aquifers. The impact of climate change on precipitation patterns has further deteriorated the water deficit and has resulted in the river running completely dry during the summer months and limited flow during the rainfall season.

Institutional intervention came in 2013 with the operation of Faneromeni dam, as a policy of both development and drought reduction policy. However, the dam (a

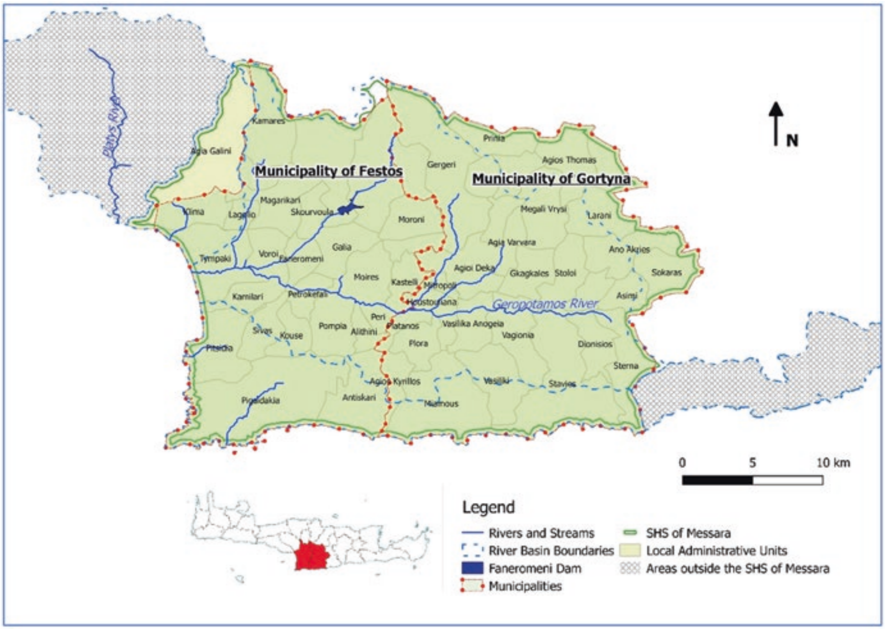

Fig. 12.15 Municipality boundaries, river basins, and major hydrological infrastructure in Messara plain (© I. Daskalakis and K. Sapountzaki, 2020)

FAO irrigation proposal) came too late and with limited potential to change the tide of the socio-economic drought. The authorities decided on the powerful and water demanding group of the greenhouse farmers, as first priority consumers of the supplementary water, attempting among others to seal their private boreholes. Nevertheless, this group based on its political, social, and economic capital keeps on pressing for more water through diversion of the nearby Platys River (Fig. 12.15), which lies in another hydrological basin. Greenhouse farmers view their adaptation to drought as a process of ever expanding natural capital to their availability and extend their resilience footprint by accessing the remote river basins and appropriating the water resources of other social-hydrological systems (SHS as a specific case of SES) and other local communities (Sapountzaki & Daskalakis, 2018).

At the same time, the powerless open-air farmers are left without access to the dam's resources and with diminishing means of resilience (financial, social, and political) to cope with drought risk. This group suffers from an ever-increasing livelihood vulnerability and an intolerable risk leading many farmers to abandon their agricultural activity and lose their respective livelihoods.

As a conclusion from this case study, it is obvious that a socially, politically, and economically powerful social group can be resilient and sustainable (with the support of local authorities), while the powerless become increasingly vulnerable, nonresilient, and unsustainable. Powerful groups and production patterns build their resilience by engaging resilience capital, thus invigorating their sustainability prospects. In contrast, the vulnerable groups lose adaptation capacity and sustainability prospects. Through time, relative water scarcity causes the once sustainable agricultural patterns to transform to unsustainable. Copying the maladaptive practices of borehole drilling becomes unidirectional for the powerless groups. Resilience and vulnerability reproduce each other and so do the sustainability and unsustainability dynamics. Eventually, inequalities in terms of access to resilience capital versus drought will prompt socio-economic transformation of the Messara plain, unless the appropriate development policies for the redistribution and enhancement of resilience capital are pursued.

6 Conclusion

Interactions between development and risk as well as their understanding by human societies have a long history. One of the oldest human activities, agriculture, is related to various forms of development—not only economic—and also to a wide range of risks—not only environmental. Besides, the potential for risk redistribution and transfer (i.e., risk management and linkages with development) has been very well known since prehistoric times. The history of insurance is an illustrative example. Respectively in the third and second millennia BC, Chinese and Babylonian traders practiced a primitive form of insurance (Vaughan, 1996). Later, in the first millennium BC, the inhabitants of Rhodes (Greece) created the "general average" which allowed groups of merchants to pay to insure their goods being shipped together. The premiums could be used to reimburse any merchant whose goods were lost during transport, because of a storm or sinkage (Lex Rhodia: the Ancient Ancestor of Maritime Law - 800 BC). Much later in the early capitalism periods, the link between risk and development became even stronger. In the mid-nineteenth century, in the poorest and densest districts of London, people were facing harsh living conditions (Cf. 1854 cholera epidemic). Yet fabric and land owners took advantage of the situation by renting and renewing the workforce. In the twentieth century, Schumpeter (1947) stressed the necessity of a greater recognition of the link between crises and disasters on the one hand, and the capitalistic mode of development on the other; he became famous with "the gale of creative destruction." More recently, the identity of the producers of risk has become elusive/blurred (due not only to globalization) while risk receivers at all levels appear much more clearly and concern unevenly the global human society and the environment.

However, despite this long-lasting presence of the risks of development, these risks have been consistently and continuously ignored and never integrated, if not covered up and played upon.

The present chapter attempts to unveil the complex relationship between risk and development on one side, and risk mitigation and development planning on the other: what risks, by whom, for whom? How are risks (re)generated, transferred, and (re)distributed through development and development planning? How the latter can become a risk mitigation process for those more at risk, even at the expense of development gains?

The most important analytical findings of the chapter can be summarized as follows:

- The root causes of risk and the most important opportunities for risk reduction come from the development processes and development planning.
- Creating and increasing (and also reducing) risk through development is a long-term multi-scalar process.
- Risk-based development planning is basically concerned with the distribution of development gains versus potential losses or “bads” among stakeholders, spatial scales, and time frames.
- Up to the present, development planning focuses on the positive aspects of development and on winners, bypassing risks and losers. This is evident even at the international scale where SDGs make only marginal reference to the risk drivers of development.
- According to the Anthropocene, as well as the climate change and systemic thinking, hazard, vulnerability and risks interact within development processes, reinforcing or reducing one another.
- Hazard mitigation is possible—through development planning—especially in cases of socio-natural hazards.
- Protective engineering infrastructure transforms and transfers hazards in ways that are not always welcome.
- The most common risk drivers of development (sometimes as hazard-exposure drivers, sometimes as vulnerability-drivers) appearing, in more and less developed countries, to varying degrees are:

  – Rapid urbanization and informal settlements in urban peripheries.
  – Socio-spatial segregation based on discrimination criteria, such as income level and poverty, racism, ethnicity, gender, etc.
  – Inappropriate institutional settings featured by dividing lines and isolation of the development policies from risk management policies.
  – A marginal and discredited role of spatial planning both in development and risk-reduction policies.
  – Socio-political stakes prioritizing both real estate developers’ and construction sector interests, and unrestricted building development (for holiday-accommodation, tourism, etc.)
  – Undue credit to environmental engineering in order to continue building development in hazard-prone areas.

The issues following reflect an outlook for future risk-development planning and some relevant recommendations:

- Risk-based development planning represents a deviation from the rationale of the traditional and conventional development planning/programming; prerequisites for its implementation are: (1) a risk-informed community, (2) risk-aware administrations and authorities, (3) a strengthened and core role for the spatial planning to promote among others the key issue of spatial risk and spatial development data collection, and (4) socio-political stakes and visions embracing the interests of those most at risk and of the environment.

- Risk-based development planning is facilitated by the systemic and SES thinking to:
  - Identify human-environment interactions generating the hazards and risks.
  - Address weaknesses and limitations of the technical protective infrastructures.
  - Capture cross-scale governance interactions impacting on local exposure, vulnerability, and resilience.
  - Highlight the catalytic factors and potential barriers to hinder risk transformation and transfer processes.
- Risk-education and risk-information dissemination are important sectoral policy fields of risk-based development planning, since the latter presupposes a risk-informed community; other key policy areas are: (1) Community infrastructures, (2) governance, and (3) sectors related to the resilience assets and livelihood vulnerability (health, housing, water and sanitation, energy, communication, agriculture and food and non-farm livelihood).
- Two basic policy paradigms emerge for risk reduction in the context of development planning: (1) Vulnerability reduction and (2) resilience building (or enabling). Despite mutual criticism and political and/or scientific arguments in favor or against either paradigm, the truth is that they are mutually complementary and interdependent: the first targets exposure and susceptibility to loss, the second strengthens coping capacities.

The following series of tables (Tables 12.2)–12.7)) presents principles and guidelines for risk-development planning, to become an attainable, purposeful, socially acceptable, effective and efficient project. These guidelines/recommendations refer to the vision, objectives and content, spatio-temporal scope, institutional background, methodological approach, tools and decision-making processes of the risk mitigation-development planning venture.

Table 12.2 Guidelines and recommendations referring to the vision of the risk mitigation–development planning venture

Vision	The vision backing RbDP is sustainability of an equitable "low-risk community"
	It is a vision embracing the interests of groups, places, and territories that are most at risk
	It is a vision pursuing equitable accessibility to resilience assets and strengthening coping capacities of the most vulnerable
	RbDP represents a deviation from the rationale of conventional planning; it is concerned with both the positive and negative potentialities of development
	It can only be processed by communities featured by high-risk knowledge, perception, and consciousness
	It can only be performed by risk-aware political leadership, administration, and authorities
	RbDP recognizes the role of socio-economic and development processes in the production of socio-natural and environmental hazards, exposure, and vulnerability, hence of disaster risk
	At the same time RbDP is the basic path to risk mitigation and strengthening of coping capacities

Table 12.3 Guidelines and recommendations referring to the objectives and content of the risk mitigation–development planning venture

Objectives and content	Addressing, evaluating, mapping, and mitigating hazards (socio-natural and environmental), exposure, vulnerability, and risks by controlling hazard and risk drivers of development
	Mapping and enhancing coping and adaptive capacities and targeting uneven distribution of resilience assets
	Identifying and controlling inbound/outbound risks and risk transfer processes (from inside or outside the community), e.g., mal-adaptation to CC practices (transferring risk to other groups or spatial scales or to the future)
	Transformative planning in the sense of a process questioning and resisting risk-introducing social values, socio-political stakes, institutions and technical practices
	Correction of exposure and vulnerability imbalances and elimination of the respective hotspots
	Putting priority on risks and their mitigation when making trade-offs between development gains and risks
	Improving risk knowledge and risk perception of the community
	Key policy areas of RbDP are risk education, risk communication, spatial planning, protective and other infrastructure planning, preparedness and contingency planning, health, housing, energy, water sanitation, agriculture food, nonfarm livelihood, governance

Table 12.4 Guidelines and recommendations referring to the methodology of the risk mitigation–development planning venture

Methodology	RbDP is facilitated by the systemic and SES thinking to identify human-environment interactions generating risk, to address limitations of the technical protective infrastructure and to capture cross-scale risk transfer in time and space
	RbDP is facilitated by anticipatory thinking (through scenario planning, action learning, etc.)
	There are two basic policy approaches to risk reduction: Vulnerability reduction and resilience building (or enabling)
	The two policy paradigms are complementary and interdependent; the first targets exposure and susceptibility to loss, and the second strengthens coping capacities
	There are several aspects of vulnerability to be reduced depending on the respective impacts to be avoided: social and economic, livelihood, institutional, building/infrastructure, ecological, systemic/functional
	Vulnerability reduction and resilience building may be implemented at the micro-level (e.g., households), meso-level (community, municipality), and macro-level (metropolitan region, cross-border region, national state)
	There are several forms of resilience to enhance depending on the systems of concern: socio-economic, social-ecological, social-technical, institutional
	Vulnerability reduction is mostly a top-down public or international assistance policy financed by public resources or international aid funds; resilience building is mainly a bottom-up, participatory approach supported by private resources

Table 12.5 Guidelines and recommendations referring to the spatial-temporal scale of the risk mitigation–development planning venture

Spatial-temporal scale	RbDP is a multi-scale approach in both spatial and temporal terms
	Administrative boundaries and jurisdictional areas are not appropriate for RbDP; it is the systems/networks involved in risk production, vulnerability reduction, and resilience building that define the spatial scope of each RbDP case
	RbDP is concerned with a broad temporal range starting from the distant past and looking forward to the distant future; this is because many risks, especially the socio-natural and environmental, have a long history and an indeterminable future
	RbDP involves both short- (e.g., contingency and preparedness) and long-term measures (precautionary, preventive, proactive); attention should be paid however to short-term resilience and adaptations deteriorating risk and vulnerability in the long run

Table 12.6 Guidelines and recommendations referring to the institutional background of the risk mitigation–development planning venture

Institutional background	RbDP is facilitated by a leading, coordinating, socially acceptable and core role for spatial mitigation planning
	RbDP is facilitated by horizontal institutional linkages between development and spatial planning authorities on one hand and sectoral risk management (for flood, seismic, forest fire risk, etc.) on the other
	RbDP necessitates an appropriate and reliable spatial data basis to reflect risk-development interactions. A "risk observatory" might be helpful to the collection and treatment of (spatial) risk data
	Public trust on spatial planning authorities and acknowledgement of their risk mitigation capacities is a precondition for RbDP
	It is necessary for the development and spatial planning legal framework to make reference of the basic terms of risk management (risk, vulnerability, exposure, adaptation, coping capacity)

Table 12.7 Guidelines and recommendations referring to the tools and decision-making processes of the risk mitigation–development planning venture

Tools and decision-making processes	Basic tools of RbDP are: livelihood vulnerability analysis, vulnerability assessment of territories, buildings and lifelines, social vulnerability profiling methods, regulatory frameworks for safety in the industrial, transportation, school, recreation, and hospital care facilities, land use mitigation planning, governance and administration reforms to ensure risk consideration in all development sectors
	Indicative spatial planning mitigation measures to support RbDP are zoning prohibiting building development, expropriations, low building development ratios, urban regeneration schemes for enhancing structural and urban safety, community/public control on land commons
	Policies and measures for counter-disaster, protective infrastructure should be always accompanied by nonstructural, land use protective measures
	The factors triggering/expediting RbDP are a traumatic disaster event, social, economic, and political crises or high-risk culture and awareness in a significant part of the community

Table 12.7 (continued)

	RbDP presupposes putting political attention, devolution of powers, and allocation of resources to people and places most at risk
	A common vocabulary and mutual understanding between development, spatial planning, and risk management authorities are a necessity
	Governance structures for RbDP should include both hazard/risk-producing agents and those becoming exposed; the latter should enjoy the first say in decision-making
	Administration reforms at national, regional, and local level may be necessary in order to promote as a cross-cutting issue the vulnerability mitigation priority in all development sectors

To conclude, the crucial dilemma of risk-based development planning is whose resilience is strengthened and whose vulnerability is reduced because the vision of "increasing resilience" or "lowering vulnerability" for all and the community is hardly achievable. What is good for development at a certain scale and for a specific group of stakeholders can be deleterious for others. What seems to improve the risk situations for some may turn to hinder the response capacity of a whole community. This dynamic and unbalanced situation stems from risk transformation and transfer processes, deeply rooted in development. But, what are their catalytic factors and causal origins? Is it the systemic structure of our world and finiteness of resources, or power relations from a historical perspective in the social world? The fact remains that development planning has not yet sufficiently integrated their understanding and control and has not the capacity to respond to the resulting trade-offs.

The research and political agenda of future efforts for risk-based development planning should focus even more on these risk transformation and transfer mechanisms, as well as on the implied trade-off decisions.

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Chapter 13
Flood Risk Instruction Measures: Adaptation from the School

Álvaro-Francisco Morote, María Hernández, and Saeid Eslamian

Abstract Floods are one of the main natural risks that affects Europe. The situation was made worse in recent years by the urban occupation of flood regions and the consequences of climate change. These general factors are joined by a specific one related to the role that education could play and linked to this as these topics are taught in school. In Spain, this content is compulsorily taught in Primary Education (Grades 1–6). The objectives of this chapter are to examine what skills teachers in training receive on floods during their school years, and to revise the didactic proposals to be carried out in Primary Education classes. In regard with these proposals is examined the level of the problematization (critical methodology) to adapt to global warming scenarios. A survey was distributed among future teachers of Primary Education (Faculty of Teaching Training, University of Valencia, Spain) during the academic years of 2018–2019, 2019–2020, and 2020–2021. The results highlight that only 20.4% of the future teachers received information about floods during their school stage. In relation to the didactic proposal, the participants showed a scarce capacity to propose instruction resources. It could contribute to future teachers not being able to face this issue in the classrooms.

Keywords Floods · Climate change · Measures · Adaptation · Primary education

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1 Introduction

In Europe, natural risks of a climatic nature in recent decades are causing a high volume of economic and human losses (Olcina et al., 2016; Parker, 1995; Pérez-Morales et al., 2015, 2021; Perles et al., 2017). Globally, according to the Centre for Research on the Epidemiology of Disasters (CRED, 2019), the risk of flooding is considered the most frequent natural hazard (43% of the total annual episodes that occur) and the one that affects the most people, both the number of victims and those affected. And, according to forecasts, in the world it is estimated that in 2050 the annual victims of these events could reach 300,000 and up to 400,000 in 2080 21st century (Intergovernmental Panel on Climate Change [IPCC], 2014). In Europe, the EM-DAT (2021) has registered that between the period 2000–2020, 1933 people have lost their lives due to 400 flood episodes, while 6.8 million people were affected.

In Spain, according to Olcina (2018), two million inhabitants live in places of high risk of flooding. Besides, the Mediterranean area being the region most affected by this hazard (Pérez-Morales et al., 2021). In this area, where the Valencian Community is located (study area), according to the Territorial Action Plan for Flood Risk Prevention (PATRICOVA, 2015), approximately 600,000 inhabitants (12% of the population) live in areas with risk of flooding. Of this population, almost a quarter of a million live in low-risk locations, but about 30,000 live in high-risk areas. Likewise, it should be noted that according to PATRICOVA (2015), 327 schools have some element located in a flood zone, and six centers are located in high-risk areas.

The phenomenon of climate change, according to climate modelling, will have different effects depending on the region and the host society (Abbot et al., 2019; Ahmad & Numan, 2015; Arnell et al., 2019; Eslamian et al., 2011). In the case of the Mediterranean basin, this area is an area with high exposure to the effects of climate change, as indicated in the Sixth IPCC Report (2021) and different studies (Centre for Research on the Epidemiology of Disasters [CRED], 2019; Pausas & Millán, 2019). The union in this territorial area of a high climatic danger and intense urbanization, specifically the coast (urban-tourist uses) explains its high risk. In fact, Calvo (2001) already coined at the time that the Mediterranean area had become a prominent risk-region worldwide. Likewise, authors such as Pérez-Morales et al. (2021) have analyzed the degree of vulnerability and exposure of this territory to episodes of intense rains in recent decades.

The latest climate change report (Sixth Report) (IPCC, 2021) identifies the Mediterranean region as a global climate change “hotspot.” Likewise, it indicates that it will be notably affected by water stress and the frequent occurrence of extreme atmospheric events (floods and droughts). These are regional effects of the warming process, closely linked to the increase in temperature of the Mediterranean Sea water (Pastor et al., 2020), which creates intensification and greater energy in atmospheric processes (Tamayo & Núñez, 2020).

The education factor takes on a greater role in relation to flood risks for several reasons: (1) it is a subject that must be taught at the school stage (Primary Education, Secondary Education, and Baccalaureate); (2) education is one of the most important structural factors in dealing with these phenomena (European Environment Agency [EEA], 2017). In other words, a society formed and aware of risks would reduce deaths and economic losses. However, as Morote & Olcina (2020, 2021) explain, it is a neglected variable with respect to other measures related to spatial planning, mitigation policies and infrastructures ("hard work"); (3) the risk of flooding will be increasingly serious due to the effects of climate change (IPCC, 2021); and (4) the importance of complying with the 2030 Agenda (United Nations [UN], 2015) with the so-called Sustainable Development Goals (SDGs).

In relation to the SDGs and the subject under study, it is worth mentioning objective 13 ("Climate action"), which pursues the following goals in relation to risks: (1) strengthen resilience and the ability to adapt to risks related to climate and natural disasters in all countries; (2) incorporate climate change measures into national policies, and plans; and (3) improve education, awareness, and human and institutional capacity regarding climate change mitigation, adaptation, reduction of its effects, and early warning. Likewise, the IPCC (2014) recorded in its Fifth Report the importance of the role of education in the adaptation of society to climate change to achieve a more resilient society. In general, these reports (IPCC, 2014; UN, 2015) emphasize that a society better educated on these issues will be more resilient to the effects of the current global warming process. Hence the need to treat these contents rigorously at school (Morote & Olcina, 2021).

Currently, information related to climate change and its associated effects has received a growing interest, both in daily life and in the academic-educational world (McEween et al., 2014; McWhirter & Shealy, 2018; Martínez-Fernández & Olcina, 2019; Masters, 2020; Nelles & Serrer, 2020). However, authors such as Ferrari et al. (2019) and Olcina (2017, 2020) explain that teaching this topic is a complex issue due to the different factors involved. If the information collected in the school manuals is taken into account, their explanation is not always correctly oriented and a catastrophist message is frequently used (Morote & Olcina, 2020, 2021). Morote et al. (2021a) have found that stereotypes are abused assiduously, while Brisman (2018) and Kažys (2018) highlight the risk posed by the "fake news" that are published in the media in order to teach about events and processes of non-simple causality and of great repercussion in society (Kurup et al., 2021; Roussel & Cutter-Mackenzie-Knowles, 2020).

Regarding the works published in the educational field on flood risk, in recent years, it is worth noting at an international level, a notable scientific production (Ollero, 1997; Williams et al., 2017). At the international level and from a school perspective, different studies have recently been carried out on flood risk analysis. For example, the teaching of this phenomenon in schools in the USA (Lee et al., 2019; Lutz, 2011), Asia (Shah et al., 2020; Tsai et al., 2020; Zhong et al., 2021), or in the African continent (Mudavanhu, 2015). In the case of Ibero-America, in relation to publications on education and flood risks, it should be noted, for example, the studies carried out in Brazil (Jacobi, 2005; Valdanha & Jacobi, 2021) or

Argentina (Lozina & Pagliaricci, 2015). In Europe, the research carried out by Bosschaart et al. (2016), Lechowicz & Nowacki (2014), or Williams et al. (2017). Regarding the territorial scope under study (the Mediterranean area), recently there have been published works related to both field conference proposals (Morote, 2017; Morote & Pérez-Morales, 2019) and research that has the objective of analyzing the works about social representations from the studens (Hernández-Ruiz et al., 2020), of teachers in training (Morote & Hernández, 2020; Morote et al., 2021b; Morote & Souto, 2020) or from resources such as the press (Cuello, 2013, 2018).

The objectives of this chapter are to examine what skills teacher in training receive on floods during their school years, and to revise the didactic proposals to be carried out in Primary Education classrooms. In regard with these proposals is examined the level of the problematization (critical methodology; activities that student should resolve problems) to adapt to global warming scenarios. This research is based on two hypotheses. The first one is that most of the future Primary Education teachers who have participated in this research did not receive any training about floods during their school years. Second, it is believed that they will show a scarce creativity to propose activities (problematic activities to carry out in classroom) and this low capacity could contribute to the future teachers not being able to face this issue in the Primary Education classes.

2 Methodology

2.1 Design of the Research

The approach of this research is based on a mixed correlational and exploratory methodology (non-experimental). It is applied the procedure and methodology utilized in studies conducted about the training on climate change and natural hazards from the Social Sciences (see Morote & Hernández, 2020). It adopts a transversal design as the information analyzed has been collected at a specific time (the academic years of 2018–2019, 2019–2020, and 2020–2021) and as a case study (Faculty of Teaching Training of the University of Valencia, Spain) (Fig. 13.1).

2.2 Context, Respondents, and Representativeness of the Sample

The selection procedure has been conducted through non-probability sampling (available or convenience sampling). The context has been three academic years (2018–2019, 2019–2020, and 2020–2021) and the respondents, two groups (fourth year of the Primary Education Teacher degree) from the Faculty of Teaching

Fig. 13.1 Region of Valencia, Spain. (Own elaboration)

Training (University of Valencia, Spain). All of them attend the subject of "Instruction of Social Sciences. Applied Aspects" (code 33651). It is a theoretical-practical subject based on geographic content and, indeed, it is the only one where this type content is taught in the Primary Education degree. Taking into account the total number of students enrolled (275), in order to achieve a confidence interval of 95% and a margin of error of 5%, at least, 161 students were necessary to constitute a representative sample. A representative number was achieved because 240 students answer the questionnaire. By reference to the social characteristics, the old range is mainly between 21 and 25 years (average age of 21.6) and most of the respondents were women (71.3%). Both data are within the normal ranges of the type of student of the Faculty of the Teaching Training (University of Valencia, 2020).

Table 13.1 Items of the questionnaire examined in this research, own elaboration

Section 1. Social characteristics	
– *Item 1*. Age	*Response type/Variables* Ended answer question/number
– *Item 2*. Gender	*Response type/variables* Ended answer question: Male/female/I prefer not to say/other
Section 4. Training about floods during the school stage	
– *Item 15*. During your school stage, did you receive any kind of information about floods?	*Response type/variables* Ended answer question: Yes/no/I do not remember
– *Item 17*. If the previous answer has been affirmative, in what educational stages do you remember having received this content?	*Response type/variables* Ended answer question: Primary education/secondary education/baccalaureate
Section 6. Teacher training about floods	
– *Item 28*. As a future teacher, what activities and information would you propose to your students to increase their knowledge about floods?	*Response type/variables* Open answer question

2.3 Questionnaire, Data Analysis, and Procedure

The instrument used to conduct the research is a questionnaire. It was organized into five sections with a total of 28 items. Considering the objectives of this chapter, the data obtained from Section 1 (social characteristics; items 1 and 2), Section 4 (training about floods during the schooling period; items 15 and 17), and Section 6 (teacher training about floods; items 22, 24, 26, and 28) (see Table 13.1) will be analyzed.

The questionnaire was conducted in an intermediate session (first 4-month period) during the last week of November (years of 2018, 2019, and 2020) and with a response time of 20 min. The questionnaire was also validated by two researchers from the Department of Experimental and Social Sciences Education at the University of Valencia (Spain), and a researcher from the Department of Regional Geographic Analysis and Physical Geography of the University of Alicante (Spain). All the respondents answered all of the questions and the respondents' anonymity was preserved during the entire procedure and confidentiality was guaranteed in writing.

3 Results

3.1 Training About Floods During the School Stage

In relation with the school training about floods (Section 4), in item 15 was asked if the participants had received training on this subject at their school period (item 15). The responses state that the majority of the future teachers did not receive such

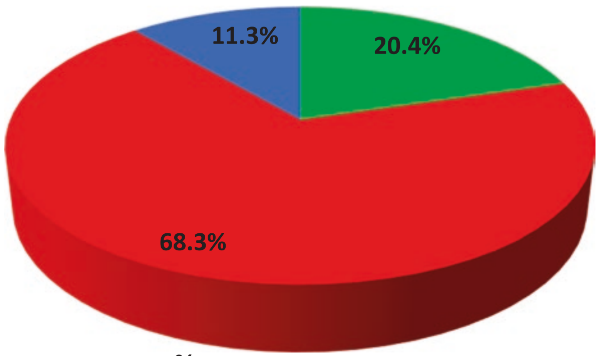

Fig. 13.2 Item 15 During your school stage, did you receive any kind of information about floods? (Source: results of the survey, own elaboration)

instruction (68.3%; *n* = 164) (Fig. 13.2). Those who indicate an affirmative answer indicate that this training was obtained mainly during the Secondary Education (46.3%; *n* = 111) and Primary stages (34.3%; *n* = 82) (Fig. 13.3). Data on Baccalaureate is low (19.3%; *n* = 46). This low percentage is mainly explained by two reasons. The first, part of the students who study this degree have not attended the Baccalaureate to access university studies since they have done so from an Educational Module. The second, the subject of geographical contents is optional in the Baccalaureate.

In the case of those students who claimed to have received information on flood risks, it is worth highlighting the examples of real cases explained in class. For example, some of the famous flood episodes in the Valencian region that future teachers cite are the "Pantaná" of Tous (1982) or the "Riuá" of the Turia (1957) (see Fig. 13.4). The linking of theoretical content with examples that have took places in the daily environment facilitates the learning process.

3.2 *Teacher Training About Floods*

The question of the Sectin 6 (Item 28. "As a future teacher, what activities and information would you propose to your students to increase their knowledge about floods?") aims to find out what educational activities and instruction proposals are put forward by future teachers to deal with floods in the Primary Education classrooms (item 28) (Table 13.2). Out of a total of 285 responses, the respondents mainly highlighted the activities related to field trips (19.3%; *n* = 55), those related

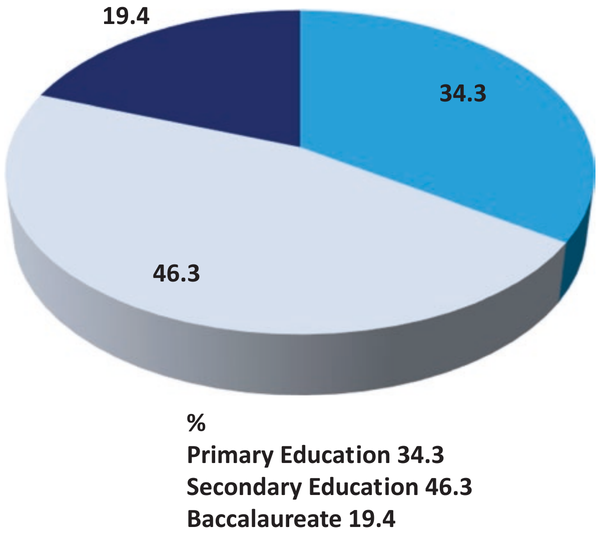

Fig. 13.3 Item 17 If the previous answer has been affirmative, in what educational stages do you remember having received this content? (Source: results of the survey, own elaboration)

Fig. 13.4 The "Riuá" flood in Valencia (14th October 1957). (Source: gentevalencia (2020))

Table 13.2 Instruction proposals to teach floods in the Primary Education classrooms (item 28)

	n	%
Field trips	55	19.3
Videos	52	18.2
Analysis of the past events	51	17.9
Conferences and emergency protocols	44	15.4
Drills	25	8.8
Workshops	14	4.9
Analysis of the land planning	13	4.6
Elaboration of teaching resources	12	4.2
Real experiences	11	3.9
Climate change analysis	5	1.8
Not trained	3	1.1
Total	285	100

Source: results of the survey, own elaboration

to the viewing videos (18.2%; $n = 52$), the analysis of the past events (17.9%; $n = 51$), and the attendance of conferences and implementation of emergency protocols (15.4%; $n = 44$).

A deeper analysis of these proposals highlights that these activities have a low "problematization" (from a critical methodology) and little implication of the students to understand the territory and seek solutions (see Table 13.3). For example, in the case of the field trips, the future teachers confuse it with "excursions." That is, activities outside the classroom but decontextualized with the content taught in class and without any activity or evaluation. There are also positive responses (although minority) in relation to the analysis of past episodes. For example, student n°9 (2020) "I would work from recent news in the different mass media. I would intend to analyze the situation in order to reach a possible conclusion. Draw from these methods, I would try to find possible solutions so that this does not happen again" (see Table 13.3).

Other responses that bring to light the lack of teacher training to explain these topics are those related to videos and documentaries and the conducting of conferences and emergency protocols by experts (see Table 13.3). Regarding the proposals on the analysis of past events, the analysis of the media (especially the consequences of floods) predominates. In these, there are practically no problem-solving activities that would be really interesting. On the other hand, the proposals that would involve students based on a critical methodology, would be those related, for example, to the analysis of land planning (how has the territory been occupied?) (4.6%; $n = 13$) and analysis of climate change (1.8%; $n = 5$).

Table 13.3 Some proposal activities to teach floods by the future teachers of Primary Education

Field trips
• "Conducting excursions to areas that have been flooded"
• "Visits to places with ease to flood"
• "More excursions to teach them the flood consequences"
• "Visits to flood-prone areas, reflecting on it and working on the contents from practical and real experiences, learning about important floods that have occurred in our territory"
• "Field trips to various swamps where you can explain what would have to happen for a flood to occur"
• "I would propose activities in which the reality of the floods can be seen, excursions to a place where it has left consequences"
Videos
• "Especially, videos where floods have been happened"
• "Videos and photographs about floods so they can reflect and visually learn"
• "Watch videos and documentaries of flood events"
• "Videos, graphics, news, etc. that will call your attention to be able to give way to know the causes and consequences of these phenomena"
• "Show videos of real cases of water rises for example, and make the explanation graphically, pointing out which places have floods, etc."
• "Videos and images that allow us to see what happens and its consequences"
Analysis of the past events
• "Sample of real cases and discussion on the topic"
• "I would analyse news about flood events that have happened with the students"
• "I would work from recent news in the different mass media. I would intend to analyse the situation in order to reach a possible conclusion. Draw from these methods, I would try to find possible solutions so that this does not happen again"
• "I would see with them news about cases that have happened, or do a simulation of what should be done if this happened"
• "Work on reality"
Conferences and emergency protocols
• "I would suggest information and measures on how to act in a flood event"
• "I would mostly do a series of performance guidelines"
• "I would put simple information forward, without giving much technical or excessive knowledge, how to act (action protocols)"
• "Some conference from an expert"
Drills
• "Basically, how to deal with a flood warning, the before and after"
• "I would explain causes and consequences, how to act in a flood event through a video for example and perform a drill"
• "Some game through which they could know prevention measures"

Source: results of the survey. Own elaboration

4 Discussions

The result of this research, from an approximation of the social representation and proposal activities of the teachers in training, has demonstrated their low level of creativity to teach floods in Primary Education. With regard to the hypotheses, all are fulfilled. The first one because most of the students affirm to have not received training about these risks during their school stage. Secondly (activities) is also fulfilled. It has been shown that the activities are not very innovative and problematic (critical methodology). In this regard, it is also indicated what are the origins and the effects of global warming. Likewise, it is pointed out that using the perspective of a local level, that is to say where the student's daily life takes place, would allow them to better understand floods and climate change. Currently, its analysis is highly influenced by what the media indicates. Besides, teaching the impacts of society activities in the environment would be a good method to vinculated flood regions and land uses.

With these results, the following question can be posed: can having received training influence the degree of teacher training? This constitutes a future research challenge. There is previous research that has analyzed training on this subject during the school stage. For example, in the work of Morote & Souto (2020) it has been found that only 12.1% of the teachers in training (Primary Education) had received some type of instruction during the school stage. Morote & Hernández (2021) show that the majority of the teaching staff in training had not received information on teaching the risk of flooding (68.3%).

Recently, in Spain, the importance of teaching atmospheric risks has gained interest in the political sphere with the intention of improving how these contents are treated in non-university stages. For example, this is the case of the United Nations Conference on Climate Change (COP25 Madrid 2019, Spain). At this meeting, the Minister of Education, Culture and Sports announced the incorporation of a subject on climate change in the school education reform process, with a concrete reflection in the school curriculum. However, they are subjects that, as Morote and Olcina (2020) explain, are already taught in certain subjects of Compulsory Secondary Education (hereinafter ESO) and Baccalaureate (Geography and/or Social Sciences). Different is that the definition of objectives, competences, and evaluation criteria should be improved, which are based on scientific rigor and specifically, on the use of this topic in the training of teachers. Likewise, these researchers point out that information on climate change is "scarce and it may be necessary to pay greater attention and scientific rigor to these contents with the commitment to greater and better training of teachers (current and future) and not so much the creation of new subjects" (p. 174).

In relation with the activities to teach floods at school, in Spain, publications on this subject have been carried out mainly from the Didactics of Natural Sciences (Díez-Herrero, 2015; Díez-Herrero et al., 2020, 2021). However, from the Didactics of Social Sciences and/or Geography it is an emerging issue in recent years, especially in the Valencian region that deals with: (1) the social representations of teachers in training (Morote & Hernández, 2020, 2021) and (2) didactic proposals based on field trips (Morote & Pérez-Morales, 2019).

For the study of flood risk, the key questions to study are human activity (occupation, distribution, etc.) and climatic characteristics. Tonda & Sebastiá (2003) explain that the study of the climate constitutes a fundamental task in the training of students for two reasons: (1) because the current curriculum establishes this; and (2) due to the enormous social importance that many of the activities in daily life have. In the Valencian region, Morote (2017) with his proposal to visit the "La Marjal Floodable Park" (Alicante city), explains that the possibilities it offers, as a public space for leisure and recreation, help students to detect, assess, and even make correction proposals from the territory being analyzed (activities for all school stages). Also, Morote and Pérez-Morales (2019) with their field trip proposal argue that in addition to being a didactic resource, it can also help society in general to understand the risk of flooding and, most importantly, understand the dimensions of the flood. The vulnerability and the how a territory can become more vulnerable to these risks due to the deficiency of the urban design practiced and the lack of knowledge of the operation of a specific geographical area. Likewise, these authors conclude that said exit serves as a "laboratory of the territory" since students are asked how to solve a problem from their own knowledge acquired in class (theory, definitions, concepts, problem-solving, other case studies, debates, etc.).

5 Conclusion

With this work it has been possible to verify that future teachers finish their formative stage without knowing how to teach flood risks. This would cause future teachers to be trained in this subject, in what could be called the "didactics of nothing"; that is, many learning strategies and cognitive processes are handled (Chevallard, 1991), but they do not know the contents of the subject. In the Spanish educational field, there is a notable challenge to improve the teacher training of future teachers, who will ultimately be those who train and make new generations aware of this global phenomenon. To conclude, it should be noted that education is a fundamental pillar when considering the vulnerability factor since a society that is better trained and aware of natural risks can be even more valuable than certain structural mitigation factors (infrastructure, etc.).

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Chapter 14
Flood Resilient Cities

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Abstract Land-use changes in the urban expansion process often modify the water cycle, aggravating floods and exposing more people and assets to risks. City growth may induce imbalances in the interaction of the natural and built environment, mainly because natural constraints are not understood and respected. Within this context, resilience emerges as a component of the risk assessment that opposes vulnerability. In general terms, resilience is characterized by the resistance ability of an exposed system to sustain its function, and the ability to recover from difficult adverse situations quickly. Flood resilient cities can be built by addressing and fostering the relationship among pluvial waters, buildings and urban spaces, using nature-based solutions and blue-green infrastructure. The integration of rainwater and drainage systems in the urban landscape harmoniously and valuing their presence as an element of revitalization for the urban space while mitigating flood problems are steps towards evolving to the concept of water sensitive and resilient cities.

Keywords Flood resilience · Urban floods · Flood risk · Resistance · Recovery capacity

1 Introduction

Human activities change land-use patterns (Suriya et al., 2012), usually altering the quality of both the natural and built environment. One of the major challenges to the increasing number of megacities refers to water issues, with a special attention related to urban storm water management (Larson et al., 2016). Worldwide, flooding is one of the most frequent and hazardous natural disasters, causing on average loss of 200 billion dollars annually in several different damages (Zevenbergen et al., 2017). However, water is an essential resource to support life and it has assumed diverse roles since the origin of the cities (Miguez et al., 2015). Important civilizations developed along rivers, using them as a source of drinking water supply, a

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vehicle for discharging waste, a source for irrigation to increase food production, a means of transportation and a natural barrier to defend cities against invasions. Nowadays, on the other hand, it is common for cities to turn their backs to rivers, literally, with back-to-water constructions hiding rivers in the cityscape. In the limit situation, it is also relatively common to find rivers running enclosed in pipelines (Chou, 2013), far from the people's view, who are unaware of the river's existence. It is relatively common that the cities face serious environmental problems, because of the excess of pollution, inadequate solid waste management, insufficient sanitation, water scarcity (either in quantity or poor quality) and floods.

Rivers can be considered the synthesis of the territories connected to them (CIRF, 2006), which means that the actions in the watershed reflect in the river corridor.

The urbanization strongly changes the urban hydrological cycle and the responses of river systems in the built environment, bringing urgent concerns on urban storm water control (Eaton, 2018). Vegetation removal, soil sealing and the implementation of urban drainage systems change flow patterns, producing greater and faster responses of the surface flows. On the other hand, these changes limit the infiltration opportunities, resulting in increased peak flows, reduced base flows, lower times of concentration and loss of river ecosystems (Sheng & Wilson, 2009). A frequent result observed in the cities is the worsening of the flood problems, related to these land use changes and urban issues, such as the housing deficit leading to the irregular occupation of floodplains (Miguez et al., 2014). Floods can degrade the built environment, interfere with several other urban systems, affect buildings and urban facilities, and devaluate areas subjected to flooding, causing business disruption and limiting mobility. Floods are also potential vehicles for spreading waterborne diseases (Mark et al., 2018) since they affect (and are affected) by inadequate collection and disposal of sewage and municipal solid waste.

In the context of a better integration between the natural and the built environment, the search for more balanced cities is a promising aspect in the urban planning process (Abrantes et al., 2016). Nature-based solutions (NBS) are being increasingly applied and they are closely related to other concepts, including the resilience to floods (Lafortezza et al., 2018). Cities are socioeconomic systems settled over the natural environment, which, in turn, is limited by its support capacity. In this sense, Rezende et al. (2019c) suggested to combine the definitions related to engineering and ecological resilience, considering the flood resilience as the ability of the city to resist the flooding over time, to adapt itself to suffer less damages, to continue functioning and providing general urban services, and to quickly recover from material losses. Therefore, increasing city flood resilience is related to increasing the capacity of resistance and response of the system over time, allowing a better coexistence of the city with this natural phenomenon, including adaptability challenges. Actions to increase the resilience converge to another important concept in the urban drainage discussion: the urban design sensitive to the water presence, which brings a multidisciplinary approach involving physical, institutional, legal, technical, and socioeconomic aspects. The water sensitive urban design aims to integrate the water in the landscape, enhancing its presence, taking advantage of opportunities for urban and natural revitalization, increasing biodiversity and recovering river ecosystems and hydrological functions, controlling floods, and always considering the need for the community participation and the construction of a legal and institutional framework to ensure its application (Brown et al., 2009). Measures related to sustainable urban drainage (Goulden et al., 2018) and low hydrological impact development (Fletcher et al., 2014), as well as actions derived from the river restoration approach (Nardini & Pavan, 2012) can be articulated in the construction of water sensitive cities.

Gusmaroli et al. (2011) proposed an ecosystem approach for rivers in urban areas to broaden the concept of *Waterfront Design*. This proposal seeks to value the contact between urban and water bodies, reintroducing the latter in the cityscape, for a wider possibility of uses, supporting urban and environmental values to reconnect the city with nature. This approach has the potential to introduce the concept of river restoration for an effective environmental improvement, looking to the city as living organism in constant transformation and, therefore, being able to modify and adapt itself. Incorporating of the concept of environmental sustainability rethinking the city growth opens a diverse set of opportunities to be explored as integrated solutions in a multidisciplinary context.

In this context, this chapter discusses the concept of resilience and aims to present the possibilities of integration between Hydraulic Engineering, Architecture and Urbanism, towards water sensitive and functional cities. The combination of urban fabric and river corridor actions join efforts towards more sustainable and functional cities.

2 Flood Risk and Its Relation to Resilience

In engineering, the risk is usually related to the occurrence of a hazardous event, with a certain probability, and its consequences over the exposed elements of a system (Sayers et al., 2013). The hazard refers to a dangerous situation that can harm or threaten the existence or interests of people, properties or the environment (UNISDR, 2009). The consequences over a system can be further subdivided, since it depends on the vulnerability of the affected elements and on their ability to react and return to the reference state, being this second part usually associated with the concept of resilience (Andersson, 2006; Godschalk, 2003; Jha et al., 2012; Prasad et al., 2009; Vale & Campanella, 2005). Moreover, the vulnerability is composed by the intrinsic susceptibility of an element to suffer damage and the value of the exposed element. When discussing floods, they are usually classified as natural disasters. However, the flood hazard is not only related to a natural cause. The source event that triggers flood disasters corresponds to an intense rainfall of a given return period, translating the probability of its occurrence. However, the simple occurrence of this rainfall event does not determine the hazard, which will also depend on how this event interacts with the watershed and is transformed into runoff and, consequently, in flooding discharges. In this context, the watershed plays a key role in this process.

Therefore, considering this discussion and adapting Sayers et al. (2013) definition, the risk can be divided into three basic components. The first one refers to the probability of occurrence of an event; the second, refers to the consequences and depends on the level of exposure of the system and its susceptibility to damages; and the third is associated with the ability to resist, react and recover. In this way, the risk is a function of hazard, vulnerability, and resilience. In a slightly simpler way, one can define the risk as the product of the occurrence of a reference flood and the consequences that it can cause (Aerts et al., 2009).

Flood impacts refer to all types of damage with detrimental effects on people, health, property, infrastructure, ecological systems, industrial production and economy (Machado et al., 2005, Messner et al., 2007). It is possible to classify these consequences in tangible or intangible, according to how easy it is to monetarily define the losses, and direct or indirect, regarding the contact (or not) with floodwaters.

Tangible damages are those with well-defined economic value, such as physical damage to buildings (structure and content). However, the damages to health, fatalities and environmental impacts are classified as intangible due to the difficulty (or even impossibility) to transform them into a monetary value.

Direct damages result from direct contact with floodwater and, above all, refer to the physical deterioration of goods and people. In turn, the main indirect damages result from physical and economic disturbances to the productive system, as well as emergency costs due to flooding, for example. They also include the costs for cleaning and emergency services, loss of profit, blocking of transportation system, interruption of telecommunication services and loss of property value. Indirect damages can affect areas significantly larger than those directly affected by floods.

The International Disaster Reduction Strategy (ISDR) defines resilience as follows:

> *The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions* (UNISDR, 2009).

Since the magnitude of threats can change over time, high resilience relates to the ability to adapt to a dynamic environment and continue to provide the essential services for which the system was originally designed. Therefore, a resilient city must face future uncertainties and challenges still performing adequately (Male, 2009).

3 Resilience Concept in Engineering and Ecology

Urban floods are consistently increasing in occurrences and intensity, causing several losses in cities around the world. These losses are becoming more important each day and human activities play a key role in aggravating of these consequences

(Nazif et al., 2021). Land use changes affect the natural water cycle, urban agglomerations become more exposed to greater flood hazards. Consequently, as a response to these threats, there is a trend for controlling floods giving way to managing flood risks (Thomas & Knüppe, 2016; Treby et al., 2006). Additionally, the definition of floods as natural hazards is gradually migrating to an interpretation of socio-natural hazards (UNISDR, 2009), since the occurrence of floods goes beyond their natural source and arises from the interaction of rainfall events with overexploited land and environmental resources (in the occupied watershed), in circumstances where human activity is present and relevant.

Traditional urban planning process frequently focuses on modifying and controlling nature, similarly to what occurs in the engineering approach to solve infrastructure problems and provide urban services. It is common to focus on "building something" and, therefore, the open spaces and their dynamics (including water dynamics) tend to be not fully recognized as drivers for planning a healthy city, mainly in developing countries (Tardin, 2017), where intense urban development occurred later and in a faster way, without proper planning and control. Since the natural environment shelters the city, recognizing that the natural supporting capacity should limit urban growth is necessary. In this way, urban planning should establish a positive or neutral balance between built-up areas and natural open spaces (Miguez et al., 2018b).

The supporting capacity is defined by Schneider et al. (1978) as the capacity of a system to accommodate the population growth and physical development, and related human activities, without significant degradation or damage. This concept is important in the resilience discussion since limited carrying capacity can aggravate a lack of resilience.

Born in the materials science, the concept of resilience originally indicated a material property to absorb energy in the elastic region, returning to the initial form when the cause of its deformation ceases. Despite its origin, other areas of knowledge came to use the term resilience with slight adaptations in its definition according to their particularities.

The pioneer work of Holling (1973) brought together resilience and ecology, discussing the conceptual aspects of resilience of ecological systems. Later, Holling (1996) also presented a discussion comparing the engineering resilience and the ecological resilience. According to this author (ibid.), the engineering resilience is focused on stability, resulting in a static equilibrium. The main features of resilience are the capacity to resist disturbance and the recovery velocity, returning to the previous system condition. On the other side, the concept of a dynamic equilibrium is accepted in the ecological resilience. It represents the capacity to assimilate a certain disturbance and consequently change (and evolve), struggling to survive. There is no returning to the previous state in this context—adapting to a new configuration is the key feature. In his comparison, Holling (ibid.) described the engineering resilience as "*efficient, constant and predictable*", while ecological resilience relied on the "*persistence, changing and unpredictability characteristics*".

Pendall et al. (2010) described two common approaches that lay the basis for the concept of resilience through different areas of knowledge, ranging from psychology to engineering:

1. The equilibrium analysis, which would consider the recovery of a normal state (in a single equilibrium system) or the shift to a new adapted normality (in a multiple equilibrium system).
2. The analysis of complex adaptive systems, underlining how the various elements of a system interact to create the dynamic experiences that can make a system adaptive.

Besides, resilience can be computed from two different perspectives: as a measure of a system capacity in a pre-stress situation, which is related to how well-prepared the system is to respond and recover from a disaster; or, in a post-stress situation, as a representation of how the system responds and recovers from a disaster (Foster, 2011).

Liao (2012) highlighted that the current definitions of community resilience usually remain in the concept of engineering resilience. However, ecological resilience could be more suitable to deal with flood risks, due to the complex character and diversity of a city and the natural environment complexity. The application of ecological resilience can be further supported by the fact that modern cities are still vulnerable to flood hazards despite the implementation of traditional flood control measures (Liao et al., 2016), accumulating significant losses over time. Although flood management has been evolving, these authors (ibid.) emphasized that the flood control paradigm persists in attempting to subjugate nature to human's own needs.

It is also important to mention that the flood control measures cannot cope with all flooding possibilities, which means that it is always possible that a rare storm can exceed the design standards, or even that a structural failure may occur. Additionally, unrestrained urban growth may lead to obsolescence of the drainage systems and uncontrolled urban sprawl may be not accompanied by the proper infrastructure provision. Recognizing that it is not feasible to completely avoid (or completely mitigate) floods, Moe and Pathranarakul (2006) and Schanze (2006) suggested to move towards the "integrated flood risk management" approach, in which non-structural measures are considered the preferable solutions (especially in early planning) and the watershed scale is used for planning and management purposes (Parker, 2000). Non-structural measures are more effective when taken early in the planning process, but structural measures are useful to reorganize flood patterns if a drainage system fails in providing flood safety conditions to a city. In any case, non-structural measures can complement the use of structural ones.

The discussion involving engineering and ecological resilience can eventually converge in the city context. Urban flood risks result from an exposed *socio-ecological hybrid system*, that considers the city as a complex system in which flood risks may lead to socio-natural disasters, as previously defined. A continuous feedback process is needed to achieve resilience in the urban system, incorporating the adaptation concept in the discussion (Rezende, 2018), even if resilience is seen by engineering lens. This continuous feedback process brings together the engineering and ecological resilience approaches since lessons can be learnt from past flood disasters allowing to face the next similar events by adapting and improving the system to be less sensitive compared to the original status. Therefore, the engineering approach will promote a step forward, moving from an original reference state to an improved reference state when feeding back a process.

Besides, since the city is a hybrid socio-ecological system, elements of engineering and ecological resilience approaches must be considered. Let's consider a city extremely altered by anthropogenic actions and suffering severe flooding consequences because of the modifications introduced in the natural environment. It would not be reasonable to live with this situation adapting to accept uncontrolled and increased flows. Alternatively, it would be fair to restore the hydrological functions modified by urban growth to the maximum possible extent, minimizing floods, but not in the traditional sense. It is not expected any kind of stability that "lasts forever". Recovering natural water cycle dynamics and reversing harmful effects introduced by the urbanization itself (similarly to approximating to the engineering resilience) should be incorporated in this approach, allowing a functional city and considering the adaptation approach (similarly to what is stated by the ecological resilience) to face residual risks. In this sense, the ecological resilience could prevent important damages when severe flooding conditions could threaten the city (Miguez et al., 2018a).

Urban planning guidelines represent an opportunity to introduce integrated flood risk management in order "to build the city" according to water dynamics and driven by them (Carmon & Shamir, 2010, Shannon, 2013). Respecting "water spaces" and recognizing water dynamics is the first step to prepare the territory to urban development.

4 Flood Resilient Cities

The United Nations International Disaster Reduction Strategy (UNISDR, 2012) defines "*a disaster resilient city*". The importance of proper infrastructure and services provision, and no housing deficit are the first points highlighted. Then an inclusive, competent and accountable local government should be concerned about sustainable urbanism and committed to build capacities to respond to a natural disaster. Risks must be known, and information disseminated. The planning process should be participative, and people empowered. At last, anticipation, mitigation, monitoring and responsiveness are key elements in the process.

Differentiating flood resilience from flood resistance is noteworthy. Both are important and correlated concepts but playing different roles. Flood resistance usually represents a defined capability to avoid floods, and it is mainly related to flood control strategies. Most projects use this concept when establishing a threshold of protection. Alternatively, flood resilience refers to the city capacity to adapt itself to live with flood events, with minor losses (even if failing) and enhancing recovery.

Note that if a project is developed to provide resistance and resilience, the solution would prevent floods related to a pre-defined threshold and account for minimal damages in the occurrence of an exceptional event. This reasoning could be an important improvement in the design process.

McBain et al. (2010) state that there are two major lines of action to improve city resilience to flooding:

1. Preventing the city from directly contacting floodwaters through zoning ordinances that forbid construction in flood prone areas or applying the concept of flood-proof buildings.
2. Diminishing the flow generated by rainfall-runoff transformation and reorganizing the resulting discharge patterns, using infiltration and storage measures distributed over the watershed.

Mebarki et al. (2012) affirmed that the resilience of a territory (neighbourhood, city, etc.) depends on the residual capacity, survival and recovery functions of the components and their interactions after a disastrous event. Therefore, improving resilience also requires the enhancement of the structural bearing capacity of the constructions.

Wong and Brown (2009) state that the concept of resilience to flood implies designing a city to face the consequences of increasing risks and reducing potential damages. Marsalek and Chocat (2002) provided an interesting panel regarding urban stormwater management, joining contributions of 18 countries. They reported the tendency to shift flood control approach from traditional hard infrastructures to green infrastructures.

There are several possibilities for discussing the city resilience and strategies for its improvement, although this theme remains largely non-practised in contemporary urban planning (Ahem, 2011). Several aspects compose the urban resilience, including, for instance, multi-functionality, redundancy and modularization, multiscale analyses, and adaptive planning and design (ibid). Note that redundancy increases the possibilities of responses, given that if one measure fails, another one is in place to minimize damages.

Therefore, a flood resilient city needs to face its growth and future challenges (considering the possibility of rare rainfall events, climate changes or unpredicted urban development) suffering minor damages in the process by reducing the total risk.

5 Design Solutions for Flood Resilient Cities

Urban drainage management is shifting from traditional measures, aimed at fast and efficiently conveying waters, to sustainable actions that recognize the natural hydrological functions and seek compensatory alternatives for city growth. Ahem (2011) stated that sustainable urban systems are moving from strictly fail-safe aims to consider fail-to-safe possibilities, moving towards the concept of resilient cities.

Considering the American and the Australian experiences, Roy et al. (2008) discussed the potentials and constraints to sustainable urban stormwater management stating three basic premises:

1. *The natural ecological structure and function of receiving water bodies should be maintained by a sustainable management of urban stormwaters.*
2. *There are available technologies to support the recovering of natural water cycle functions and to reduce stormwater pollutants.*
3. *Sustainable urban stormwater management must be carried out in the watershed scale.*

This approach incorporates benefits both to nature and urban health (Fletcher et al., 2014). It is important to understand the natural water cycle functioning and use this knowledge to design solutions integrated with nature, instead of simply converting nature to urban aims. In this sense, this process should emphasize source control distributed throughout the watershed. According to Andoh and Declerck (1999), distributed measures are less sensitive to operational failures, since when one or a few measures of small dimension fail, their functions can be assumed, at least partially, by other distributed measures. On the other hand, if a great engineering work fails (like a dam or a dyke, for instance), protecting a large area, the negative consequences will be significant, and the great volumes involved in this case of failure will not be rearranged among other elements of the system. Another important question raised by these authors is that distributed measures are less expensive than traditional canalization costs. The cost reduction varies from 25 to 80%, tending to be more expressive in flat areas (ibid).

Another study, developed by Ahiablame et al. (2012), presented an extensive review of sustainable drainage practices, showing that they are effective both in the watershed scale and lot scale.

Thus, it is possible to state that distributed measures can contribute both to the city resistance and resilience to floods, due to their capability to reorganize flow patterns, preventing (or reducing) flooding effects, and to cause fewer damages when failing under unexpected conditions that eventually can overcome the design standards. Among these measures, in different scales, it is possible to mention some examples:

1. Use of urban open spaces with storage functions, also creating opportunities to revitalize degraded urban areas and recover green permeable areas (Miguez et al., 2007; Woods-Ballard et al., 2007).
2. Use of on-source control measures, including small scale actions in urban lots and streets, favouring detention and infiltration—in this category, rain barrels (Prince George's County, 1999), green roofs (Stovin, 2010) and rain gardens (Davis, 2008; Roy-Poirier et al., 2010) appear as possible alternatives.
3. Use of river restoration approach, seeking a better ecological quality to the river system, and offering storage volumes in the related fluvial space along its flood plains (Nardini & Pavan, 2012; Nilsson et al., 2007; Shields et al., 2003).

This last approach seeks to put the river in a good environmental status and involves a series of integrated factors, such as hydrology, morphology, water quality and the presence of healthy river ecosystems (CIRF, 2006). Besides, river restoration searches for a more harmonic balance between human needs and nature dynamics, providing sustainable opportunities to deal with the hydraulic risk. It explores the territory opportunities, rethinks land use, and reorganizes settlements and infrastructure to make room for rivers, reconnecting them to their flood plains.

However, in urban areas, the watershed is already usually heavily modified and degraded, in a way that the river restoration approach is limited, and only partial results can be obtained (Bernhardt & Palmer, 2007; Clifford, 2007; Dufour & Piégay, 2009; Martín-Vide, 2001; Prior, 2016; Rozos et al., 2013; Zhao et al. 2007). In this case, built-up restrictions and lack of open spaces are significant constraints. However, non-consolidated urban areas can offer the opportunity to "build the city" in a more balanced way, considering water dynamics (Tardin, 2013). Once working in a very anthropized territory, non-developed spaces can represent the opportunity to integrate flood risk management and alternative urban planning guidelines (Miguez et al., 2018b; NRC, 1992).

Defining spaces to preserve water dynamics in urban planning and providing the proper space required to accommodate this process is a key point that is gaining increasing interest (Benedict & McMahon, 2006; Firehock, 2015; Forman, 1995; McHarg, 1969; Simensena et al., 2018, Pietersen et al., 2013; Steiner, 2014; Watson & Adams, 2011). The general idea of this approach is to give space to water (Tardin, 2017) in urban planning, by recognizing its dynamics and providing proper spaces in built-up areas. This approach also implies learning to live with water (Liao, 2012; Steiner, 2014) in a socio-ecological system. Therefore, some principles related to biophysical attributes should be encompassed in the urban planning process: (1) by conserving water ecosystem as much as possible (Benedict & McMahon, 2006; Firehock, 2015) and (2) by seeking urban benefits while keeping the city working during and after flood and avoiding losses (Miguez et al., 2018b; Shannon, 2013).

6 Methods to Measure Resilience

As discussed in the previous sections, resilience involves a complex concept, which reflects in the relatively low number of mathematical models that calculate and quantify the resilience in a tangible way, demonstrating the difficulty of capturing, in essence, its quantitative value. However, this is a picture that has been changing in the past recent years, with more works appearing with this aim, because of the relevance of the discussion.

Kotzee and Reyers (2016) emphasized the importance of moving towards approaches that manage a system's flood resilience by understanding and managing the vulnerability constraints and adaptability aspects. Within this context, these authors (ibid.) presented a quantitative method, in which 24 indicators associated to floods and relevant social, ecological, infrastructural and economic aspects (e.g.

infrastructure, soil retention, income disparity, land use diversity, among others) were chosen to compose an index to measure and map the distribution of resilience over the territory.

Razafindrabe et al. (2015) proposed an approach to measure and evaluate the community resilience to flood disasters based on a set of biophysical and socioeconomic indices. These authors concluded that to improve resilience, it is necessary to legally reinforce the institutional capacity of administrative units for the disaster risk reduction initiatives through land use development plans. On the other hand, Mugume et al. (2015) presented an approach named Global Resilience Analysis (GRA), which analyses the system performance when it is subjected to many different scenarios of failure, instead of using the threats as the object of analysis. In this approach, the magnitude of the failure and its duration are combined into a resilience index that quantify the system residual functionality at each stage of failure, both for the existing system and for the adaptation strategies tested.

In another attempt to measure resilience, Miguez and Veról (2017) proposed an integrated Flood Resilience Index called FResI to assess the city response when facing an adverse future that was neither foreseen nor considered in the design process. This index was proposed to measure the integrated resilience response of an interest area, by comparing present and future risk assessment, allowing to hierarchize a set of proposed flood control design alternatives, according to their behaviour over the considered horizon of time.

Later, an evolution of the FResI was proposed, offering the Urban Flood Resilience Index—UFRI (Rezende, 2018; Rezende et al., 2019a, c), intending to support the spatialized discussion on residual risk and resilience. This index combines three subindexes representing the main properties of resilience: the system resistance, the functional recovery capacity and the material recovery capacity. It is built as a multicriteria quantitative index ranging from 0 to 1, using a normalized common scale for all indicators. More information about this index and its subindex is presented in the next section, where the UFRI is applied to an illustrative case study.

Some other works can illustrate this discussion. There are efforts to measure vulnerability focusing on social aspects through approaches that also tend to be directly or indirectly related to resilience. For instance, Kors et al. (2014) presented a social vulnerability index, which interpretation is somehow related to low resilience, given that the higher the social vulnerability index, the lower the resilience. On the other side, Tsakiris (2014) proposed to measure the improvement in the risk control process by modelling the reduction in system vulnerability as the integral of the avoided losses; therefore, using economical metrics. Some of the existing methods to measure resilience are summarized in Table 14.1, to illustrate this discussion.

The purpose of this section is to show the reader that, at least to a certain extent, resilience can be described by mathematical models. Therefore, it can be considered quantitatively to support planning and design decisions. It is quite difficult to imagine a complete model representing flood resilience, but it is possible to specify the main interests related to a certain case and then process a quantitative resilience value, although never forgetting the simplified hypotheses adopted to develop the model and their consequent limits of representation, to use the results consistently.

7 Case Study: Canal do Mangue

This section provides an example of a resilience spatial analysis for the Canal do Mangue catchment, in Rio de Janeiro, Brazil, as presented in Fig. 14.1. The main aim of providing this example is to illustrate a quantitative approach to measure resilience in the flood control planning and design activities. It is not expected to exhaustively cover the matter of flood resilience and its role in planning and designing flood resilient cities—this is only a step forward fostering this discussion.

This watershed is highly urbanized, suffers frequent flooding and covers an area of 45 km^2, containing parts of the downtown and the traditional neighbourhoods of Grajaú, Andaraí Tijuca, Vila Isabel, Maracanã and Rio Comprido. The main watercourses are the Joana, Maracanã, Trapicheiros, Comprido and Papa-Couve Rivers. The Canal do Mangue catchment receives all the five main rivers and outflows into the Guanabara Bay, through an artificial channel that gives name to the watershed.

This catchment has suffered extensive anthropic changes, aiming at substituting wetlands and mangroves by dry areas, to allow the urbanization in Rio de Janeiro. Consequently, the stormwater drainage systems were significantly modified, limiting rainwater retention, and conveying increased discharges through artificial channels.

Although most of the population living in the watershed may be classified as being representative of an intermediate social status, according to the most recent national demographic census (IBGE, 2010), part of the urban occupation refers to informal substandard settlements, denominated "*favelas*" (slums), which tend to contribute to higher flooding vulnerability. This population has no access to adequate infrastructure and services and almost no recovery capacity since their income is usually fully committed to basic goods. Therefore, even lower intensity events (and, hence, higher frequency) are critical, resulting in irrecoverable damage to these people (Guimarães & Miguez, 2020). The Canal do Mangue catchment is already consolidated, making it almost impossible to remove the people and properties from flood risk areas (Rezende et al., 2019b). Within this context, distributing sustainable urban drainage measures on the watershed, from the local scale to the basin scale, can be an alternative to traditional drainage solutions, avoiding the implementation of greater channels or pipes and bringing benefits to quality of life, as a side effect, by fomenting green spaces and urban revitalization.

Two sets of interventions were designed, as examples of possible lines of action, one with concentrated large reservoirs and the other with distributed minor reservoirs (Rezende et al., 2019a, c). Therefore, three scenarios were simulated and compared:

Table 14.1 Methods to measure resilience

Method	Objective	Indicators	Case Study	References
Flood Vulnerability Index (FVI)	Identify and develop action plans to deal with floods by selecting measures to reduce vulnerability at local and regional levels	28 indicators for the sub-catchment FVI equations (e.g. population density, proximity to river, land use, topography and flow velocity)	The Tisza, Bega and Timis sub-catchments, in the Danube River Basin, the Neckar sub-catchment in the Rhine River Basin and the Mun sub-catchment in the Mekong River Basin	Balica et al. (2009)
Flood Risk Index	Provide a practical urban flood risk assessment with the potential to stimulate a multidisciplinary or multi-sectoral way of thinking and a comprehensive GIS-based flood risk map that can be used by local stakeholders	12 indicators related to hazard, vulnerability and elements at risk (e.g. flood probability per building block, proportion of buildings with poor construction material per building block, number of people, infrastructure and buildings)	La Reina and Peñalolén (Santiago de Chile, Chile)	Müller (2013)
Flood Risk Assessment Index System	Establish appropriate model for reflecting the impact of urbanization on flood risk and put forward effective countermeasures for flood control and disaster mitigation in urbanization areas	12 indicators related to hazard, vulnerability and elements at risk (e.g. annual maximum daily rainfall, city area ratio, per capita fixed assets, flood control standard and post-disaster reconstruction capability)	Yangtze River Delta region (China)	Li et al. (2013)
Global Resilience Analysis (GRA)	Quantify the residual functionality of the system at each failure level	(1) Total flood volume; (2) Total inflow into the system; (3) mean duration of nodal flooding; (4) Total simulation time	Nakivubo catchment (Kampala, Uganda)	Mugume et al. (2015)

(continued)

Table 14.1 (continued)

Method	Objective	Indicators	Case Study	References
Resilience Index	Identify more fragile areas that require more attention in the flood risk management process	(1) flood depth; (2) density of exposed household; (3) buildings affected; (4) recovery capacity; (5) flood duration	Joana River sub-catchment (Rio de Janeiro, Brazil)	Tebaldi et al. (2015)
Flood Resilience Index (FRI)	Categorize flood effect under scope of resilience with urban functions and services and quantify flood resilience	91 indicators related to social, economic, institutional, physical and natural dimensions (e.g. available resources, increase of households, existence of flood management plans, existing structural measures protection and drainage capabilities)	Barcelona (Spain), Beijing (China), Genoa (Italy), Hamburg (Germany), Nice and Châtelaillon-Plage (France), Rethymno (Greece) and Taipei (Taiwan)	Batica and Gourbesville (2016)
Flood Resilience Index	Measure and map the spatial distribution of flood resilience levels	24 indicators related to floods and its relevant social, ecological, infrastructural and economic aspects (e.g. water infrastructure, sanitation infrastructure, soil retention, income disparity, land use diversity)	George, Knysna and Bitou municipalities (South Africa)	Kotzee and Reyers (2016)
Flood Resilience Index (FReSI)	Measure the city's response in terms of flood risk control when facing a rare adverse future, not foreseen in the project or even exceeding its horizon	(1) Flood depth; (2) speed factor; (3) permanence factor; (4) household density; (5) income; (6) traffic; (7) inadequate sanitation	Dona Eugênia River Basin (Rio de Janeiro, Brazil)	Miguez and Veról (2017)

(continued)

Table 14.1 (continued)

Method	Objective	Indicators	Case Study	References
Resilience to Emergencies and Disasters Index (REDI)	Classify and rank the relative resilience capacity embedded in localized urban systems	24 indicators related to social infrastructure and community connectivity, physical infrastructure, economic strength and environmental conditions (e.g. population density, distance to nearest fire station, lack of economic diversity and building density)	New York (United States)	Kontokosta and Malik (2018)
Spatial Decision Support System (DS3) Model	Assess and map resilience levels to floods considering critical infrastructures networks as urban risk propagators	Indicators related to social, urban and technical aspects (e.g. age of population, median of salary, urban density and urban networks)	Hamburg (Germany) and Avignon (France)	Serre and Heinzlef (2018)
Urban Flood Resilience Index (UFRI)	Assess resilience in a distributed way over the watershed and considering the residual risk over a project horizon	(1) Building exposure; (2) urban infrastructure exposure; (3) flood depth; (4) relative value; (5) social vulnerability; (6) aid access difficulty; (7) mobility risk	Canal do Mangue catchment (Rio de Janeiro, Brazil)	Rezende (2018), Rezende et al. (2019a, c)

1. C0—reflects the current state of flooding in the Canal do Mangue catchment, without interventions.
2. C1—considers a set of concentrated large interventions, based on the proposals of the Urban Water Management Master Plan of Rio de Janeiro City, published in 2010.
3. C2—provides distributed interventions over the watershed, based on a previous study, the Canal do Mangue Flood Control Project, presented in 2000, but not implemented.

The modelling results of the scenario C0 confirmed the current critical situation, with more than 40% of the watershed flooded with depths greater than 15 cm for a 25-year event, which is the official reference event for design purposes in the city. A significant part of the catchment (almost 44%) corresponds to upstream hills, explaining the absence of flooding. Flood depths above 50 cm, which are

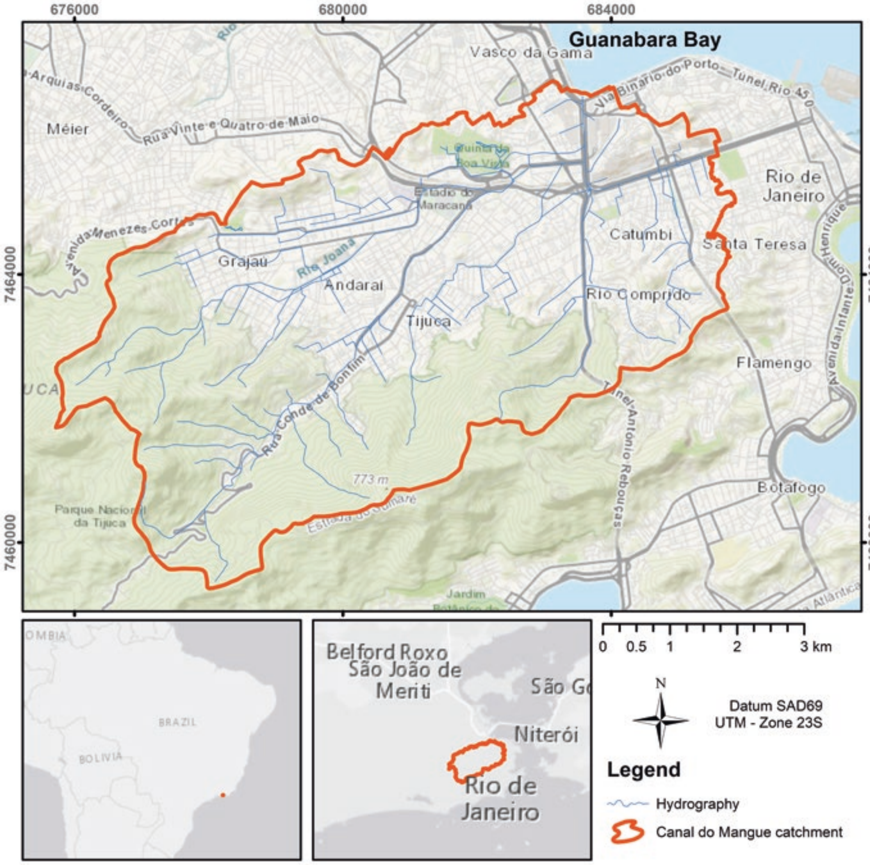

Fig. 14.1 The Canal do Mangue catchment (Rezende et al., 2019c)

considered cause for damaging buildings and urban facilities, covered about 12% of the watershed. It is important to stress the importance of mathematical models as predictive tools to identify areas exposed to one or more hazardous events (Alberico & Petrosino, 2015).

The scenario C1 introduced four large reservoirs that were foreseen in the Urban Water Management Plan. Two of them are in the Joana River and other two are in the Trapicheiros Rivers. Additionally, a diversion of the Maracanã River into the Joana River and the subsequent diversion of the latter into the Guanabara Bay were also proposed. The reservoirs in the Joana River watershed have volumes of 143,000 m^3 and 50,000 m^3 and were able to respectively reduce the flow peak of a 25-year event by 50% and 67%. The reservoirs in the Trapicheiros River watershed have lower volumes, of 70,000 m^3 and 18,000 m^3, due to limited urban spaces. The former reduced the flow peak of a 25-year event by approximately 36%, while the latter produced minor impacts on the river dynamics—this reservoir intended to control minor drainage overflows in a lowland area. It promoted a great reduction in the flood depths of a local critical region (around "*Praça da Bandeira*" *Square*).

The diversion of Maracanã River had a significant impact on the reduction of its outfall. The diverted peak flow exceeded 50 m^3/s, reducing by 72% the peak discharge of the Maracanã River. Finally, the diversion of Joana River to the Guanabara Bay produced a significant impact on the hydraulics of the whole system. Considering the 25-year event and the concentrated interventions proposed in the scenario C1, the flood depths above 50 cm reached less than 7% of the watershed, improving flood control, although not solving everything.

Following a different approach, the scenario C2 proposed distributed interventions throughout the watershed, from the foothills to the urban plains and intended to provide a more sustainable alternative to manage storm waters. A set of 18 upstream reservoirs at the foothills with a total volume of 203.860 m^3 was proposed. Additionally, 31 reservoirs in public squares were added to C2 scenario, providing an extra storage capacity of 120.697 m^3. In addition to the reservoirs, permeable pavement in large parking lots and open impervious areas was also considered. Besides, an additional intervention was considered in the Trapicheiros River, opening underground channelized reaches of the river. Finally, the diversion of the Maracanã River into the Joana River and the diversion of the latter into the Guanabara Bay were also considered here. Flood depths above 50 cm in the scenario C2 covered less than 4% of the watershed, representing a lower percentage than those of the previous scenarios C0 and C1.

The Urban Flood Resilience Index is applied to the case study (Rezende et al., 2019a). This index combines three properties of resilience: the absorptive, the adaptive and the restorative capacities. The first one is represented by a subindex related to the resistance capacity; the second, to the system functional capacity; and the last one, to the material recovery capacity.

The general arrangement of UFRI is shown in Fig. 14.2 and its formulation is shown in Eq. (14.1), with the composing indicators described in Table 14.2. The detailed formulation of all indicators can be found in Rezende et al. (2019a), but it is not the main objective here.

$$\text{UFRI} = a\cdot\left(1-\text{Si}_{\text{R}}\right)+b\cdot\left(1-\text{Si}_{\text{C}}\right)+c\cdot\left(1-\text{Si}_{\text{F}}\right) \tag{14.1}$$

where:

Si_{R} → Risk to Resistance Capacity Subindex
Si_{C} → Risk to Material Recovery Capacity Subindex
Si_{F} → *Risk to System Functional Capacity Subindex*
a, b, c → Weights of each term

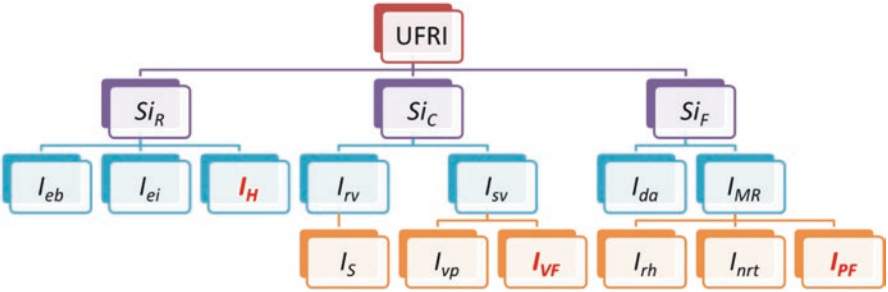

Fig. 14.2 Hierarchical arrangement of Urban Flood Resilience Index (UFRI)

Table 14.2 Composition of the Urban Flood Resilience Index (UFRI)

Subindex	Indicator	Sub-indicator
Si_R Subindex of risk to resistance capacity	I_{eb}—Building exposure	
	I_{ei}—Urban infrastructure exposure	
	I_H—Flood depth	
Si_C Subindex of risk to material recovery capacity	I_{rv}—Relative value	I_S—Building susceptibility
	I_{sv}—Social vulnerability	I_{vp}—Vulnerability of people
		I_{VF}—Velocity factor
Si_F Subindex of risk to system maintenance capacity	I_{da}—Aid access difficulty	
	I_{MR}—Mobility risk	I_{rh}—Road hierarchy
		I_{nrt}—Non-rail transport service
		I_{PF}—Permanence factor

7.1 *Subindex of Risk to Resistance Capacity (Si_R)*

The subindex of Risk to Resistance Capacity represents the resistance to damage. It considers three indicators in its formulation: (1) the building exposure indicator—I_{eb}; (2) the urban infrastructure indicator—I_{ei}; and (3) the flood depth indicator—I_H. Eq. (2) shows the subindex calculation.

$$\mathrm{Si_R} = \left[a \cdot \left(I_{eb}^{\ n1}\right) + b \cdot \left(I_{ei}^{\ n2}\right)\right] \cdot I_H^{\ n3} \tag{14.2}$$

7.2 *Subindex of Risk to System Functional Capacity (Si_F)*

The subindex of Risk to System Functional Capacity represents the ability of continuing to provide services during flooding events.

The mobility risk indicator, combining flood information with road hierarchy railway stations, indicates the impact of flooding in the traffic of vehicles and people. It also considers the impact on the rescue services, by identifying flooding in the squares of fire department location and their surroundings, indicating potential difficulties in the organization of emergency actions. Two indicators compose this subindex: (1) the aid access difficulty—I_{da}; and (2) the mobility risk—I_{MR}. The general formulation is given by Eq. (14.3).

$$\mathrm{Si}_{\mathrm{C}} = \left(I_{\mathrm{MR}} \cdot a\right) + \left(I_{\mathrm{da}} \cdot b\right) \tag{14.3}$$

7.3 Subindex of Risk to Material Recovery Capacity (Si_C)

Finally, the subindex of Risk to Material Recovery Capacity represents the socioeconomic aspects of the flood risk, using a "relative value" that correlates the potential damages caused by floods and the income of the population directly exposed. In its composition, the relative value indicator (I_{rv}) and the social vulnerability indicator (I_{sv}) appear in the formulation presented in Eq. (14.4).

$$\mathrm{Si}_{\mathrm{C}} = \left(I_{\mathrm{rv}} \cdot a\right) + \left(I_{\mathrm{sv}} \cdot b\right) \tag{14.4}$$

Therefore, considering the previous brief explanation, the Urban Flood Resilience Index can be mapped for the three scenarios proposed for the Canal do Mangue catchment case. The spatial results, presented in Fig. 14.3, show a better system response after implementing the flood control measures for both projects (C1 and C2). Green colours represent higher resilience values, while red ones indicate very low resilience. As expected, the current scenario (C0) has extensive "low resilience" areas, since the exposure, vulnerability and hazard indicators are high. The proposed interventions significantly reduced flooding. For the scenario C2, this reduction is more effective due to the wider distribution of stormwater detention measures over the watershed.

The adoption of more concentrated measures (scenario C1) increased the extension of areas classified as "very high resilience" by 33%, while the "very low resilient" areas were reduced by 77%. When considering the distributed measures (scenario C2), the "very high resilient" areas increased by 41%, while those classified as "very low resilient" areas were reduced by 87%. However, in both design scenarios, the permanence of many places with low or moderate resilience indicates the criticality of flooding problems in the Canal do Mangue catchment. Figure 14.4 shows these tendencies.

Another approach that may indicate the resilience status of the same urban watershed was applied to the same case study for comparison and consequent validation of the results. Rather than focusing on several indicators, this method incorporates long-term effects considering the socioeconomic fragility of the catchment

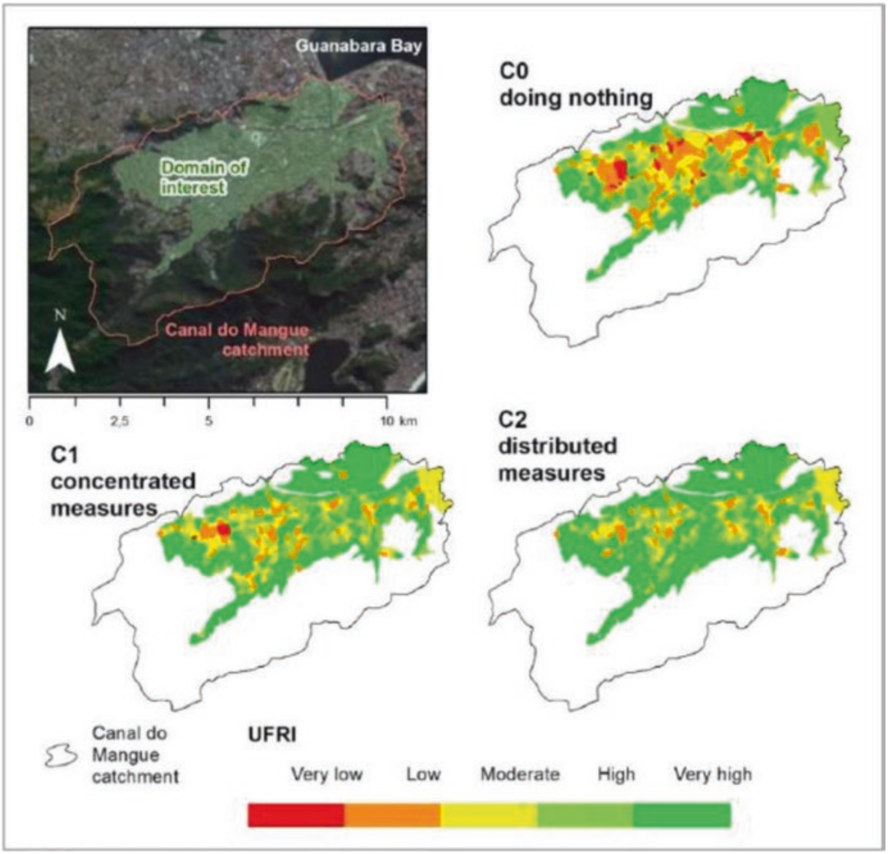

Fig. 14.3 Spatial results of the index for a 25-year event (Rezende et al., 2019c)

when successive flood events occur through an assessment of the population recovery capacity (Guimarães, 2016; Guimarães & Miguez, 2020).

This approach defines a horizon of analysis and a set of reference return periods as a first step. The method proposes the adoption of a horizon of 50 years and reference return periods of 1, 2, 5, 10, 25, 50, 100, and 500 years to limit the sample space by discretizing the continuous probabilistic distribution using punctual probabilities of occurrence. Then, random draws of the reference return periods were used to create sequences of 50 years of events, considering each given event's individual probability of occurrence. For constructing an "average sequence", representative of the most likely situation, events were drawn to compose 10,000 sequences and then organized according to their degree of criticality. Considering the middle tertile, the mean number of events of each return period were calculated and randomly positioned along the horizon of analysis.

Flood simulations were performed for each reference return period with the support of integrated hydrological and hydrodynamic modelling. Then, the damage

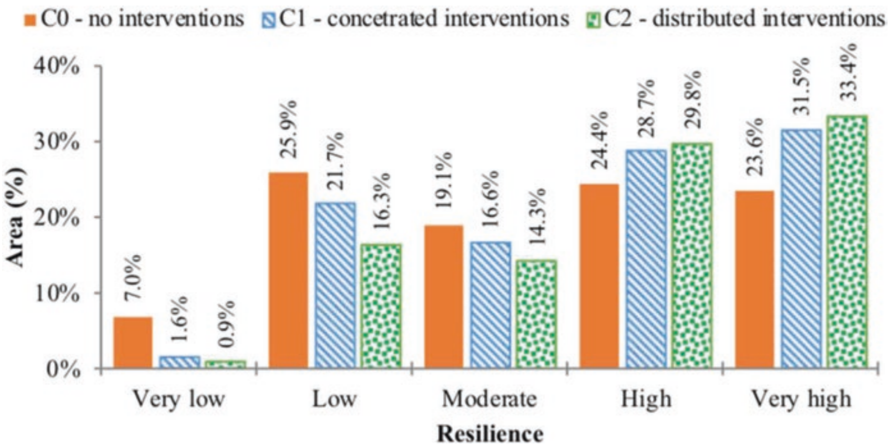

Fig. 14.4 Distribution of resilience classes in the percentage of the area of the interest domain (Rezende et al., 2019c)

was estimated through a depth x damage curve adapted from a previous study (Nagem, 2008). This study considered the costs of waterborne diseases, residential damage, house cleaning, material damage to vehicles and diseconomies related to lack of mobility. However, according to the results, damage to homes (structure and contents) and vehicles accounted for approximately 96% of the total losses estimated. Besides that, these losses fall on the population shoulders and, therefore, can estimate the recovery capacity extent. For these two reasons, only residential damage and material damage to vehicles were considered. More details of damage estimation can be found in Guimarães and Miguez (2020).

Considering that this approach aims to analyse the socioeconomic fragility, it was proposed to compare the damages with the recovery capacity of the local population, which was defined as the monetary value that someone can invest to recover and/or replace damaged goods. This variable was based on the concepts of average monthly household income and minimum income required to sustain living.

Considering that the cost of living is equivalent to the minimum value of income required for basic needs, it is possible to calculate the percentage of disposable income for a family. When this percentage is equal to or greater than 100%, there is no capacity for recovery, since the whole value is committed to basic items indispensable for survival. If the percentage is less than 100%, the remaining income, called disposable income, can be used to replace flood-damaged assets.

By combining and comparing the damage estimation and the recovery capacity along the sequence of events developed in the first step, it is possible to understand the effects of successive floods through the recovery deficit, which represent the value still to be recovered, calculated according to the following equations:

$$\mathrm{RD}_1 = \begin{cases} 0, & \text{if } \mathrm{TL}_1 - \mathrm{RC} \leq 0 \\ \mathrm{TL}_1 - \mathrm{RC}, & \text{if } \mathrm{TL}_1 - \mathrm{RC} > 0 \end{cases} \tag{14.5}$$

$$RD_i = \begin{cases} 0, & \text{if } RD_{i-1} = 0 \text{ and } \mathrm{TL}_i - RC \leq 0 \\ \mathrm{TL}_i - RC, & \text{if } RD_{i-1} = 0 \text{ and } \mathrm{TL}_i - RC > 0 \\ RD_{i-1} + \mathrm{TL}_i - RC, & \text{if } RD_{i-1} \neq 0 \text{ and } RD_{i-1} + \mathrm{TL}_i - RC > 0 \\ 0, & \text{if } RD_{i-1} \neq 0 \text{ and } RD_{i-1} + \mathrm{TL}_i - RC \leq 0 \end{cases} \tag{14.6}$$

where:

RD_i = Recovery deficit in year *i*
TL_i = Total losses in year *i*
RC = Recovery capacity

A possible outcome of this approach is the analysis of the number of years in which a given area remains without fully recovering from damages, considering the proposed sequence of rainfall events. Figure 14.5 presents these results for the current scenario (C0).

Although this approach considers only an economic indicator, it gives evidence of the Canal do Mangue catchment's resilience, due to the long-term assessment. Therefore, public managers can use it to decide on the allocation and prioritization of resources in areas with higher socioeconomic fragility.

It is notorious that the areas identified as "*very low*" and "*low*" in the results of the UFRI (Fig. 14.2), for the current scenario, coincide with the places where the population has greater difficulty for recovering from losses, as shown in Fig. 14.5. Comparing these maps, one can conclude that, despite using different methodologies, the similarity of the results allows to validate both analyses and identify the least resilient urban areas of the watershed. Moreover, the analysis shows the importance of socioeconomic aspects in flood risk evaluation.

8 Conclusions

This chapter discussed the concept of resilience and its importance when addressing the urban floods. Different definitions, with slight adaptations according to the area of knowledge, were presented, emphasizing on the concepts of engineering and ecological resilience. Recovering the hydrological functions through reversing the harmful effects introduced by urbanization resembles what is sought in engineering resilience. On the other hand, adapting the city to respond to the residual risks and future challenges, resembling the ecological concept, should complement this action.

It also presented the possibilities of integration between the Hydraulic Engineering and the Architecture and Urbanism, towards cities sensitive to water presence, while increasing resilience. Rearranging floodwaters in the city landscape

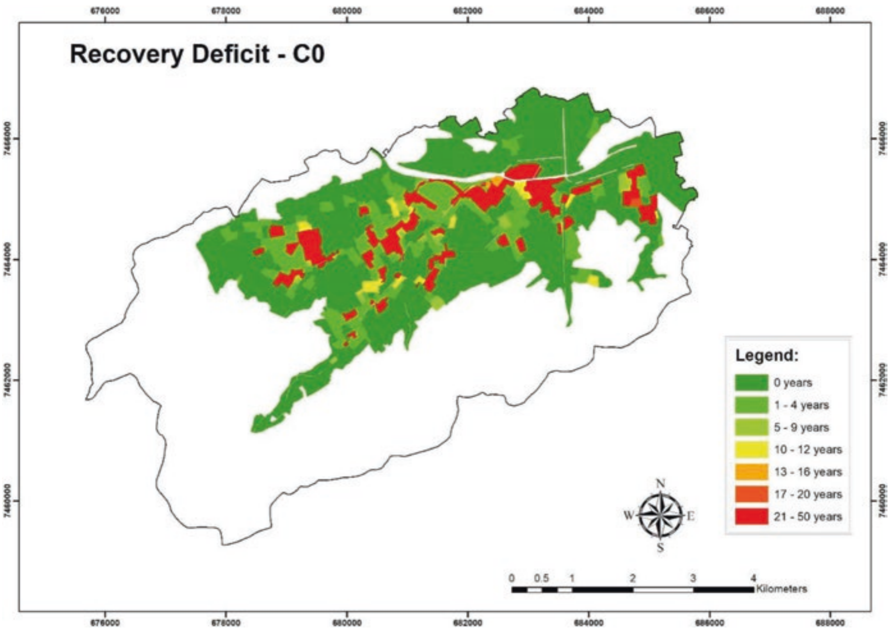

Fig. 14.5 Evaluation of the recovery deficit for the current scenario

and implementing on-source control measures and river restoration actions allow more sustainable and functional cities. Therefore, preventing floods to a certain extent and building the city to live with floods, when needed, brings resilience to the city and highlights the rainwaters as part of the city life, no more as a threatening factor but as a driver for the city working in a socio-ecological system. Henceforward, it is not enough to adopt risk management as an approach to urban flood treatment and recognize the limitation of flood control measures by introducing adaptation actions.

Although important, resilience assessment is quite complex, which explains the still low number of mathematical models that calculate and quantify the resilience in a tangible way. Simplified methods, like the Urban Flood Resilience Index—UFRI, taken as an example in this chapter, try to give numbers to this concept and can help to guide public actions to fragile areas. This method can be used as a decision support tool assessing flood risk mitigation projects, as presented in the case study of the Canal do Mangue catchment. Despite its limitation of representation, this index can quantify the resilience, at least to some extent, bringing the theme to city planning discussions and focusing on the adaptation strategies that improve the social coexistence with floods. In general, any representative index, even simplified, can help support the decision-making process, adding information to this significant matter of flood risks and city resilience.

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Chapter 15
Coastal Flood Prone Communities and Sustainability

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Abstract Exposure of communities to coastal flooding is enormous and this ultimately requires strategic attention. The study assessed the socio-economic impacts of sea level rise and the adaptive mechanisms employed by the Ilaje coastal communities against coastal flooding induced hazards through an integrative biophysical-geospatial-social approach. These were with a view to assessing the flood vulnerability levels and coping strategies of the coastline communities. The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Digital Elevation Model (DEM) and Landsat Multispectral medium resolution image covering Ilaje for the years 1987, 2007 and 2017 were acquired. The ASTER DEM was used to delineate the watershed of Ilaje while the Landsat imageries were used to evaluate the rate of shoreline change for Ilaje through the Digital Shoreline Analysis System (DSAS) in the GIS environment. The socio-economic impacts of sea level rise and adaptive mechanisms employed by communities were identified through field survey using an android fulcrum customized device to elicit information from 320 respondents in settlements that were purposively sampled to be within a 1 km buffer of the shoreline. A Coastal Vulnerability Index (CVI) was developed using 15 indices to assign flood vulnerability rankings to the coastline communities. Geomorphology, relief, slope, wave height, tidal range, shoreline change, population density, type of aquifer, proximity to coast and adaptation mechanisms were employed as regular CVI indices. Groundwater consumption, availability of shelter, emergency services, communication penetration and oil exploration were brought

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in for this study as novel indices and they proved to contribute significantly to vulnerability levels. The results showed that 14 communities distributed within six watersheds (A–F) were identified from the 1-km buffer created around the shoreline. The CVI developed produced a range of results for the watersheds which provided basis for vulnerability ranking through percentile ranges 0.3 (very low), 0.78 (low), 0.83 (medium), 0.95 (high) and 1.0 (very high). The vulnerability assessment revealed that watershed A, B, C, D, E and F had very low vulnerability, high vulnerability, low vulnerability, very high vulnerability, moderate vulnerability and low vulnerability, respectively.

The study concluded that vulnerable coastlines exposed inland areas to sea level rise effects, opening gateways for storm surges, inundation and coastal erosion which aggravates the need for more effective and sustainable coping strategies for coastal communities. This is of critical importance as coastal areas are home to nearly 30% of the world population and house numerous biodiversity essential necessary to regulate the ecosystems and economic potentials around the planet.

Keywords Sustainability · Coastal flooding · Flood prone communities · Flood vulnerability · Biophysical-geospatial-social approach · Climate change · Resilience · Communities · Vulnerability

1 Introduction

Floods are water-related disasters that causes the temporary inundation of dry land and leads to a catastrophe in the affected area, for example, loss of lives and properties and obliteration ofinfrastructure. Floods are described as a regular occurrence in most areas in Nigeria and the historical impacts of flooding on people are alarming, causing hundreds of deaths and thousands of persons and properties are being displaced (Akinbobola et al., 2015).

Coastal areas with low elevation and high population densities have an increased risk of flooding because of heavy precipitation and storm surges, due to sea level rise (SLR). Naturally, coastlines are dynamic in nature (Winarso & Budhiman, 2001). Their elevation status and the other coastline dynamics makes them susceptible to the coastal flooding which is attributed a combination of the high water levels, resulting from tides, wave actions and storm surges which is a possible cause of overflow of the beach fronts and submerging of low-lying zones, thereby increasing the number of destruction to lives and property (Adagbasa & Ige-Olumide, 2014).

SLR is a major recompense of global warming. Despite the conflicting reports and uncertainties concerning the nature and level of exposure of SLR and climate change, the exacerbating coastal problems could be implied from the scientific evidence of possible climate change induced SLR (Ogba & Utang, 2007). Coastline changes frequently lead to the erosion of the coastal zones or growth of silt. These changes are contingent on the dominant processes acting on the coastline (Pidwirny, 2006). Various anthropogenic activities as mineral exploration, construction of ports, breakwater infrastructure and barrages, dredging and removal of backshore vegetation have also impacted coastlines on the large and small scales (Pandian et al., 2004). Notwithstanding the beneficial food and natural resources and the various delicate fragile ecosystems the coastal zones is made of, there still exist arrays of frequent conflicting uses. The present indiscriminate exploitation of natural resources and uncontrolled development carried out indiscriminately in the coastal zones exposes the expected economic benefits into an environmental havoc that may be catastrophic for the present and future generations (Olufayo et al., 2013).

The Nigeria coastline is very dynamic and undergoes the rapid changes especially in the littoral communities which are becoming increasingly vulnerable to ocean surges with associated challenges to coastal population (Fabiyi & Yesuf, 2013). Vulnerability is crucial in the debate of both natural and artificial disasters with regard to environmental changes and provides an important structure for coastal flooding assessment. The Intergovernmental Panel on Climate Change, IPCC (2007) characterizes vulnerability as the degree to which a system is exposed to the sustaining harm from environmental change. Two key contributors to the vulnerability are largely dictated by the development context which strongly influences households' income, access to right information and education, people's susceptibility to ecological risks in their households and the working environments, the extent and quality of service and infrastructure made available (Wilbanks et al. 2007). The levels of vulnerability experience certain variations within a system, for this reason, indices are utilized to determine such levels. Such indices could be the ecological, socio-economic, institutional, political and technological factors of the system concerned.

Studying change patterns within the coastal ecosystems requires the use of hydrological model and remote sensing data (Moore, 2000). Other recent methods have included the simulation of changes within the coastline by integrating mathematical models and other mapping tools such as the global Positioning System (GPS) receivers for mapping and monitoring coastal dynamics. Another technique for vulnerability assessment is the coastal vulnerability index (CVI), which integrates and quantifies different variables which determine the coastal zones levels of exposure and susceptibility. The CVI concept was introduced by Gornitz (1990). It utilizes coastal data used to measure the relative vulnerability of coastline division to the consequence of SLR on different scales. Various researchers have since modified and applied the CVI approach in their assessment of the coastline vulnerability around the world (Thieler & Hammar-Klose, 2000; McLaughlin et al., 2002; Dwarakish et al., 2009; Ozyurt & Ergin, 2009; Kumar et al., 2010; Pendelton et al., 2010; Kumar & Kunte, 2012; Dinh et al., 2012; Torresan et al., 2012; Yin et al., 2012; Balica et al., 2013; Musa et al., 2014; Oyegun et al., 2016; Jana & Hegde, 2016; Di Risio et al., 2017). The CVI adopted for this study made use of the biophysical and socio-economic indices.

1.1 Concept of Climate Change

Climate change is quite possibly the most remarkable difficulties confronting the international community, therefore various definitions as being ascribed to it by various scholars regarding their relativity and perception. Ozor (2009) and (Ozor and Nnaji 2010) described the climate change as an alteration in climate over the long haul, regardless of whether it is because of the regular fluctuation or on account of human action and is broadly perceived as the most genuine ecological danger confronting our planet today. This definition shows the gravity of the danger constituted by climate change and the urgent call to combat it.

Climate change which has become more significant over the years is because of earth's natural variations and human actions that leads to the emanations of the ozone harming substances and therefore increasing global warming. This change in climate is induced by global warming and this is supported by finding that over the past 100 years, the earth's average surface temperature has ascended by around 0.74 °C (Direct Gov, 2010). And when necessary actions are not taken, there will be a continuous earth temperature increase that exposes human beyond the acceptable limit/threshold. This statement draws out more on the gravity of the risks presented by climate change to the globe especially during the period of the dependence on climate-sensitive resources to unsure sustainable livelihood and development.

1.2 Concept of Sea Level Rise

The crucial results of the current climate warming are ocean level change causing the dissolving of Antarctic and Greenland ice sheets, glacial masses and the warm development of provincial climatic vacillations. IPCC report referenced that the anticipated ocean level of the twenty-first century moves up slowly at the pace of 1–2 mm each year, which is mainly attributed to physical and human-induced global climate change. The fourth evaluation report of IPCC poses (by flowing check perception) that the difference in normal ocean level in the twentieth century is around 1.5 ± 0.5 mm each year, even though it has been assessed, it was around 1.8 ± 0.3 mm each year in the middle of 1950–2000.

The increased water level is triggered by the thermal expansion induced by the increasing sea surface temperature (IPCC, 2013), subsequently, the coastline shifts farther away from the coast. Also, atmospheric warming results in the melting of mountain glaciers and polar ice sheets, hence expanding the ocean levels. With reference to historical data, the eustatic sea level changes within the period 1950 and 2009 recorded 1.7 mm year^{-1}. Lately, satellite altimetry measurements (1993 and 2003) have demonstrated an increase in this rate to more than 3 mm year^{-1} (IPCC, 2007).

1.3 Concept of Flooding

Flooding is a major environmental and recurrent crisis in the coastal regions of the world. As reported by Bariweni et al. (2012) and Ologunorisa (2009), floods are brought about by numerous elements such as substantial precipitation, exceptionally quickened snowmelt, extreme wind condition over water, bizarre elevated tide, torrents, or dams breakdown, levees, or water retained by different structures. They also attributed the coastal flooding to climate change pointing out that warmer climate leads to the heavy rains, rise in relative sea level around most shoreline and frequent extreme sea level events. Flooding has many impacts. Rigasa et al. (2015) pointed out that flooding damages property and is a threat to the public health and safety and local biodiversity. Coastal flooding leads to submergence of shoreline communities and affects ecosystems such as wetlands along the shorelines.

1.4 Concept of Vulnerability

Vulnerability as earlier described is basically linked with the natural hazards such as droughts, flood, and social risks most especially destitution/poverty. In recent times, vulnerability is widely utilized in climate change literature to signify the degree of damage an area is expected to be influenced or impacted by climate change (Ajayi, 2009).

Vulnerability is described in regard to nature, extent, and rate of climate variation that a framework or system is exposed, its susceptibility or sensitivity, and its coping strategy (IPCC, 2007).

1.4.1 Biophysical Vulnerability

Biophysical vulnerability is influenced by geographical and environmental factors such as distance from the shoreline, elevation above mean sea level, the effectiveness of artificial or natural barriers to protect or dissipate energy of surges and the resilience or adaptation ability of the flora and fauna (Ogba & Utang, 2007). These factors determine a coast's exposure to the flood vulnerability (Musa et al., 2014).

1.4.2 Socio-Economic Vulnerability

The socio-economic vulnerability of a system is dependent on the system's ability to adapt andrecover from damage that are aftermaths of hazards. It entails the resilience embedded in quality of the physical infrastructures and preparedness of communities to manage potential hazards (Ogba & Utang, 2007). Nigeria's coastal regions are active economic hubs characterized by a high population density with many inhabitants engaged in an array of economic activities. The region has over the years attracted development leading to the influx of migrants from the other parts of the country. The desire for spatial transformation of the coastal zone to cater for the exploding population has resulted in serious modification of parts of the coast, increasing its vulnerability to the flooding and inundation (Arokoyu & Ogoro, 2014; Musa et al., 2014). The major economic activities in coastal zones are fishing, salt farming, shrimp cultivation, and agriculture. These actions are completely subject to natural resources and environmental sustainability as the coastal economy could experience serious impact from sudden changes in the ecological setting (Fabiyi & Yesuf, 2013; Oyegun et al., 2016).

1.5 Adaptation and Coping Strategies

Adaptation is a comprehensively utilized phrase; however, in certain examples it necessitates that the term is characterized and recognized from the term coping.

In their discussion of adaption, Berkes and Jolly (2001) explain the difference between coping mechanisms and adaptation strategies. Coping responses are the ensemble of short-term responses to the potential impacts that can be effectively integrated season-to-season or year-to-year as basis to secure a resource, occupation/livelihood, etc. Some forms of coping are expressly expectant and appear as, for instance, protection plans and emergency preparedness. Adaptive responses allude to the ways people, family units, and communities change their beneficial activities and adjust their principles and organizations to limit danger to their resources and livelihoods. Contingent upon the recurrence, duration, and suddenness in the beginning of a pressure, and on the resilience of a framework, either coping or adaptive responses or both will become possibly the most important factor. With a progression of change in climatic conditions, coping mechanisms may at some point be overburdened, and by requirement superseded by adaptive responses. It is also emphasized that the terms adaptation and coping are occasionally used interchangeably and recognizing the difference that exist between coping and adaptation is crucial to providing the sustainable solutions to long-term climate change (Taylor et al. 2010).

Azevedo de Almeida and Mostafavi (2016) ascertained that an essential component of alleviating the adverse impacts of increasing sea level on coastal metropolitan areas is the variation of assembled framework systems. They further posited that the increase in precipitation as well as recurrence and extent of inland flooding facilitates the erosion of intersections and thereby making them more susceptible to damages. In a quest to combat flood and reduce vulnerability, coastal dwellers and flood management stakeholders come up with the mitigation and adaptation strategies for flood risk reduction and control. Communities can take responsibility for maintaining local flood mitigation and adaptation regimes, while guidance, funding and local capacity must be provided by governments (Rigasa et al., 2015).

There are methods adopted to minimize or avoid the disastrous effects of flooding, several of which have been practised since ancient times. Current strategies according to Scottish Environmental Protection Agency, SEPA (2009) include:

1. Draining vulnerable land through the Sustainable Drainage Systems (SUDs) to divert flood water.
2. Flood prevention through afforestation and the construction, dikes, dams, levees, reservoirs or ponds to retain the excess water in the course of extreme rainfall events.
3. Flood alleviation by providing relief and emergency services to a flood-affected communities.
4. Managing flood risk.

Fabiyi and Yesuf (2013) noted that coastal settlements have identified local methods for survival reasons in the face of climate change and flooding events, identifying some of the strategies as local policy while some being physical. Different communities construct the local and advanced engineering structures as mechanisms to combat flooding. Such mechanisms include: use of sand bags along shores, use of half buried tyres, use of logs of woods, utilization of bare sea shells discarded and gathered overtime, building river/shore embankments, building of mud and concrete embankments, construction of canals, channels, culverts, gutters, cranes and wooden bridges, building of dwelling on stilts/raised platforms, high engineered projects such as dykes, breakwaters and walls, weirs, dams, dredging of water bodies, mangrove reforestation campaigns as the natural barriers against storm surges, etc.

2 Materials and Methods

2.1 Study Area

Fourteen communities (Aiyetoro, Alagbon, Awoye, Eruna, Idiogba, Idogun, Kesumeta, Maran, Oloja, Olotu, Orioke Iwamimo, Oroto, Seja Odo, and Yaye; Fig. 15.1) along the coastline of Ilaje Local Government Area, Ondo State, Nigeria fell within the scope for this study. The area falls within 4.349948° and 5.149688° East of the Greenwich meridian and 5.842676° and 6.682662° North of the Equator. It is a transgressive mud coast extending for about 75 km east of the barrier lagoon ending at Benin river estuary in the north-western part of the Niger delta coast. The coastline which is low lying with an elevation of less than 15 m is home to thousands of Ilaje people (a Yoruba subgroup in Ondo state, Nigeria) and has witnessed change in its configuration over the years making it susceptible to sea level rise induced coastal flooding. It is muddy in nature and backed by freshwater swamps with medium, coarse, and poor sorted silt sediments (Mmom & Chukwu-Okeah,

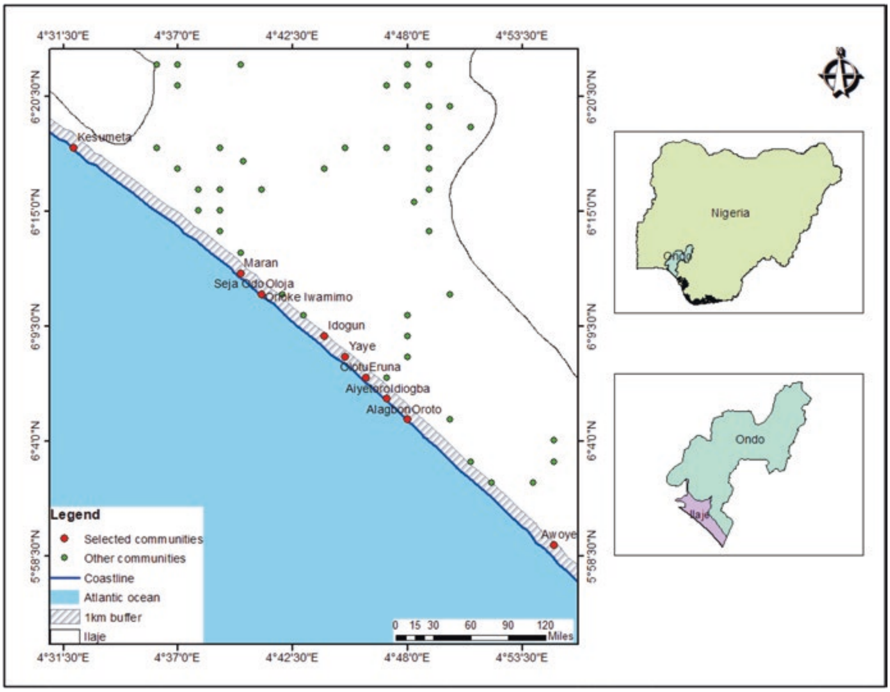

Fig. 15.1 Map of Ilaje Local Government Area, Ondo State showing the 14 communities within the 1 km inland buffer of the Atlantic

2011; Fabiyi & Yesuf, 2013; Adagbasa & Ige-Olumide, 2014; Adetoro & Akanni, 2018).

Majority of the population are fish farmers. Fishing business is supplemented by trading and farming of crops such as plantains, bananas, yams, cocoyams, paddy-rice and other vegetables as well as the tropical fruits such as mangoes, guavas and pineapples. Various food and cash crops for example timber, palm oil and kernels, cassava and coconut are also cultivated. Smoked and dried fish are usually processed for export from the local government (START, 2012; Fabiyi & Oloukoi, 2013).

The mean annual rainfall is between 1500 and 2000 mm (NDRMP, 2004). The area experiences equatorial climate with a lengthy rainy season which spans between April and November and a short dry season between December and March. Rainfall is convectional with heavy showers often accompanied by thunder and lightning. Temperatures are high all through the year and range from 28 to 30 °C. Lower air temperatures however occur during the rainy season (Ebisemiju, 2016).

2.2 Justification

Coastal zones are usually exposed and are susceptible to the flooding events due to their low elevation thereby increasing their exposure and susceptibility to sea level rise. Vulnerability and resilience to sea level rise induced by coastal flooding is determined by the physiographic state of the coastal zones and their interaction with other attributes. The flooding events affect the existence of the littoral communities impacting flora and fauna and stalling daily and periodic activities of residents, with aftermath effects on the ecological system and socio-economic situations of the coastal area and the country at large.

Considering the amount of losses connected with flood catastrophe around the globe, the United Nations (UN) and many other international organizations have encouraged concerted efforts by national and international agencies to create the practical measures for management of flood disasters. Among the strategies endorsed by the UN is the application of geospatial techniques (Remote sensing and GIS) for disaster reduction and coastline management (START, 2012). There is therefore an urgent need to map out the biophysical and socio-economic vulnerability of settlement in the western part of the Nigerian coastline to flood disaster at watershed levels and using the Coastal Vulnerability Index (CVI) approach. This would help in preparing to mitigate the effects before occurrence, thereby managing the coastal environment, its people and resources.

2.3 Methodology

A smartphone-based field survey tool (Fulcrum) was used to build a questionnaire in digital format and administered to elicit information about the socio-economic impacts and adaptive mechanisms to coastal flooding. A buffer zone of 1 km was generated in the ArcGIS environment for each watershed. Households in communities that fell within the 1 km buffer inland from the coastline were systematically selected for questionnaire administration.

Fourteen communities fell within the 1 km buffer created, accounting for a population of 67,174 of the Ilaje people. Considering a 95% Confidence Level and Confidence Interval of 5.465, Survey Monkey, an online sample size calculator was adopted to deduce a sample size of 320 which was employed as frame for questionnaire administration from the population frame. Twenty copies of questionnaire were apportioned to each of the communities except for Aiyetoro and Awoye which had larger land mass than the other communities and were apportioned 40 questionnaires each. The copies of questionnaire were systematically distributed among the households and of the 320 questionnaire administered, 305 were retrieved and analysed using the R statistical package.

2.4 Watershed Delineation

The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Digital Elevation Model (DEM) for the study area was acquired and delineated into watersheds with the hydrology tool in the ArcGIS environment. Procedure for watershed delineation is shown in Fig. 15.2.

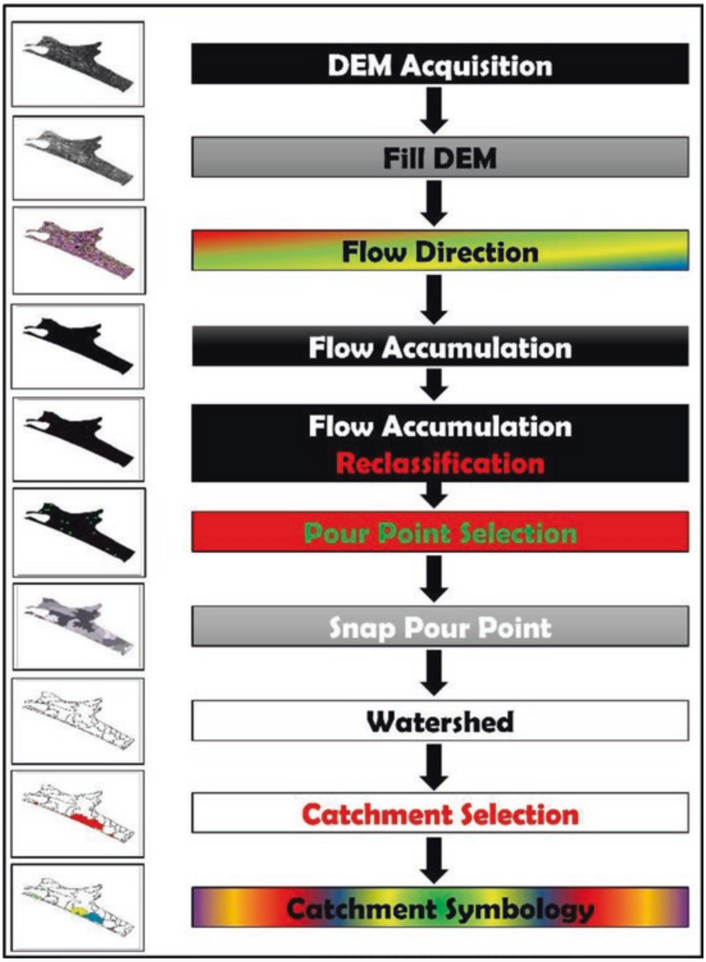

Fig. 15.2 Flowchart of watershed delineation

2.5 Coastal Vulnerability Index

The Coastal Vulnerability Index (CVI) is a commonly utilized method for evaluating coastal vulnerability to overflow (Gornitz, 1990; Thieler & Hammar-Klose, 2000; Ozyurt & Ergin, 2009; Dwarakish et al., 2009; McLaughlin et al., 2002; Kumar et al., 2010; Pendelton et al., 2010; Dinh et al., 2012; Kumar & Kunte, 2012; Torresan et al., 2012; Yin et al., 2012; Balica et al., 2013; Musa et al., 2014; Jana & Hegde, 2016; Oyegun et al., 2016; Di Risio et al., 2017). Reason is since CVI provides a numerical base that permits the ranking of coastal zones with respect to their level of exposure and susceptibility to the flood hazards which allows adequate planning as extremely vulnerable areas adequately recognized. These CVI results can be presented as maps revealing information on zones' vulnerabilities (Oyegun et al., 2016). The CVI method involves the classification of coast with simple standard that provides numerical data that cannot be connected directly with physical effects but rather reveals the zones mostly affected by the hazard (Jana & Hegde, 2016). The method of computing the CVI is like that used by Pendelton et al. (2005), Thieler (2000), Musa et al. (2014) and Jana and Hegde (2016); and Gornitz (1991) described CVI on n number of physically ranked variables ($x_1, \ldots, x_n$) as:

$$CVI = \sqrt{\frac{x_1 \cdot x_2, \ldots, x_n}{n}}. \tag{15.1}$$

In Eq. (15.1), x represents the ranked variables and n represents the number of ranked variables. Local variable values are quantified and/or determined and compared with recorded ranges of the values for that variable when CVI techniques are concerned. This comparison provides for a ranking of physical variables that reveals the level of vulnerability (Musa et al., 2014). The database of the variables examined for Ilaje was initially built by sorting data acquired from the different sources. This study considered geomorphology, relief, slope, wave height, tidal range, shoreline change, population density, type of aquifer, proximity to coast, groundwater consumption, availability of shelter, emergency services, communication penetration, oil exploration and adaptation mechanisms as variables used for the CVI analysis. The data values of variables were assigned a vulnerability ranking with emphasis on the value ranges promoting coastal vulnerability, and the non-numerical variables were ranked qualitatively. The ranking was modelled after Musa et al. (2014) and Oyegun et al. (2016) as shown in Table 15.1.

Watershed segments were defined and the values of the variables chosen were determined for each of them. The watershed segments were then ranked based on the overall vulnerability conditions computed for each watershed.

Table 15.1 Ranges of vulnerability ranking variables

S/N	Indicators	Very low (1)	Low (2)	Moderate (3)	High (4)	Very high (5)
1.	Geomorphology	Rocky, high cliffs, seawalls, etc.	Medium cliffs, indented coast, bulkheads and small sea walls, etc.	Low cliff, alluvial plain, etc.	Cobble beach, estuary, lagoon, etc.	Barrier beach, sand beach, mud flat, delta
2.	Relief (m)	>6	4–6	3–4	1–3	0–1
3.	Slope (%)	>1.2	1.2–0.9	0.9–0.6	0.6–0.3	<0.3
4.	Wave height (m)	0.3–0.5	0.5–0.8	0.8–1.1	1.1–1.4	>1.4
5.	Tidal range (m)	<0.1	0.1–0.3	0.3–0.6	0.6–1.0	1.0–2.0
6.	Shoreline change (m/year)	0–1 m	1–5 m	5–10 m	10–15 m	>15 m
7.	Type of aquifer	Confined		Leaky confined		Unconfined
8.	Proximity to coast (m)	>800	600–800	400–600	200–400	100–200
9.	Population density (people/km^2)	<100	100–300	300–500	500–800	>800
10.	Adaptation mechanisms	Very effective	Effective	Moderately effective	Mildly effective	Not effective
11.	Groundwater consumption	Very low	Low	Moderate	High	Very high
12.	Oil exploration	Very low	Low	Moderate	High	Very high

13.	Shelter house	Available/equipped with relevant facilities and accessible by road/ boat	Available/equipped with relevant facilities but only accessible by boat	Available/equipped with relevant facilities but located in another community	Available but not equipped with relevant facilities	Absent
14.	Emergency services	Present in the community and formally trained (city/ LG HQ/oil company)	Present in community but not formally trained (settlement located far from LG HQ)	Only present at local government level	Only present at the state level	Absent
15.	Communication penetration	Print and electronic media; city/proximity to local government HQ	Access to print and electronic media; town/ settlement located close to oil company	Traditional rulers/town criers; access to radio communication; village settlement	Only through direct contact; access to radio communication; remote areas	None

Source: Musa et al. (2014) and Oyegun et al. (2016)

2.6 Selected Indicators for CVI

The importance of the selected indices and the procedures for generating them for use in CVI assessment are explained below:

2.6.1 Geomorphology

Geomorphology as defined by Kumar et al. (2010) is the investigation of landforms and scenes including the depiction, grouping, root, advancement and history of planetary surfaces. This communicates the overall erodibility of a landform type as cliffs are not really inclined to erosion particularly when it has a rough surface (Oyegun et al., 2016). Hammar-Klose and Thieler (2001) indicated that geomorphology determines coast response to sea level rise and the cumulative effect of the resistance to the impact of waves. A 30-m ASTER DEM was used to acquire data on the elevation, and this provides required information necessary to understand the geomorphology of each watershed's environment.

2.6.2 Relief

The relief is the average elevation of a specific zone above mean sea level (Kumar et al., 2010). This is required to identify and estimate the extent of land area exposed to future SLR (Jana & Hegde, 2016). Locations that are low lying or at same position with Mean Sea Level (MSL) have a higher risk of being inundated by sea level rise than areas averagely above MSL (Oyegun et al., 2016). Watersheds were categorized into relief classes utilizing the geospatial and statistical tools on the DEM. Relief was also recorded from an online elevation map checker.

2.6.3 Slope

The slope of an area is the degree of steepness with regard to a point in an encompassing area (Musa et al., 2014). The coastal slope is change in height for a unit horizontal distance between any two points on the coast (Jana & Hegde, 2016). The slope of a coastal zone influences the level of vulnerability to inundation by flooding (Thieler, 2000). The lowest level at which water can percolate or inundate a region is determined by the slope. Coastal areas having lower or gentler slopes tend to be more susceptible to tidal waves and activities than areas with steeper slopes (Pendelton et al., 2005; Dinh et al., 2012). The regional slope of the watersheds was extracted from Google Earth's elevation display and DEM in the ArcGIS environment.

2.6.4 Wave Height

The wave height clarifies the abundance of a wave and decides the energy that drives the seaside sediments as the waves make for the preparation and transportation of waterfront silts sediments (Oyegun et al., 2016). Coastal wave height and energy increase causes land loss and this leads to inundation and accelerated run-off along the shore. Hence, areas with high wave heights are more vulnerable than areas with low wave heights, as they have more energy to move materials offshore (Musa et al., 2014). Wave height values for the western part of the Nigerian coastline were obtained from NIOMR (2010) and Ebisemiju (2016) who published wave heights of 1.9 and 2.0 m for the Awoye and Aiyetoro parts of the coastline, respectively.

2.6.5 Tidal Range

The tidal range is the difference between high and low tides. It is attributed to lasting and episodic dangers from sea level rise and tempest flood (Yin et al., 2012). Considering seaside susceptibility, territories with lower flowing ranges have lower susceptibility than those with high ranges (Kumar et al., 2010; Musa et al., 2014; Jana & Hegde, 2016). Tidal range values for the western part of the Nigerian coastline were generated using the *wXTide32* tidal model, an algorithm developed by the US National Oceanic Service in 2007 to predict tides.

2.6.6 Shoreline Change

This is communicated as move in the intersecting zone between the land and water over a period (Oyegun et al., 2016). Seaside measures which are constrained by wave qualities, the resultant close shore resultant, sediments attributes and seashore structure among others subject shorelines to change. Coasts subjected to erosion tend to be more vulnerable due to confirmed loss of the properties and essential natural and ecological habitats such as beaches, dunes and marshes whereas areas of accretion are known to be of lower vulnerability as they shift closer to the sea which increases the land areas (Kumar et al., 2010). The coastline was digitized from LANDSAT images for Ilaje for the years 1987, 2007 and 2017 in the ArcGIS environment. The near infrared band recognized as most acceptable for demarcation of the land–water boundary was used to extract the shoreline for the 3 years. The digitized shorelines for the years were used as input for the Digital Shoreline Analysis System (DSAS) to calculate the rate of shoreline change.

2.6.7 Population Density

Coastal areas have high population density as compared to upland areas (Jana & Hegde, 2016). Population exerts pressure on the coastal system and hence, areas with higher concentration of people are more vulnerable to flooding than areas with lower concentration of people (Hegde & Reju, 2007). Population figures were sourced from the Ilaje Local Government office, the National Population Commission (NPC) of Nigeria, the National Bureau of Statistics, and from Population Statistics, Charts, Map and Location of City population published by Brinkhoff (2017).

2.6.8 Type of Aquifer

Aquifer type dictates the vulnerability level of the groundwater to salt intrusion. Semi-confined and unconfined aquifers allow interaction with surface materials and are more vulnerable to contamination than confined aquifers which are curtained by resources with very low permeability and are less vulnerable (Musa et al., 2014). The Niger Delta Regional Development Master Plan and NDRMP (2004) report were considered for Ilaje coastal aquifers ranking into semi-confined and unconfined categories.

2.6.9 Proximity to Coast

Proximity of land, infrastructure or settlement to the coastline determines its level of vulnerability to sea level rise for example erosion, floods, storm surges and wave action (Musa et al., 2014). Distances from the shore were recorded from Google earth imagery. Distance of at least three settlements were averaged for each community before an overall average was computed for the watersheds and ranked accordingly.

2.6.10 Groundwater Consumption

Musa et al. (2014) documented that inland intrusion of saline water has a likelihood of polluting underground aquifers leading to the potable water shortage for coastal areas. High dependence on groundwater as the main source of drinking water makes an area highly vulnerable than those with a low dependence on groundwater. The rate of groundwater consumption was calculated from the data obtained through the questionnaire and ranked accordingly.

2.6.11 Availability of Shelter

Access to the shelters during disasters determines the number of people that can be saved at appropriate time and subsequently serve to help in restoring the affected community (NEMA, 2010). Musa et al. (2014) affirmed that regions with buildings situated on non-vulnerable/very low vulnerable locations that can be considered for shelters are more resilient to the impacts of sea level rise than those lacking such opportunity. It was revealed that structures erected on safe locations are used as schools during flooding, but where none is available, emergency shelters are provided. The level of availability of shelter was calculated from the data obtained through the questionnaire and ranked accordingly.

2.6.12 Emergency Services

Emergency services at the local level are controlled by the Local Emergency Management Agency (LEMA) which affirms trained local settlement structures consisting of local associations, clubs, religious bodies, schools, etc. (NEMA, 2010). Communities with trained personnel and well-equipped emergency services are more resilient to the impacts of sea level rise compared to those without (Musa et al., 2014). The level of availability and access to emergency services was calculated from the data obtained through the questionnaire and ranked accordingly.

2.6.13 Communication Penetration

NEMA through its disaster prevention strategy provides information about impending disasters to the vulnerable communities through print and electronic media as well as informal channels like traditional rulers, religious leaders, etc. (NEMA, 2010). NEMA (LEMA) staff that disseminate this information are found in the local government headquarters. Settlements along the coastline of Ilaje Local Government are located far away from Igbokoda, the local government headquarters and might not be easily reached. The level of communication penetration was sourced from the data obtained through the questionnaire administered to citizens and disaster department of the local government. The data obtained were analysed and ranked accordingly.

2.6.14 Oil Exploration

Land subsidence increases the vulnerability to sea level rise. Ericson et al. (2006) reported that the occurrence of subsidence in the Niger deltas is increased by oil extraction from underground sources. Ebisemiju (2016) also postulated that the regional subsidence process in the Niger Delta had probably been pushed by the withdrawal of oil and gas from the formations that underlie the unconsolidated deposits of silt and clay materials in the area. The level of oil exploration activities was calculated from the responses of residents to the questionnaire administered and ranked accordingly.

2.6.15 Adaptation Mechanisms

Vulnerability of an institution is determined by the sensitivity and ability to adapt. Vulnerability is influenced by resilience, involving the preparedness of communities, the quality of physical infrastructure and the strength of the structure to recover from hazard in case it occurs (Ogba & Utang, 2007). The level of adaptation mechanisms was observed in the watersheds and ranked based on the responses from questionnaire administered.

3 Results and Discussion

3.1 Watershed Delineation

The results of the study area delineated into six watersheds with the communities falling within 1 km buffer of the shoreline are shown in Fig. 15.3. Table 15.2 shows the communities that fall within each of the watersheds. Figure 15.4 shows the watershed map with the six watersheds for this study identified. Each of the watersheds are individually presented in Fig. 15.5.

3.2 Biophysical Vulnerability Indices

3.2.1 Geomorphology

Table 15.4 shows that the watersheds A, C and F were awarded the very high vulnerability ranking of 5 because their coastlines were sandy beaches and the mud flats as categorized in Table 15.3. Watersheds B, D and E had the high ranking of 4 as their coastlines were estuaries.

3.2.2 Relief

With their low relief values of 2 m, watersheds B, C and F received the high ranking of 4 while watersheds A and E with relief values 5 and 4 m respectively were lowly ranked with the value 2. Watershed D with 3 m relief had the moderate ranking of 3. Relief classes for the watersheds are shown in Fig. 15.6.

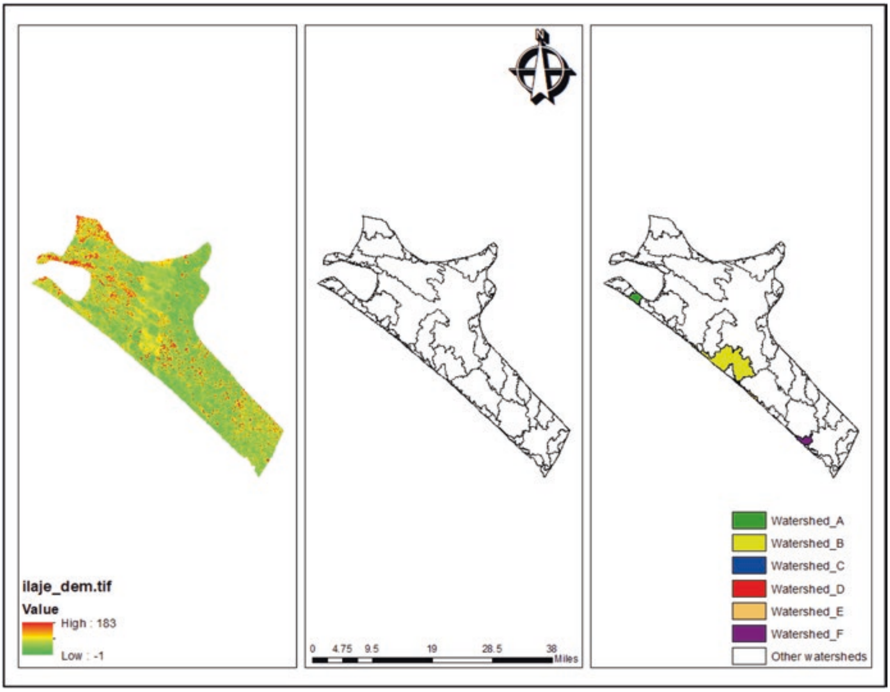

Fig. 15.3 Watershed delineation from Digital Elevation Model (DEM)

Table 15.2 Watersheds and communities of respondents

Watershed	No of communities	Community names
A	1	Kesumeta
B	5	Idogun, Maran, Oloja, Orioke Iwamimo, Seja Odo
C	3	Aiyetoro, Idiogba, Yaye
D	2	Eruna, Olotu
E	2	Alagbon, Oroto
F	1	Awoye

3.2.3 Slope

Watershed D had a slope of 0.4%, B and C both had slopes of 0.5%, A and E sloped 0.6% while Watershed F had a slope of 0.7%. The slope percentages as shown in Table 15.3 were used to rank all the watersheds in Table 15.4.

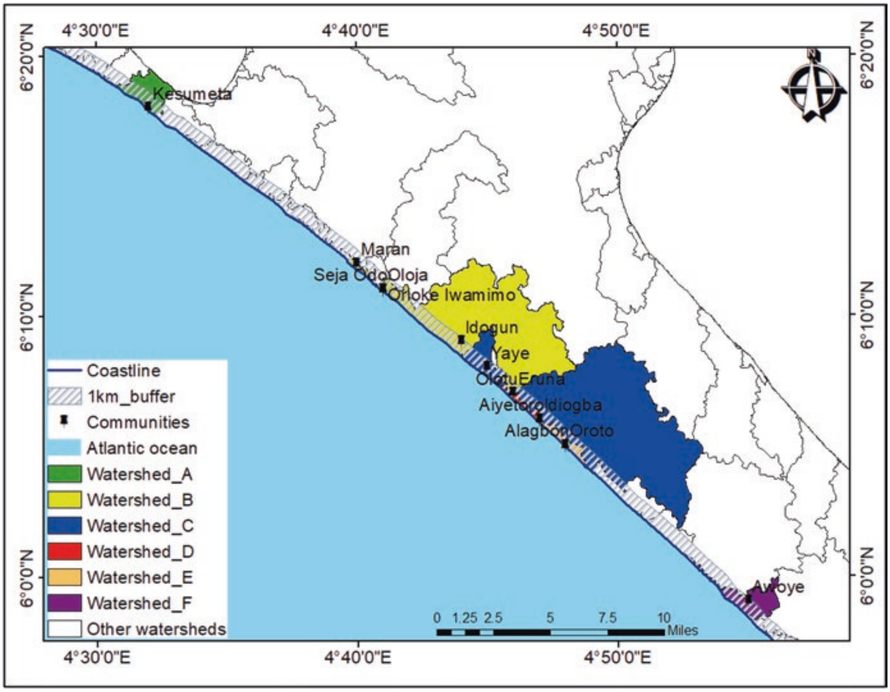

Fig. 15.4 Six sub-catchments identified in the watersheds

3.2.4 Wave Height

As reported by NIOMR (2010) for the western portion of the Nigerian shoreline, all watersheds were rated with mean wave height of 1.5 m except watersheds C and F which were reported by Ebisemiju (2016) to have the mean wave heights of 2.0 and 1.9 m, respectively. These values were used to rank all of the watersheds as very highly vulnerable in Table 15.4.

3.2.5 Tidal Range

The tidal range value 1.6 m was the same for watersheds A, B, D and E. Watersheds C and F had the tidal ranges of 1.5 and 1.3 m, respectively. The watersheds were also ranked accordingly as shown in Table 15.4.

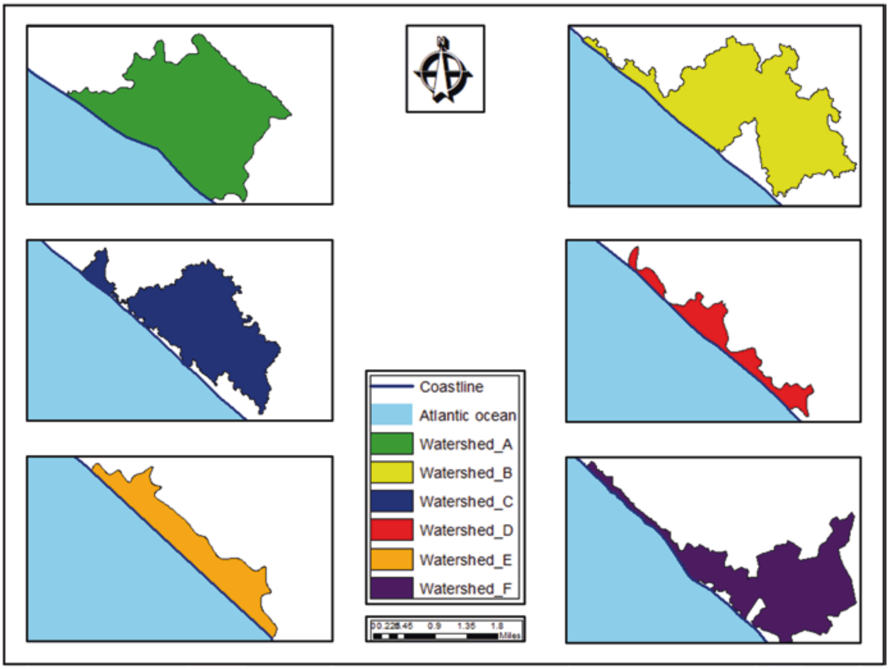

Fig. 15.5 Zoomed in maps for Watersheds A to F

3.2.6 Shoreline Change

Table 15.3 shows the shoreline change per year for the watersheds. For watersheds A, B, C, D, E and F, shoreline advancement rates of 64, 58, 65, 64, 66 and 22 m into the communities were recorded respectively leading to the very high vulnerability ranking value of 5 as shown in Table 15.4.

3.2.7 Type of Aquifer

Table 15.4 shows that watersheds A, B, D and E were awarded the very high-ranking value of 5 while watersheds C and F were moderately ranked with the value 3. This resulted from watersheds A, B, D and E having the unconfined aquifers while watersheds C and F have the leaky confined aquifer as shown in Table 15.3.

Table 15.3 Index Values across Watersheds

S/N	Indicators	Watershed A	B	C	D	E	F
1.	Geomorphology	Barrier beach, sand beach, mud flat, delta	Cobble beach, estuary, lagoon, etc.	Barrier beach, sand beach, mud flat, delta	Cobble beach, estuary, lagoon, etc.	Cobble beach, estuary, lagoon, etc.	Barrier beach, sand beach, mud flat, delta
2.	Relief (m)	5	2	2	3	4	2
3.	Slope (%)	0.6	0.5	0.5	0.4	0.6	0.7
4.	Wave height (m)	1.5	1.5	2.0	1.5	1.5	1.9
5.	Tidal range (m)	1.6	1.6	1.5	1.6	1.6	1.3
6.	Shoreline change (m/year)	64	58	65	64	66	22
7.	Type of aquifer	Unconfined	Unconfined	Leaky confined	Unconfined	Unconfined	Leaky confined
8.	Proximity to coast (m)	121	319	322	348	241	577
9.	Population density (people/km^2)	170	224	463	864	807	625
10.	Adaptation mechanisms	Mildly effective	Not effective	Mildly effective	Not effective	Mildly effective	Mildly effective
11.	Groundwater consumption	Very low	Very low	Very low	Very low	Very low	Very low

12.	Oil exploration	High	High	High	High	High	High
13.	Availability of shelter house	Absent	Absent	Absent	Absent	Absent	Absent
14.	Availability of emergency services	Absent	Absent	Absent	Absent	Absent	Absent
15.	Communication penetration	Only through direct contact; access to radio communication; remote areas	Only through direct contact; access to radio communication; remote areas	Traditional rulers/ town criers; access to radio communication; village settlement	Only through direct contact; access to radio communication; remote areas	Only through direct contact; access to radio communication; remote areas	Only through direct contact; access to radio communication; remote areas

Source: Author

Table 15.4 Ranking per indicator for watersheds

S/N	Indices	Watershed					
		A	B	C	D	E	F
1	Geomorphology	5	4	5	4	4	5
2	Relief	2	4	4	3	2	4
3	Slope	3	4	4	4	3	3
4	Wave height	5	5	5	5	5	5
5	Tidal range	5	5	5	5	5	5
6	Shoreline change	5	5	5	5	5	5
7	Type of aquifer	5	5	3	5	5	3
8	Proximity to coast	5	4	4	4	4	3
9	Population density	2	2	3	5	5	4
10	Adaptation mechanisms	4	5	4	5	4	4
11	Groundwater consumption	1	1	1	1	1	1
12	Oil exploration	4	4	4	4	4	4
13	Availability of shelter	5	5	5	5	5	5
14	Emergency services	5	5	5	5	5	5
15	Communication penetration	4	4	3	4	4	4
	CVI	516.40	1686.55	1385.64	2309.40	1460.59	1385.64
	Normalized result	0.30	0.95	0.78	1.00	0.83	0.78

Source: Author

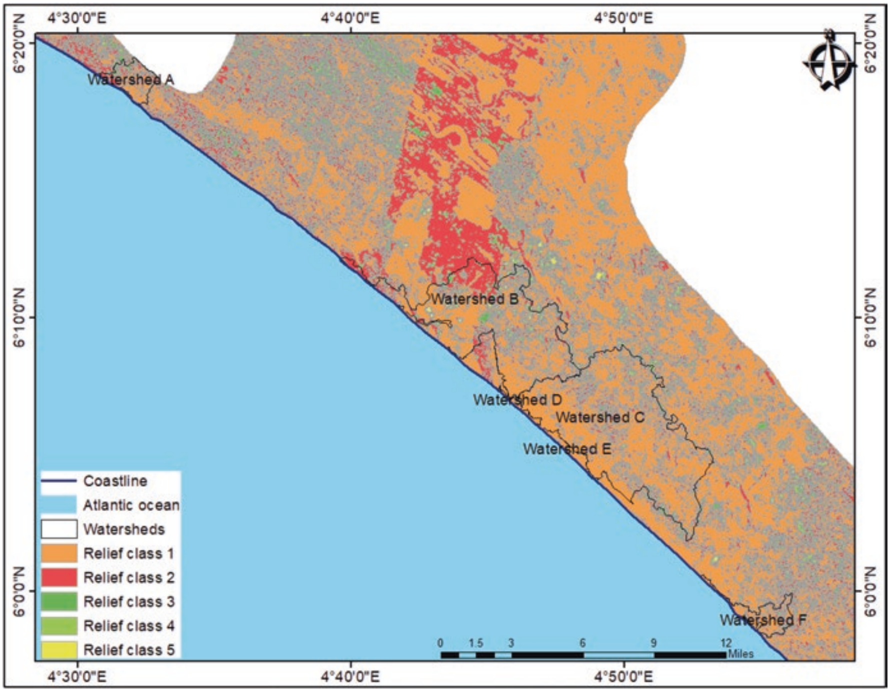

Fig. 15.6 Relief map of Ilaje showing watersheds A to F

3.2.8 Proximity to Coast

Table 15.4 also shows the vulnerability rankings for the watersheds based on their proximity to the coastline with values 5, 4, 4, 4, 4 and 3 for watersheds A to F, respectively. This was based on their distance from the coast recorded in metres with the values of 121, 319, 322, 348, 241 and 577 from the watersheds A to F respectively as shown in Table 15.3.

3.2.9 Population Density

For population density, Watershed A and B received the low ranking with value of 2, watershed C was ranked moderately with the value of 3 while D and E were ranked very high with the value of 5 and watershed F was ranked highly with the value 4 as shown in Table 15.4. They were ranked based on the number of people per square kilometre following the population density results shown in Table 15.3. The population density for the watersheds is shown in Fig. 15.7.

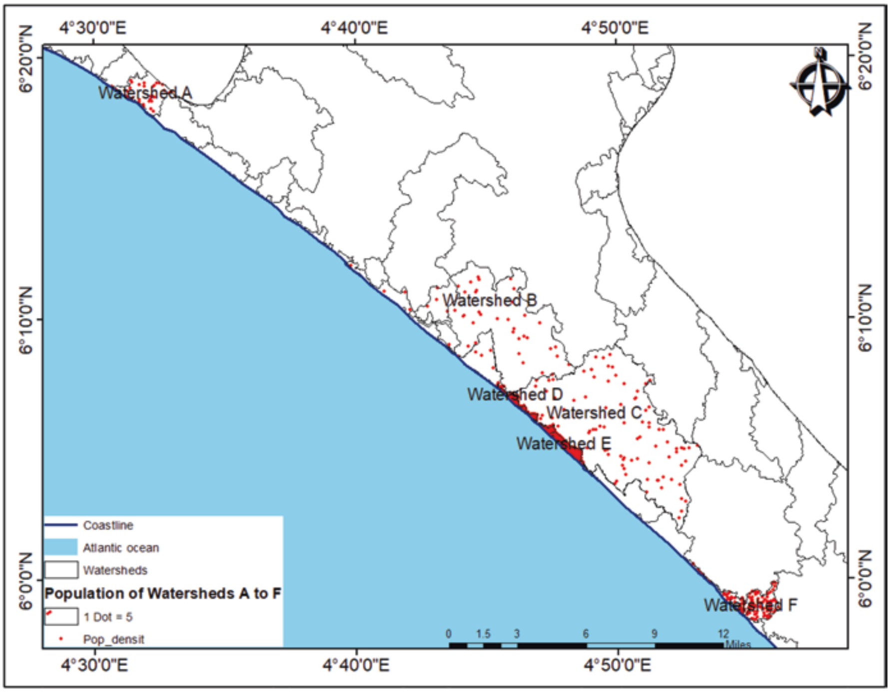

Fig. 15.7 Population density of watersheds A to F

3.3 *Social Vulnerability Indices*

3.3.1 Groundwater Consumption

All respondents except one from Watershed C reported that their communities do not engage in groundwater consumption hence the very low ranking of 1 across all watersheds in Table 15.4.

3.3.2 Oil Exploration

Oil exploration was reported to be high across all of the watersheds leading to the high vulnerability ranking of 4 for all the watersheds as shown in Table 15.4.

3.3.3 Availability of Shelter Houses

On the availability of shelter houses in case of flooding disaster across the watersheds, all respondents from the watersheds reported the absence of shelter houses in their communities, hence the very high vulnerability ranking of 5 in all watersheds as shown in Table 15.4.

3.3.4 Availability of Emergency Services

On the availability of emergency services when water-related disasters occurred, reports showed that the majority of the respondents reported absence of such services in their communities with only 1.1 and 5.3% of respondents from Watersheds B and D respectively reporting that the emergency services were only present at the state level. This caused all of the watersheds to be very highly vulnerable with a rating of 5 as shown in Table 15.4.

3.3.5 Communication Penetration

Respondents were asked about the level of communication penetration into the watersheds for anticipated flooding events. Majority of the respondents reported that such information was provided only through the direct access to radio communication. A lesser percentage reported that they were often informed by the traditional rulers and town criers. Only 12.8% of respondents from Watershed C reported that they had access to print and electronic media with another 2.6% of respondents from Watershed C stating proximity to the local government headquarter. None of the respondents reported a zero access to information. Corresponding vulnerability ranks for the communication penetration are shown in Table 15.4.

3.4 Calculation of CVI

For the calculation of the CVI for the communities within 1 km of the Ilaje coast, six watersheds were used. The watershed delineation was based primarily on flow direction, flow accumulation and drainage pour point through a common outlet. More so, each of the six watersheds displayed in Fig. 15.9 reveals a region with common drainage outlet. The size of each watershed differs in length. Although, on average, the watershed length is 34 km. Vulnerability indicator for each watershed is calculated and ranked. The results range for the coastline watersheds were normalized and classified into five vulnerability classes (very low, low, moderate, high and very high) based on percentile ranges. Accordingly, the calculated results gave the following ranks of vulnerability: 0.3 (very low), 0.78 (low), 0.83 (medium), 0.95 (high) and 1.0 (very high). The indicator rankings for the six watersheds along the coast are presented in Table 15.3. The most vulnerable watershed (Watershed D) had a low slope (0.4%), low relief (3 m), very high shoreline change rate (64 m/year), very high population density (>800 people per square kilometre) and an unconfined aquifer. These characteristics made it highly vulnerable to coastal flooding while the least vulnerable watershed (Watershed A) had a higher slope (0.6%), a relief of 5 m and a lower population density (170 people per square kilometre). Figure 15.8 reveals the calculated CVI plot for the Ilaje coast. The results revealed that 50.0% of the coastline had “very low” to “low” vulnerability, 16.7% had “moderate” vulnerability, while 33.4% had “high” to “very high” vulnerability, as shown in Fig. 15.10.

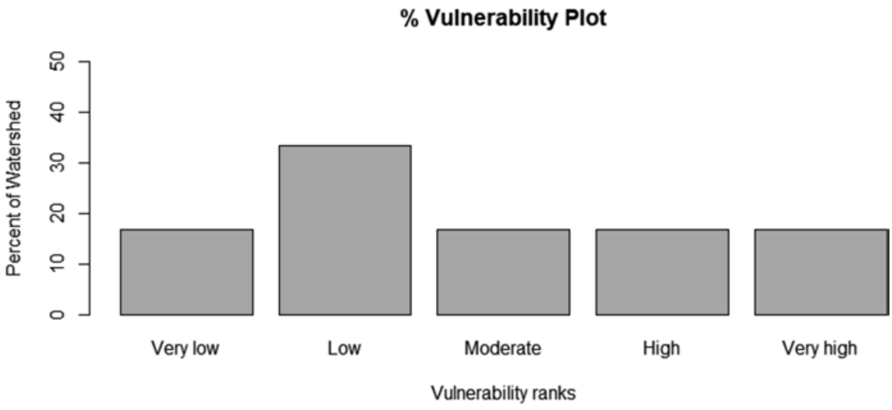

Fig. 15.8 Percentage vulnerability plot

3.5 Discussion

The Digital Elevation Model for the Ilaje Local Government was used for watershed delineation and six watersheds were identified for the communities that fall within 1 km of the coastline. The watersheds A to F respectively covered 1, 5, 3, 2, 2 and 1 communities. Watershed C was the biggest among the watersheds as it covered three communities with an area of 82.8 km^2. This may be because it contained the Aiyetoro community which was one of the earliest found riverine Ilaje communities from which the neighbouring communities were formed. It could also be a result of the bigger landmass, for example, Aiyetoro and Idiogba communities collect water from many drainage channels defining a larger boundary for the watershed C as compared to the other watersheds.

The dominant adaptation mechanisms recorded were construction of wooden bridges, building of dwelling on stilts/raised platforms, dredging of water bodies and construction of culverts and gutters. Construction of wooden walkways and building on raised platforms is necessitated for the community dwellers' movement around their environment (Ebisemiju, 2016). This supports the findings of Fabiyi and Oloukoi (2013) that traditional technologies have helped the construction of bridges using wooden planks, rock embankments for shoreline protection and concrete embankments for village protection. The communities have adapted their building materials and style to be resilient to the frequent devastating flood occurrences as reported in other researches (NDRMP, 2004). Communities take a cue from the natural features in the areas to construct their buildings, through the use of pile and raft in constructing the building foundations as evidenced by other studies (Fabiyi & Yesuf, 2013; Ebisemiju, 2016). Ojile et al. (2017) also reported that the affected communities along the Nigerian coast have developed some ingenious local strategies such as use of *sand bags* down the shore and erection of canals, channels and other systems of the water drainage for adaptation and to build resilience against coastal flooding.

The communities rarely made use of groundwater for the domestic purposes except bathing. They are however conditioned to use the available water for any purpose when potable water supplies become very scarce (Ebisemiju, 2016). Portable water is made available in limited quantity at the certain points or platforms where the community residents take turn to fetch from aside the normal rainwater harvesting practised by the communities. The rare utilization of underground water could be attributed to the saline content of the water resulting from groundwater infiltration and surface water pollution by sea water. This is in low conformity with the NDRMP (2004) report of over 40% dependence on groundwater by residents of coastal communities along the Nigeria coast.

Oil exploration was also reportedly carried out in some of the communities as the Niger Delta has abundance of crude oil and natural gas deposits, and this relied upon by the Nigeria's economy as its mainstay. This region is being patronized and operated by numerous multinational oil and gas companies (Musa et al., 2014). Exploration and exploitation of oil and gas has resulted in environmental degradation because of abandonment and inadequate government attention and the multinational companies in managing the environment of the area (Mmom & Aifesehi, 2013). Oil and gas extraction have increased the land subsidence in the delta, with the values ranging between 25 and 125 mm per year (Syvitski, 2008). This subsidence reduces the elevation of coastal areas and leads to relative sea level rise.

Shelter houses in the periods of flooding are unavailable across all watersheds, emergency services are also unavailable with communication penetrating the communities mainly through direct access to the radio signals and recently mobile phone usage. These conditions which combine to make the watersheds socially vulnerable may result from the limited access by road to the coastline communities for establishment of the infrastructures and facilities to aid coping and build resilience against coastal flooding. The NDRMP (2004) similarly reported that many roads or stretches of roads leading to the coastal communities are in poor condition as around 40% of the total length of road in the Niger Delta region falls into this category making the coastal communities difficult to access.

Considering the results of the biophysical vulnerability indices, the watersheds with sand beach and mud flats were ranked with the highest risk rating of 5 while the estuaries and lagoon fronts were assigned the risk rating of 4. The risk ratings of 5 and 4 were recorded for watersheds A, C, F and B, D, E respectively. Watershed A is the most elevated with a relief of 5 m with the other watersheds averaging a relief of 2.6 m. This may be because watershed A is farther upland as compared to the other watersheds. Level of elevation of communities is crucial when discussing their vulnerability to flood and inundation (Tol et al., 2008; Vaughan, 2008; Jana & Hegde, 2016). At the point when the Niger Delta shoreline is immersed, the beach front locale of the Niger Delta and its seepage example would permit the internal progression of sea water inland with the capability of immersing inland networks of lower elevation than that of higher elevation (Musa et al., 2014; Oyegun et al., 2016).

Other biophysical indices considered such as slope, tidal range, wave height, shoreline change, type of aquifer, proximity to the coast and population density in interaction with the social vulnerability indices were ranked and utilized for the computation of the CVI for each watershed (Eslamian & Maleki, 2021). These factors influence the community and watershed susceptibility to the coastal disaster for example, flooding and inundation (Thieler & Hammar-Klose, 2000; McLaughlin et al., 2002; Dwarakish et al., 2009; Pendelton et al., 2010; Torresan et al., 2012; Balica et al., 2013; Musa et al., 2014; Oyegun et al., 2016; Di Risio et al., 2017).

The CVI map for the Ilaje Coast is displayed in Figs. 15.9 and 15.10. The calculated CVI values range from 0.30 to 1.00 and this is detailed in Table 15.4 for each watershed. The CVI scores were grouped into "very low", "low", "moderate", "high" and "very high" vulnerability levels considering the percentile rankings. The lower range of the CVI values indicates very low risk, then low risk, moderate risk, high risk, and ends with the upper range of values indicating the watersheds having very high risk. Six watersheds covering an area of 154.3 km^2 along the shoreline were ranked in the study. Watershed D covering an area of only 1 km^2 of the coast was found to be very highly vulnerable while 56.5 km^2 of the coast's area for

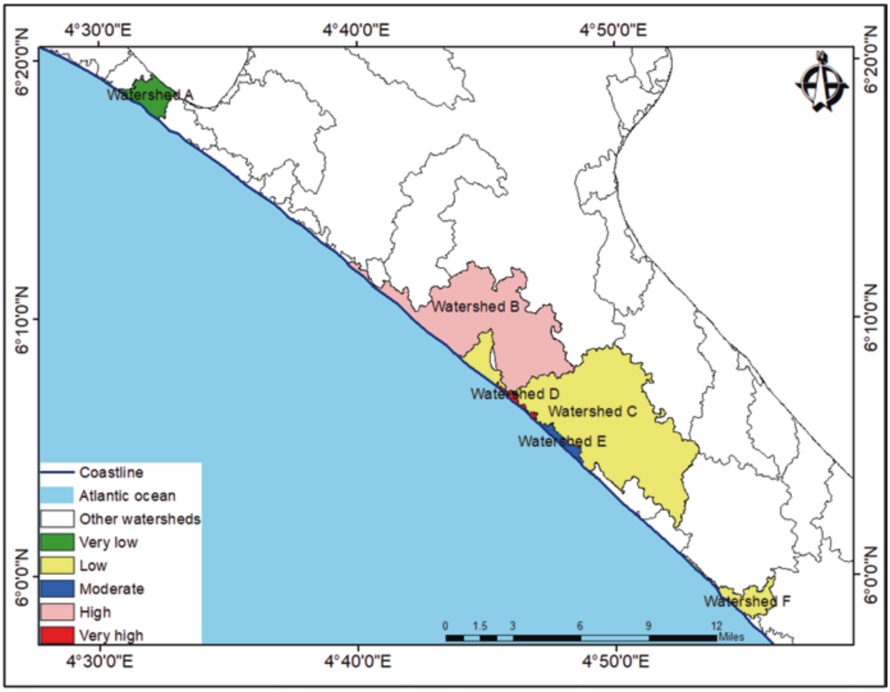

Fig. 15.9 Watershed vulnerability map

watershed B was highly vulnerable. 1.9 km^2 area for watershed E was of moderate vulnerability while 82.8 and 6.0 km^2 areas for watersheds C and F respectively were of low vulnerability. Watershed A covering an area of 6.2 km^2 was the least vulnerable watershed and categorized with very low vulnerability.

Watershed D is the most vulnerable watershed as it was placed in the "very high" ranking. This may be because it has a lower slope (0.4%), low relief (3 m), very high shoreline change rate (64 m/year), very high population density (>800 people per square kilometre) and an unconfined aquifer. These attributes could suggest why it is most vulnerable of all the watersheds to coastal flooding. Watershed B is ranked highly vulnerable. Watershed E is moderately vulnerable and has the second highest relief of 4 m. Watersheds C and F may have a low vulnerability because they have more land mass than the other watersheds with leaky confined aquifers and mildly effective adaptation mechanisms with more distant proximity to the coastline. On the other hand, the least vulnerable watershed (Watershed A) had a higher slope (0.6%), a relief of 5 m and a lower population density (170 people per square kilometre). These attributes may have caused the watershed to be the least vulnerable to the coastal flooding. It may also be attributed to the watershed A located farther upland as compared to the other watersheds.

The findings imply that in case of a flood occurrence along the Ilaje coastline, with reference to communities within a 1 km distance from the shoreline, Eruna and

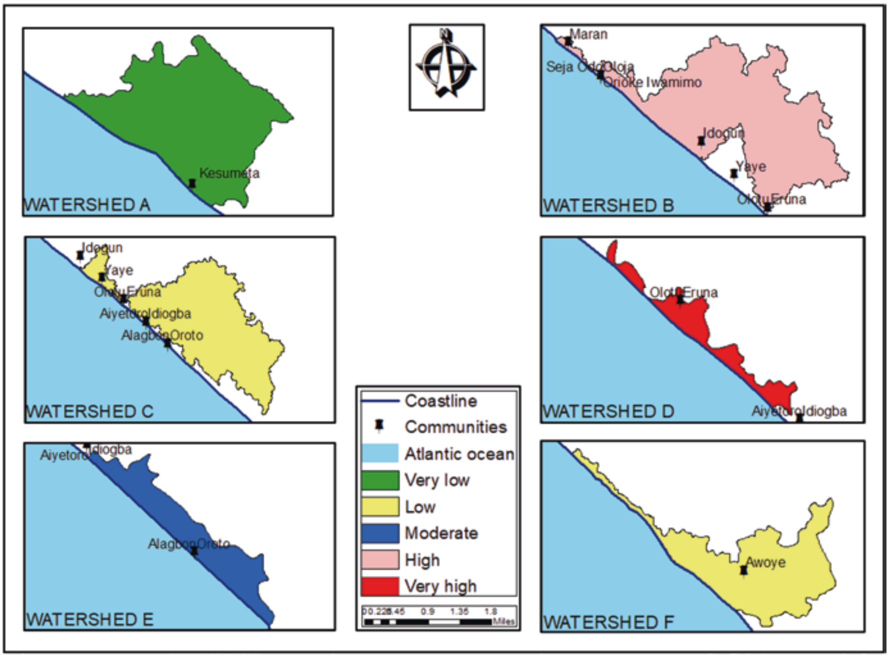

Fig. 15.10 Vulnerability map for each watershed

Olotu communities of watershed D would be most likely inundated while Kesumeta of watershed A would be least affected.

These variables represent the biophysical and social coastal properties with adaptation measures interacting to define the vulnerability of the watersheds. The biophysical properties are the intrinsic qualities of the framework that is exposed to probable risk (Cutter et al., 2008). The social properties are the attributes of a vulnerable system that dictates the level of harm from a disaster (Birkmann, 2007). The adaptation measures increase the resilience of the watersheds enabling them to adapt to and decline the conceivable effect of the calamity on the vulnerable populace.

4 Conclusion

Vulnerable coastlines expose inland regions to the SLR effects, opening gateways for storm surges, inundation and coastal erosion. Considering the rising ocean levels and other beach front risks, an evaluation of coast for its exposure to these dangers is significant, it is crucial to adopt/develop adequate and sustainable strategies for protection of the populace, their properties and even the high/very highly vulnerable ecological zones. The CVI employed for this study provides further insight on the vulnerability of the Ilaje Coast to erosion, coastal flooding and SLR at watershed levels.

The six watersheds identified in the study covering an area of 154.3 km^2 of the coastline were ranked into vulnerability classes based on selected indicators. Watershed D covering an area of just 1.0 km^2 of the shoreline was ranked very highly vulnerable while 56.5 km^2 of the shoreline for watershed B was ranked highly vulnerable. About 1.9 km^2 for watershed E was categorized as moderately vulnerable while 82.8 and 6.0 km^2 for watersheds C and F respectively were categorized under low vulnerability. Watershed A covering 6.2 km^2 was the least vulnerable among the watersheds and categorized under very low vulnerability. From survey and observation, the communities within the watersheds are not sustainably equipped to manage flood occurrences. There were no proper and systematic frameworks from community, local and state governments for reducing the flood risk and related events. The few measures observed were adaptive in nature and get only strengthened in times of inundation to cope with a current episode of flood attack.

The study observed the need for integration of traditional knowledge with western climate information for climate risk reduction strategies, which will empower the coastal communities with recent and effective tools for combating the current and future flood disasters. The results indicated a gap between community coping strategies and government provided coping strategies. An Integrated Coastal Zone Management (ICZM) will be effective to fill this gap if public and private agencies engage in scientific and transdisciplinary knowledge co-produced with researchers to successfully manage coastal flood risks.

The study conclusively reveals the importance of remote sensing data and geographic information system analysis tools for coastal vulnerability assessment. The vulnerability maps produced therein provides information on the level of threats to people living in the coastal regions and suggests the communities to be prioritized based on their vulnerability levels to achieve the coastal community coping strategy sustainability.

The findings and recommendations of this study are relevant for most parts of the Nigerian coastline which face inundation and associated environmental, social and economic challenges as global sea level rises. Further study is recommended using more inclusive approaches to flood and disaster management in coastal areas, employing more wholesome indices and variables with the use of recent and relevant data which were limiting factors during this study.

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Chapter 16
Disaster Risk Reduction: Detecting Himalayan Glacial Lake Outburst Floods

Prabal Barua, Abhijit Mitra, and Saeid Eslamian

Abstract The planet's largest and young aged mountain belt is Himalayas, which is not a single range with various valleys and plateaus or duns among them. The mountain area contributes as the living places of nearly 10% of the earth's population. The topography of Himalayan mountain is physically active, extremely susceptible to the climate change induced different hazards and acting as an important contribution in world hydro-meteorological cycles and biodiversity. With the rising influences of changing climate to the glaciers as well as ice caps during the period of the last some decades, population living around the region of Himalayas have considered as the most susceptible for the greater vulnerability of Glacial Lake Outburst Floods (GLOFs). The climate change effects around the surrounding area of the mountains of the Hindu Kush-Himalaya (HKH) are clearly observed according to the different devastating impacts recorded. Increasing climate variability is by now affecting the unavailability of ground and freshwater, environmental ecosystem, crop production, and severe changing pattern of weather ultimately responsible for the increasing rate of flash floods, debris flow, and distressing landslides. Climate change is anticipated to have the tremendous effects in the upcoming decades in HKH. Adaptation options in retort to the climate change are gradually rising around the Himalayan region, but policymakers of the surrounding countries are facing complex challenges. Respective governments of the surrounding countries of HKH are taking adaptation strategies that are typically incremental and still not well coordinated with progress plans and initiatives. In this book chapter, the authors focus on the history of Himalayan glaciers outburst flood and their types, disaster risk reduction and adaptation practices by the communities and Government agencies for reducing the damage of the outburst flood in the affected areas across the eight

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nations with the boundary in the HKH—Bangladesh, India, Pakistan, Afghanistan, Bhutan, China, Myanmar, and Nepal. This is the leading requirement of countries around HKH to formulate the right strategies and approaches for integrating the coordination mechanism and monitoring process for glaciated topography and to cooperate in deducting the recurrent damaging impacts of GLOFs on the nearby countries population that is susceptible to this natural hazard.

Keywords Disaster · Risk reduction · Himalaya · Glacial lake · Flood · Natural hazard

1 Introduction

The mountain which is known as the Himalayas becomes dwelling to the largest peak in Mount Everest at 29,000 feet, that also the third-highest ice and snow deposited mountain in the planet. The mountain of Himalaya is currently amongst the nearly all vigorous tectonic zones in the world and traverses eight nations that are Bangladesh, Bhutan, Afghanistan, India, China, Nepal, Pakistan, and Myanmar that support to continue the smooth flow of the 10 most vital important river systems—Brahmaputra, Ganges, Amu Darya, Indus, Irrawaddy, Salween, Mekong, Tarim, Yellow, and Yangtze. This mountain system covers an area of bout 2400 km^2 within 3500 km wide of the Hindu Kush–Karakoram–Himalayan (HKH) ranges and is enriched with biodiversity, vast natural resources, and diverse weather characteristics. Frequently considered as the third pole, the HKH glaciers encompass the largest ice cover outside the North and South poles, which are a serious foundation of water for 240 million inhabitants who are presently living in the mountain belt and its surrounding foothills.

The role of topographic analysis on the landscape of Himalayas mountain indicated that this mountain region becomes the high prone to an earthquake because plate tectonic fault created nearly 100 years ago (Kirby et al., 2008). Presumptuous the long-term river erosion in mountain belts can be replicated as an influence ruling purpose in the conduit slope versus discharge of water (Whipple & Tucker, 1999), the progressive decrease of the gradient of the conduit with upstream vicinity is conventional (Hack, 1960). Besides, extended profiles of rivers that created from Himalayas do not refuse from their mountain foundations asymptotically to the Gangetic Plains but in its place display the downstream steepening over vigorous fault structures like the Main Central Thrust (Seeber & Gornitz, 1983). Quantification of the scale of steepening has facilitated the differential rock to strengthen the fields and their connected structure of the fault to be recognized in a range of settings (Kirby & Whipple, 2012) with an earliest relevance in the Himalaya (Hodges et al., 2004).

Glaciers are considered as a functional pointer of changing climate in the elevated mountain atmosphere while having noteworthy pressure on the regional water availability (Immerzeel et al., 2010). Their recoil has been recorded and monitored in a lot of mountain areas (Ostrom, 2005; Raup et al., 2007; Scherler et al., 2011). Further glaciers reduction also forecasted for the South Asian region's mountains (Bolch et al., 2012). In spite of the hydrological outcome of the glaciers of HKH for the contiguous lowlands, all the surrounding areas of Himalayas are spare and inconsistent. There is an absence of longer period series and research studies, predominantly for the Himalayan glaciers at greater elevations (Armstrong, 2010).

Regional differences of climatic variabilities among the cold weather nations and seasonal monsoons depended on countries whose version for the indecisiveness is on the trend in shifting of glaciers at the level of the entire Himalayan region (Thayyen & Gergan, 2010). The small country Bhutan is a neighbor country of India and very close to the Central Himalayas, found moving back at different rates during the rainy season glacier flood occurred (Bhambri & Bolch, 2009), changes are significantly smaller in the location of west part of greater Himalaya (Schmidt & Nusser, 2009). Likewise, Siachen Glacier observed in the east site of Karakorum comes into the view to have been comparatively stable over the last 50 years (Ganjoo & Koul, 2009).

Since the year of 1990s, there is no even information about the Himalayan glaciers that located on the western side of the Karakorum mountain which located the border of India, China and Pakistan (Gardelle et al., 2013). This is proposed that Trans-Himalayan areas of Ladakh may be positioned at the boundary between the shrinking and advancing glaciers. Because of semi-arid circumstances and moderately high temperatures in these areas (Heid & Kääb, 2012), glaciers existing in the location of innermost of Ladakh are comparatively small (<0.75 km^2) and characteristically located at 5000–6000 m above sea level. Some authors (Hewitt, 2007; Kääb, 2008) stated that small glaciers as a superior pointer to the changing climate because of their direct response to comparatively short-term fluctuation of climate, whereas other authors stated that small glaciers are not to signal for warning of climate change (Quincey et al., 2009; Schmidt & Nusser, 2009).

2 Melting of Himalayan Glacier

Himalayan glaciers considered as third largest reserve of ice which lie outside the polar region with a probable area of about 33,000 km^2. Bajracharya et al. (2007) recorded nearly 15,000 glaciers and nearly 9000 glacial lakes were documented around the Himalayan mountain zone from 1999 to 2003 period. The planters glaciers are among the top nature's furthermost renewable depositories of water which mostly are freshwater in the earth. The mountain region itself hosts the various diverse cultures and a widespread assortment of the large diversity of fauna and floral species among the world. This also acts as an obstruction to the northerly wind flow during the season of winter and hold down the monsoon season that is the major source of precipitation for South Asia.

As a consequence of speedy urbanization, industrialization, and anthropogenic actions during the last few decades, this was noticed that there has been an increase trend of global temperatures and a rapid move away of snow cover internationally. Glaciers are the superior indicators for studying differences in the air temperature over the world history. These ice masses are being lengthily deliberate to comprehend the current process of the climate change induced universal warming. Following the termination of the glacier advance at the end of the Modest Ice Year (more than 100 years ago), a general trend of depletion and retreat has been observed in glaciers across the earth. The Himalayan glaciers are no exception to the prevailing impacts of global warming and climate change. As a response to the warming atmospheric temperatures, glaciers melt, forming lakes at the terminus of the ice mass or within the main body of the glaciers. As consequences of the swift accrual of the melting cold water in various mentioned lakes, that is called as a glacial lake induced outburst flood (GLOF) (Table 16.1).

Table 16.1 Principal glacier-fed river systems of the Himalayas

River	Mountain area (km^2)	Glacier area (km^2)
Indus	268,842	7890
Jhelum	33,670	170
Chenab	27,195	2944
Ravi	8092	206
Sutlej	47,915	1295
Beas	12,504	638
Jamuna	11,655	125
Ganga	23,051	2312
Ramganga	6734	3
Kali	16,317	997
Karnali	53,354	1543
Gandak	37,814	1845
Kosi	61,901	1281
Tista	12,432	495
Raikad	26,418	195
Manas	31,080	528
Subansiri	81,130	725
Brahmaputra	256,928	108
Dibang	12,950	90
Lohit	20,720	425

Sources: Richardson and Reynolds (2000)

3 Flood History of Himalayan Glacier

Glacial lake-induced outburst floods (GLOFs) become the most destructive natural disaster on the planet that creating an enormous loss of the Himalayan mountain-based countries. During 1975, 61 Himalayan glaciers induced floods have been occurred while 16 flood events are recorded before 1975. Chronologically, the majority record of outbreak GLOFs are concerted nearly the year of 1990s. There are record of 17 glacial lakes outburst occurrences after the year of 1990, and that lakes lingered steady from the outbreak year of 2015, excluding Luggye Tsho as well as Jialongco. Among the 17, 14 lakes could be well checked and confirmed for Glacier Lake Outburst Flood through images of remote sensing process. Nie et al. (2017) found that among the 61 events, 27 well-recorded GLOF events show that all of them occurred between April and October with the majority (18) occurring between June and August. These statistics entail that GLOFs hardly ever happen at the moment of frozen phase from the month of November to March (Fig. 16.1).

The main general cause of moraine-dammed failure in the Himalayas is mass movement entering the lake and subsequently overtopping and eroding the damming moraine (Rounce et al., 2016). The configuration and incidence of Himalayan Lake flood induced disasters are frequently topic to the different factors, categorized into the external hazards like landslides, snow rushes, downpour, glacier proceed, earthquakes, and internal hazards such as meltwater, leakage/piping, and others (Luijting et al., 2018).

According to the collapse approaches, Himalayan glacial lake outbursts could be categorized into five categories: (1) Outburst floods are generated through the wave actions, the level of floodwater increases, and the surface of the lake produces a displacement impression and the swarming water kick off the violation of the moraine dam devoid of the opening of the outlet channel (Pradhananga et al.,

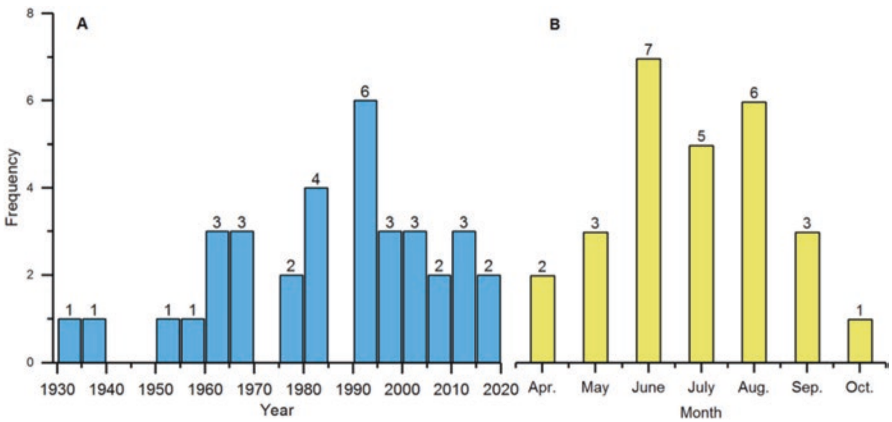

Fig. 16.1 Chronological (**a**) and seasonal (**b**) frequencies of historical GLOFs labeled with the number of outburst events (Nie et al., 2017)

2014). (2) The Himalayan outburst floods activated by the leakage/piping. While huge amount of buried ice surround around the moraine dam as dissolve or seepage stages, the capacity of dam become overflow and then outburst of glacier lake damaged the loss of property nearby the community living places. (3) Outburst floods prompted through the strong earthquake and during the time of happening, moraine dams could suddenly crumple. (4) Outburst floods provoked by the flowing water corrosion because of the damaged of moraine dam, that is creating momentous hazards which ultimately fraction of the moraine dam will suddenly smash. (5) Outburst floods are consequences of the various joined factors and during the moment snow/ice/rock bodies reach the Himalayan glacial lake they further submerge the slit of the outlet conduit which consequences in dam crest damage and lastly outburst floods.

4 Disaster Risk Reduction

The Government and other relevant stakeholders of the Himalayan mountain-based countries should incorporate the Himalayan Glacial Lake Outburst Flood as a disaster risk management approaches. The local communities always suffered huge damage to life and assets due to the lack of disaster preparedness strategies. To ensure the disaster-free life and livelihood with jeopardy, taking precautionary actions is one of the guiding principles which is vital for the disaster induced disaster risk management (Dalezios & Eslamian, 2016).

This is assessing that Himalayan glacial lake outburst is an occurrence with the few happening, and its jeopardy is habitually derelict by the communities and respective countries' governments. This is recorded that the financial fatalities are consequences through the damage of Himalayan glaciers devastating flood which are the most significant rather than other damaged that happened to combine moraine dams and discharge the flood waters in the opportune method.

Prevention and control measures for pre-disaster management are far more effectual than the recovery of post-disaster period and the time of the reconstruction process (Wang et al., 2015). Among the risk factors associated with the glacier lake outburst flood, the most devastating flood are the consequences of Himalayan glaciers considered as very tricky or luxurious to preventing controlling process, but the revelation place and susceptibility of the uncovered rudiments downstream could be declined by the advancing the capacity of climate change. Respective Government of Himalayan mountain-based nations should be taken initiative on climate change adaptation and risk associated management through the time of early warning and forecasting developing the disaster treasury, disaster preventive engineering approach, and disaster indemnity.

The local Government administration should take proper monitoring and prevention approach to reduce the damage to the Himalayan glacial lake flood hazards to the community people. But sensible measures of engineering process that decrease the capacity of the Himalayan lakes and strengthen the moraine dams are significantly efficient to alleviate or manage the GLOF disaster induced risk—what measures are most appropriate varies mainly on the circumstances of the moraine dams, the outburst jeopardy, and the difficulties of engineering approach among the other processes (Emmer & Cochachin, 2013).

Several stakeholders such as the different levels of Government department, autonomous body, civil society, academicians, researcher, non-government organizations, and local communities required to involve in the whole progression of the protection, prevention, and deduction of the Himalayan glaciers disaster risk outbreaks and associated damages. In meticulous, the people based community disaster risk management approaches required to be developed and community depended monitoring and prevention systems need to be enhanced. But many adjacent rivers and glacial lakes have carried our the noteworthy water supplies, facilities for hydropower and leisure service purposes, and communities could also take the benefit of these natural resources for the building of reservoirs, irrigation water supply, and constructing the hydropower services and applying Himalayan glacial lakes as the attraction of the tourists, particularly at the time of development planning by the respective Government of Himalayan mountain-based countries. The Government of Himalayan mountain-based countries should finalization of the natural disaster risk management planning and implementation before development and remain all the constructing buildings, highways, roads, and other infrastructures are away from potentially hazardous Himalayan glacial lakes, in contrast, to keep away from needless harm.

5 Coping/Adaptive Capacity of Local People and Government Agencies

The present stages of adaptation learning required significantly and interferences precise to the Himalayan mountain situations carry on to be extremely limited due to inadequate information of impact for climate change on the population and ecosystem of Himalayan mountain. At the similar moment, climate change adaptation is fetching significantly necessary for the Himalayan region and number of research studies indicated that climate variability significantly raised that impact severely on water availability, ecosystem degradation, and production of agricultural crops in the surrounding nations. The enormous effect of recurrent severe weather actions on life, livelihoods, and assets in the region underlines the necessity of the circumstances and the requirement to slope up the climate adaptation action there.

Among the eight HKH countries, Afghanistan, Pakistan, Nepal, Bhutan, and Myanmar are mostly mountain-based nations and, at the alike moment, four nations (excluding Pakistan) are recognized as Least Developed Countries (LDCs). In China, the people who are living nearby the mountain areas pass their livelihood with the poverty line (Luijting et al., 2018).

This is evidence that India and Nepal among the other surrounding nations of Himalayan region have experiences of many devastating disasters and the anxiety about the requirement of coping and resilience mechanism in response of climate change and other environmental degradation. Most countries have a range of the DRR management and adaptation of climate change strategies and activities; it is important to ensure that these are coordinated and that GLOF risk reduction is incorporated as one component. The government of all the countries prepared National Adaptation Action Program in response to climate change. This is a strategic tool to assess the climate vulnerability and systematically act in response to climate change by developing and implementing appropriate adaptation measures. Effective strategies for disaster risk reduction and integrated close monitoring of Himalayan glaciers outburst flood will be required for the precedence activities recognized for the surrounding eight nations which are formulation of early disaster warning systems, strengthening organizational capacity, assessment of the natural hazards, formulating the contingency policies and plans, starting of Himalayan outburst floods and climate resilience disaster management research, and effective planning for the development. The respective countries Government also sanctioned national adaptation planning frameworks of action that offers the tools and guidelines for the development and execution of different effective plans in an integrated method. Some climate change adaptation and disaster mitigation strategies have already conducted by Nepal and India for deducting the disaster risk of Himalayan outburst flood from their communities. The adaptation and mitigation plan of strategies are deducting the level of lake water with the application of siphoning test, building the unbolt channel, and development of early disaster warning system. The channel building effectively reduced the level of lake by 3 m. The early disaster warning system comprises 19 automatic signals in 100 villages, with the 3 relay centers, covering maximum human settlements with Himalayan outburst flood vulnerability along the Rolwaling/Tamakoshi Valley, Indus Valley, and other regions of India, Nepal, China, and also about 100 km downstream.

However, the system only worked for 4 years; the batteries and solar panels were taken from almost all of the stations during the insurgency, and the system collapsed. A micro-hydropower plant with 15 kW installed capacity has been constructed using the water discharge from the artificial channel at the outlet of surrounding lakes of the India, Nepal, and China, but this is not functioning at full capacity; the power is used only for the project. Through the assistance from the Global Environmental Fund and the UNDP, Nepal recently initiated a project for Himalayan glacial lake to reduce the GLOF risk by lowering the lake level and establishing a community-based early-warning system. People prefer deducting the level of lake water to installing the early-warning systems. People also keen to participate and contribute to lake lowering through construction of an open channel, and want to develop hydropower using the water discharge. The electricity could easily be supplied to the hotels and lodges in different countries, which would also help in developing the tourism activities in this area.

6 Conclusion

This is well established that impact of climate change on the Himalayan mountains is already in reality and the rising climate variability has formerly influenced the water availability, ecosystem circumstances, production of crops, and severe weather. Changing patterns of climate variability become the consequences of the outbreak of flash floods, sudden landslides, debris flow, waterlogging, and other hazards. Changing climate is expected to have solemn influences in the upcoming decades in the Himalayan mountains and within the year 2050, temperature of Himalayan mountain around the countries is predicted to rise beyond the average of 2 °C and more at advanced altitudes. The Himalayan people, particularly in isolated locations, were found further susceptible to impacts of climate change compared to non-stack areas.

This book chapter focused on the historical trend of Himalayan outburst flood, causing of flood, melting types of Himalayan glaciers, disaster vulnerability mitigation strategies, and adaptation practices for reducing the damage of communities through the outburst floods crossways the eight nations with boundary of Himalayan regions which are Bangladesh, Bhutan, Afghanistan, India, Nepal, China, Pakistan, and Myanmar. It is urgently necessary for taking the climate change adaptation strategies as the first priority for countries' policy development, but policymakers are not well motivated for taken the effective planning. In Responses to climate change, Government of respective countries initaitive as adaptation practices are typically additional and not yet strongly coordinated with the program development for disaster risk reduction.

The authors have recommended that the governments of Himalayan mountain-based countries should be taken effective climate change adaptation like the local adaptation plans for action (LAPAs) extensively for mitigation of citizens' life and livelihood loss and economic loss for the country. Governments of the HKH surrounding countries will advantage from mainstreaming these gadgets in their preparation, implementation program and process of budgeting for activities. Organizational adaptation capacity is required to strengthen at every stage of the good governance. Additionally, the community-based autonomous adaptation responses to the climate changes and severe events should be required to be thoroughly analyzed, preserved, documented, and validated for practices in other areas for mitigation of changing climate. These types of adaptation responses required to produce grave, community-based feedback for effective planning of adaptation on the elevated good governance stages. This is therefore the leading necessary for the Himalayan countries to formulate the mechanisms and strategies for the integrated monitoring of the Himalayan terrain and oblige for deducting the recurrent, damaging effects of GLOFs on surrounding communities that are susceptible to this natural hazard.

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Part IV
Climate Change Impacts and Communities

Chapter 17
Communities, Organizations, and Partnerships for Climate Change Mitigation and Disaster Reduction

Mufaro Chitsa, Subarna Sivapalan, and Khai Ern Lee

Abstract The urgent need for climate change mitigation and disaster recovery plans has resulted in the formation of resilient communities combating climate change and its impact, aided by organizations and partnerships working towards achieving Goal 13 of the Sustainable Development Goals. In this chapter, we discuss the extent to which communities, organizations, and multi-sector partnerships have helped pave the way towards the realization of the common goal on climate change mitigation and recovery. Focusing first on current methods adopted by various countries in climate change mitigation, this chapter then delves into ongoing endeavors within communities within the context of climate change and disaster reduction. The chapter concludes with the role of partnerships as a way forward in climate change mitigation and disaster reduction.

Keywords Community development · Climate change mitigation · Disaster reduction · Partnerships · SDGs · Goal 13 · Goal 17

1 Introduction

Climate change remains one of the key contributing factors towards some of the current catastrophic events taking place on our planet. Changes in the global climate intensify climate threats and magnify the probability of extreme weather catastrophes. While increase in water levels and air temperatures have led to rising sea

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levels, storms, wind speeds, prolonged drought and flooding, there are also indications that shifting weather patterns may be a threat to global food production (Thornton, 2012). Disasters associated with climate change are taking place concurrently in various segments of the world and have led to a chain of impacts to the environment and people. Climate-related disasters have also led to a rise in migration of people to countries that are seemingly more climatically stable. These relocations additionally lead to displacement of communities (Martin et al., 2017) especially those of minority backgrounds (Malik, 2011).

One of the key differences within disaster-prone countries is its ability to mitigate and recover from the environmental, social, and economic impacts resultant from the disaster. Learning from past experiences, most countries have begun to put precautionary measures in place to avoid deficits resulting from climate change disasters. First world countries seem to have in place sounder climate change mitigation and disaster recovery plans in comparison to lesser developed countries, given their economic stability. Poor countries unfortunately have been more vulnerable to the effects brought about by climate change, and largely lack disaster preparedness and mitigation plans due to insufficient financial resources. This has inadvertently resulted in communities having to adopt resilient practices to avert the threats of disaster.

Climate change and resilient communities have become a major agenda of international development plans. In 2015, United Nations Member States embraced the 2030 Agenda for Sustainable Development (United Nations, 2015). Also known as the United Nations Sustainable Development Goals (SDGs), Agenda 2030 aims at "ending poverty, improving health and education, reducing inequality and increasing economic growth" (United Nations, 2015, p. 1), while tackling climate change via 17 goals. Goals 13 and 17 particularly stand out for the importance it places on climate action and stakeholder partnerships. SDG13 focuses on "taking urgent action to combat climate change and its impacts" (United Nations, 2015, p. 1). Goal 17 meanwhile seeks to "strengthen global partnerships to support and achieve the targets of the 2030 Agenda" (United Nations, 2015, p. 1).

The effects of climate change to the people and planet were further accentuated via a 2016 United Nations report on the progress towards the SDGs. Findings presented in the report show that climate change presents the sole greatest risk to development, burdening the poorest and most vulnerable. This paved the way to the signing of the Paris Agreement in April 2016, aimed at reducing the pace of climate change and accelerating the many climate measures and investments that are essential for a future that is sustainable and low-carbon (Hickmann et al., 2019). Further to this was the urgent call to bring together governmental and private sector entities, the civil society and related stakeholders, as well as the global community in partnership to accelerate progress in achieving the SDG targets, particularly those related to climate action (Fjäder & Eslamian, 2021).

Much work has been conducted within global and local contexts supporting community-based climate change mitigation and disaster reduction initiatives. In this chapter, we discuss some of the available mechanisms in combating climate change, and ongoing efforts within communities, both top-down and vice versa, in climate change and disaster reduction. Also discussed is the manner in which communities and organizations can come together in multi-stakeholder partnerships for climate change mitigation and disaster reduction.

2 Combating Climate Change

According to the Intergovernmental Panel on Climate Change (IPCC), release of carbon dioxide (CO2) and related greenhouse gases (GHGs) must be lowered to half by the year 2050, in comparison with 1990 levels. This will require even more effort on developing countries, namely 80–95% by the year 2050, while nations such as Brazil, China, and India are required to reduce their emission progress (UN, 2019). The United Nations Framework Convention on Climate Change (UNFCCC) was initiated as a primary step towards attaining reduced global emission.

Approximately 10% of the total global emissions emanate from the EU member states. The United States, which is a significant contributor to the global GHG emissions, opted out of ratifying the protocol. In addition to the United States, several other significant contributors to the ever growing GHG emissions, such as China, have not set binding emission targets following the protocol (EEA, 2016). Signatories are to achieve their projected emission reduction objectives by resorting to national policies and processes, but they could deliver portions of their emission targets through investment in emission-lowering projects in developing countries (Bond et al., 2012). Important sustainable development aspects such as the financing of projects related to renewable energy can also be supported via the potential of the Clean Development Mechanism (CDM) (Bond et al., 2012).

The United Nations, via its numerous agencies, has been working to fight disaster reduction. One of these agencies is the United Nations Office for Disaster Risk Reduction (UNISDR), whose goal is to coordinate disaster risk reduction. It warrants collaborations between the applicable initiatives of the United Nations agencies and regional organizations including that of economic, social, and humanitarian focuses. Amongst its many roles, the UNISDR supports the execution and review of the Sendai Framework, besides advancing the goals of the 2030 Agenda and its targets, as well as the Paris Agreement on climate change (Mysiak et al., 2016).

The vision of the UNISDR is closely aligned to the Sendai Framework, which aims to foster a sustainable future with significantly lower disaster losses and risks (Mysiak et al., 2016). The Sendai Framework for Disaster Risk Reduction 2015–2030 seeks to strengthen resilience building as a common determinant, thereby prioritizing its emphasis towards the management and reduction of risk. Countries therefore codify their efforts towards disaster risk reduction by prioritizing the setting of action and specific targets using its framework. This enables them to use a methodical and systematic review process of global progress in disaster risk reduction. This systematic process would also be subject to updates in sustainable development, with the UNISDR acting as the processes' central facilitator and clearing house (Aerts et al., 2018). Supporting the Sendai Framework, UNISDR will additionally have an engaged international disaster risk reduction community. This community will include governmental sectors and policy makers, the United Nations, organizations (both regional and global), private sector entities, civil society, and scientific and technological advocates. The community will assess the improvements in the Sendai Framework by examining challenges and prospects in practice and policy consistently, while working in partnership with the Sustainable Development Goals (SDGs) and the Paris Agreement, and will also promise alignment with Agenda 2030 targets (Kelman, 2017).

Many nations around the globe have taken great strides in combating climate change. Zimbabwe for instance has formulated a child-friendly climate strategy which is aimed at educating school going children about climate change, and at the same time promoting climate-friendly habits in relation to the protection of forests and wetlands as well as the wider use of low-emissions technologies. The policy was a climate change approach aimed at achieving its international carbon-cutting pledge. The new policy stresses on guaranteeing that farmers and agricultural enthusiasts implement climate-friendly farming practices. The country's initial inclusive national climate policy purposes to help Zimbabwe formulate the legal provisions required to direct businesses towards becoming more sustainable in meeting its emissions-reduction goals as outlined in the Paris Agreement. According to the country's climate scientists attached to the Ministry of Environment, Climate and Water, the national policy would also emphasize heavily on climate adaptation, since the nation's communities are mostly rural, and agricultural focused, despite mounting droughts (Chanza, 2018). The primary focus is on encouraging adaptation because Zimbabwe, as an unindustrialized country, has a reduced scope for mitigation or emissions due to little industrialization compared to the developed world (Chanza, 2018). In Pakistan, to show that disaster recovery and climate change adaptation is their main agenda, the government established several disaster management bodies and re-named their Ministry of Environment to the Ministry of Climate Change (MoCC). The key policies and approaches established by federal institutions include the Environment Protection Act, the Pakistan Climate Change Authority Mandate, and the National Forest Policy (Khan & Yaseen, 2017).

The legal aspect is yet another interesting dimension to combating climate change. More people in different parts of the world seem to not hesitate to take legal action over issues relating to the climate. A survey on climate change lawsuits conducted by the United Nations Environment Program and Columbia Law School indicate that incidences of lawsuits will increase, with courts playing a major role in combating global warming over the years to come (Smith, 2018). Interestingly, citizens have also resorted to suing their State as well as some of the most prominent and largest global oil and energy conglomerates over failure to provide a safeguard against the dangers and potential consequences of climate change. One such case is the case of Citizens vs. the government of the Netherlands. The case, which set a precedent climate lawsuit in 2015, involved a total of 900 Dutch citizens who were represented by the Urgenda Foundation to take action against the government in order to reduce greenhouse gas emissions nationwide. The group won, signaling the increasing importance of climate change mitigation. Citizens vs. the government of the Netherlands was the first case to see such success in its lawsuit. As a result, the Dutch court ordered the government to ensure that they reduce their emission of greenhouse gases by approximately 25% across the entire nation by the year 2020, which is a significant change in comparison to 1990 levels. This compelled the Dutch state to take extra measures to counter climate change. Similar litigations soon followed suit across the globe. A recent example of this can be found in Belgium, where musicians, artists, and filmmakers collectively sued the Belgian State government, challenging it to improve on its greenhouse gas emission reduction pledge, and for the state government to increase its climate change strategy and commitment (Brändlin, 2018).

Unfortunately, the organizations and actors exemplified above face hurdles in applying concrete adaptation and mitigation measures. Firstly, with climate change hazards taking place more frequently and intensely, many institutions have not yet reached the maturity level that is often required in developing competent human capital and the expertise required to tackle these multifaceted issues (Brändlin, 2018). Secondly, the efficiency of development and humanitarian organizations is also often hindered by the interplay of political influence and power relations between them and government bodies. Lack of accountability on obligations moreover impedes progress, particularly where security concerns persevere (Brändlin, 2018). While funding has also influenced ways in which climate-focused institutions function, data and statistics are also significant in considering the influence and costs of disasters to enable nations to formulate data-driven policies that may help reduce the risk of disasters and build resilience.

3 Communities as Frontliners of Disaster Risk Reduction and Climate Change Mitigation Efforts

In disaster-prone countries, it is crucial to revert to the principle of disaster risk management when an emergency strikes so as to safeguard the people and assets. This mindset can be augmented into society by developing a safety-oriented culture in disaster-prone zones to reduce costs and risks in terms of loss of lives and property. During events of a localized nature, communities are the first line of defense and have the potential to effectively identify, handle, and address risks related to disasters. Hence communities must be provided the necessary capacity building, awareness, and training to plan for disaster reduction solutions that minimize susceptibility to natural hazards within their regions (Sutherland, 2019). Instances of such efforts are illustrated in the paragraphs that follow.

The adoption of impending disaster warning systems has been on the rise most notably in regions where natural disasters such as active volcanos are on the rise. An example of such is the Early Warning Systems (EWS) for volcanoes. The United Nations has formulated a set of basic EWS guidelines which are not binding and optional (Dewanti et al., 2019). While such systems help in lessening and even eradicating the harmful social and economic impacts of volcanic activity by managing and setting communication tools for the parties affected, its effectiveness in monitoring and forecasting volcano hazards as well as managing volcano observatories vary (UNDP, 2010). Volcano EWS can be managed by any selected party in the community, with variations expected as a result of the respective countries' disaster management policies.

In Madagascar for instance, the country's Community-Based Disaster Preparedness Project (CBDPP) involved initiating a public education campaign on the various types of threats and exposures affecting their country. This led to a drop in losses and reparations, besides saving lives from disasters. The country's awareness creation on dealing with cyclones and flood hazards also produced positive impact. However, the country was engulfed in an economic situation which led to its reliance on donor support, which impacted its financing measures (Sufri et al., 2020).

Malawi is another example of a nation that has implemented CBDPP. With its districts experiencing drought and floods regularly, these have become the most common natural hazards the country has had to manage. Given that the districts of Nsanje and Chikwawa are frequently affected by these natural disasters, a CBDPP project was implemented in the Chikwawa district which lies along the lower flat basin of the Shire River. The success of the project was attributed to the country's terrain. The district is bordered on the eastern side by the Thyolo escarpment, which is the source from where most rivers and streams flow. The zone is mostly dry, with below average rainfall. To its drawback, over 63% of the population depends on agriculture for their income. Farming is largely reliant on rainfall, as irrigation infrastructure and development are below par. As a result, an EWS that was also intended to be user-friendly was set up for the affected communities. The successful implementation of this disaster preparedness project was also due to the roping in of other stakeholders such as the educational sector vis-à-vis schools. Further contributing to the successful implementation was the involvement of faith groups and leaders. Through weekly gatherings, faith groups and their respective leaders boosted the effectiveness and efficiency of information dissemination, leading to savings in terms of time and money (Šakić-Trogrlić et al., 2018).

In 2006, World Vision Mozambique (WVM) in collaboration with Tulane University (USA) developed a community-based disaster preparedness project named Gestão de Risco a Nível da Communidade (community risk management) GERANDO. The project was designed to address the susceptibility of communities where WVM was present. The primary aim of the project was to design a Community Early Warning System (CEWS) to contribute towards the reduction of risks associated with both man-made and natural hazards. GERANDO made sustainability its primary focus, considering the current economic situation in Africa which has made most of the continent economically unstable (Macherera & Chimbari, 2016). Through factoring in the country's economic state, the project was therefore able to empower communities to concentrate on detecting and acting on their own problems. The project also had the additional advantage of increasing community self-efficacy that is often absent in poor communities. This was achieved through assisting the larger community in using their own skills to tackle their difficulties and establish priorities via consensus. The communities were also able to participate in their own mitigation initiatives. However, similar to any other new methodology, there is room to take stock of improvements so as to make future iterations of similar programs less challenging (Djafar et al., 2019). Established best practices formed the basis in shaping the approaches, tasks, timing, and responsibility of each step under GERANDO. Further to reinforcing the quest to help communities understand their own potential, was the significant participation of the community in the decision-making process. This project saw the significant involvement of previously overlooked community members such as women, the elderly, and youths in the decision-making process. As a result of the community improving their self-efficacy, the community's reliance on external sources of support was also considerably reduced. A greater sense of ownership and collective accountability additionally reduced dependence on Non-Governmental Organizations (NGOs) for distribution of funds and potentially higher repayments. To effectively implement such community-based projects, greater level of stakeholder agency, transparency in processes as well as greater commitment in promoting sustainability and minimizing or eliminating dependency is vital (Sufri et al., 2020).

As current efforts to reduce disaster risk, poverty, and adaptation to climate change are hardly linked to each other, a 2009 ISDR global report suggests a paradigm shift in disaster risk reduction is needed (DRR). This paradigm shift, which seems to be the way forward, points towards embedding a mainstream development thought process towards DRR. This can be attained by infusing sectoral based approaches and tools, linking policy and governance frameworks to DRR, combating poverty, and conceiving strategies for climate change adaptation to bring out the best in local practices (Klein et al., 2019).

4 Partnerships Between Communities and Organizations as a Way Forward for Climate Change Mitigation and Disaster Reduction

It is encouraging to note that the last few years have witnessed major growth in the recognition of the important role played by partnerships in improving humanitarian outcomes. Partnership models differ to achieve its intended outcomes (MacDonald et al., 2019). Multi-stakeholder partnerships for instance are essential for successful disaster risk reduction (DRR), given that such collaborations play a crucial role in the alignment and integration of DRR. NGO-driven partnership models, namely those between international NGOs, between local and international NGOs, international NGOs partnering with local and federal governments, or NGOs opting to directly partner with local communities (MacDonald et al., 2019) are equally essential in disaster risk reduction and climate change mitigation, and have become the common go to model adopted and trialed in DRR initiatives. Partnerships are critical in the integration of DRR with adaptation to climate change, humanitarian responses to disasters, and sustainable development. Two such partnership initiatives are presented here as a point of comparison.

Malaysia enjoys a relatively safe climate change and disaster risk status as it has not experienced major catastrophic natural disasters. However, there are various parts of the country which are affected by seasonal floods at various times of the year annually. Partnerships are seen to be essential in the nation's preparedness efforts. In 2007, MERCY Malaysia, a non-profit that focuses on giving medical relief for vulnerable countries in times of crisis launched a program to increase the community's preparedness for disasters. The inaugural program began in the state of Johor, with a local school being the focal point of the program (Shafie, 2009). As a result of this initiative, the pilot project *The Safe School Programme* was launched. This project subsequently evolved, generating two distinct spin-offs, namely the *School Watching Workshop* and the *School Preparedness Program*. The success of the partnership project has now seen it becoming a model initiative within Malaysia and across the region in terms of fostering programs aimed at ensuring preparedness. The program has acted as a benchmark in MERCY Malaysia's ties with other local and international partnerships in Cambodia, China, and Indonesia. The benefits of such partnerships have also seen MERCY Malaysia directly train approximately 2995 students and over 491 teachers. Over 150 schools, students and teachers have also participated in training of trainers programs (Chan, 2015). The Southern Climate Partnership Incubator (SCPI) initiative is another instance of partnerships for climate change and disaster risk mitigation. The program included the formulation of an international report on South-South cooperation on climate change (Weigel & Demissie, 2017). The cooperation was also meant to act as a platform upon which developing economies can voluntarily offer developmental support and help each other in relation to climate change strategies focusing on sustainable development and poverty reduction. These collaborations were indicative of a movement towards greater climate action cooperation (Tigre, 2016).

5 Conclusion

Climate change mitigation and disaster recovery remain an ongoing journey that calls for communities, organizations, and multi-stakeholder partnerships to work together. In this chapter, we have discussed the importance of partnerships and the coming together of communities, organizations, and other key stakeholders in combating climate change and the risk of disasters. The discussion and scenarios presented in this chapter point to the fact that the success of partnership efforts for climate change and disaster risk reduction can vary due to many factors. The key to ensuring the sustainability of partnerships lies in awareness, implementation, and monitoring efforts, both top-down and bottom-up. Policy also plays a crucial role.

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Chapter 18
Coastal Wetland Hydrologic Resilience to Climatic Disturbances: Concept, Quantification, and Threshold Response

Yu Zhang, Wenhong Li, Ge Sun, and John King

Abstract Climate change, the rising air temperature and changes in the intensity and frequency of rainfall, and sea level rise (SLR), represents one of the most important threats to coastal wetlands that have numerous ecosystem services from erosion and water quality control to wildlife habitat. Climate change-induced disturbances affect the sustainability of coastal wetland ecosystems mainly through altering their hydrologic functions. However, how to assess wetland hydrological resilience, the ability of wetland hydrology to recover from climate disturbances remain challenging. This chapter first summarizes current knowledge of the coastal hydrologic cycle and the influence of climate change on the coastal hydrologic cycle. Then, we define hydrologic resilience, identify the hydrologic conditions, and quantify the hydrologic resilience. Last, we present a case study on bottomland hardwood forests along the Atlantic coast. We applied a physically based watershed-scale wetland hydrological model (PIHM-Wetland) to the coastal wetland system and quantified the hydrologic resilience in response to climate extreme events during the recent 20 years using a distributed-system approach. The case study shows that the metrics to quantify hydrologic resilience to drought, extreme rainfall events, and sea level rise are effective and may be appliable to other similar regions.

Keywords Wetland · Hydrologic resilience · Climatic disturbances · Threshold response · Climate change

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1 Introduction

Coastal wetlands link the terrestrial landscapes and ocean providing important ecosystem services to attenuate flood, store water and carbon, stabilize the shoreline, and provide habitats for wildlife (Roulet, 1990; Tiner, 2013). However, the wetland benefits to people and wildlife are rapidly diminishing due to the serious threats from climate change in terms of the significant changes in temperature regimes and precipitation variability (Poff et al., 2002), as well as the short-term sea level variations due to hurricane, storm surge, and long-term sea level rise (SLR) (Park et al., 1989). These climatic changes disturb the coastal wetland ecosystem functions (e.g., biogeochemical and geomorphological functions) mainly through affecting the wetland hydrologic functions, the capability of coastal wetlands in storing and releasing the water through the wetland surface and subsurface (Zhang et al., 2019). For example, the changes in precipitation, temperature, and sea level affect the wetland surface and aquifer storage, thereby impacting the surface and subsurface hydrologic interactions, freshwater-saltwater balance, and groundwater level. Consequently, these hydrologic changes would influence soil organic carbon storage and vegetation productivity (Silvestri & Marani, 2004). Also, climate change impacts the capability of coastal wetlands in absorbing and releasing water through wetland surface and subsurface, therefore altering surface and subsurface flow rate and direction, which are critical drivers for coastal erosion and nutrient transport (FitzGerald & Hughes, 2019). Thus, a complete understanding of how the coastal ecosystems respond to climate change may not be achieved without a comprehensive understanding of their hydrologic responses to climate change.

Hydrologic resilience (HR) is a measure of how the hydrological processes of coastal wetlands respond to climate change because HR describes the capability of a wetland ecosystem in resisting disturbances, recovering and rerunning to its prior-disturbance hydrologic conditions (Peterson et al., 2012; Ridolfi et al., 2006; Zhang et al., 2019). Although the concept of hydrologic resilience has been accepted in the science community, its definition is still vague. For example, to what extent can one say that a disturbance is absorbed? to what extent can one say that a system goes back to its prior-disturbance condition? In addition, the method for quantifying HR is still not well developed. A lacking quantitative definition can result in an inaccurate understanding of coastal wetland resilience.

The objective of this chapter is to discuss the basic elements required for quantifying the hydrologic resilience of coastal wetlands, providing a predictive understanding of the response of coastal wetlands to climatic change. The first part of this chapter focuses on the description of hydrological processes of the coastal wetlands to provide a framework for assessing coastal hydrological response to climatic disturbances. The second part of the chapter introduces the concept of coastal hydrologic resilience and quantitative methods. The last part of the chapter presents a case study for understanding the coastal hydrologic resilience to climatic variability. The coastal wetlands are excluded in the high latitude region, like Arctic coastal wetlands, in this chapter.

2 Coastal Hydrologic Processes and Their Responses to Climatic Disturbances

Similar to the hydrologic cycle in other terrestrial landscapes, the dynamics of coastal wetland hydrology is controlled by precipitation, surface and subsurface water flow, plant transpiration, canopy interception, soil evaporation, and possibly snow in the winter season. However, unlike the inland wetlands that are dominated by precipitation and local runoff as water inputs and influenced by high topographic gradient (Fan & Miguez-Macho, 2011), coastal wetlands are located at the low gradient flood plains with relatively shallow groundwater table. Thus, the coastal wetlands are more surface water-fed but groundwater-supported wetlands (Fan & Miguez-Macho, 2011). Since the topographic gradient is small, the drainage divides of coastal catchments are not strictly defined based on their topography. Therefore, the coastal wetlands are not topographically isolated, and regional hydrologic connectivity between the upland terrestrial landscape and coastal wetlands is important to the wetlands' hydrology (Zhang et al., 2018). In addition, coastal wetlands interact with coastal processes, such as tide, sea level rise, hurricane, and storm surge, which affects the surface water flow and water storage, subsurface saturation condition, groundwater flow, and saltwater intrusion in a coastal aquifer.

Climate-induced disturbances are expected to increase in frequency and intensity and affect the hydrologic cycle of a coastal wetland ecosystem in various ways. For example, the warming climate will increase evapotranspiration. Climate change also causes a change in the intensity and frequency of precipitation. The deficit between the precipitation and evapotranspiration defines the water availability, which determines the local water supply to coastal wetlands. If climate change results in a decrease in water availability, surface water, soil moisture, and groundwater table will decline. In contrast, with an increase in water availability, soil moisture and groundwater table may rise and flooding is more likely to occur. Zhu et al. (2017) suggested that the groundwater table depth of five coastal forested wetlands along the southeast coast will drop by 4–22 cm in response to the decrease in water availability (precipitation minus evapotranspiration) in the future based on 20 general circulation model (GCM) predictions. Besides precipitation and temperature, the sea level rise (SLR) is another consequence of climate change in coastal regions. The rising sea level will intensify coastal flooding (the storage of surface water). For example, Kirshen et al. (2008) estimated that the present-day 1%-occurrence flood level was projected to become the 26%-occurrence flood level by 2100 under SLR. SLR will also break the balance of freshwater-saltwater interaction in a coastal aquifer. A large amount of saltwater will intrude into coastal wetlands and push fresh groundwater landward, thereby changing the coastal subsurface groundwater flow and soil salinity.

3 Coastal Hydrologic Resilience: Definition and Quantification

3.1 The Concept of Hydrologic Resilience

The term "hydrological resilience" can be traced back to the concept of "ecological resilience" introduced by Holling (1973), who suggested a new way to help understand the nonlinear dynamics of ecosystems under disturbances. After decades of the introduction of this concept, the definition of ecological resilience was still ambiguous. Folke et al. (2002) summarized the previous definitions into one comprehensive definition: "the capacity of a social-ecological ecosystem to absorb perturbations and to sustain and develop its fundamental function, structure, identity, and feedbacks through either recovery of the original state or reorganization in a new context, still maintaining original functions." Following this definition, coastal wetland hydrologic resilience describes the capacity of coastal wetlands in (1) absorbing the disturbances without significant change in its hydrologic regime and (2) recovering to its prior conditions before the disturbances (Peterson et al., 2012; Zhang et al., 2019).

3.2 Definition of Hydrologic Regime

From the description of hydrologic resilience above, an important part of its definition is to define/identify the hydrologic regime and the "significant change" of the regime after disturbances. First of all, the hydrologic regime refers to the variations in the state and fluxes of a water body which are regularly repeated in time. The hydrologic states include the states of water storage in the coastal wetland system, such as surface water height, soil moisture content, and groundwater table depth. The hydrologic fluxes include the release of water in a coastal wetland system, such as surface overland flow, channel flow, infiltration, groundwater flow, and saltwater intrusion. Since the coastal wetland hydrologic system is a nonlinear dynamic system, its hydrologic states and fluxes vary through time and space driven by regular external climatic forcing. Thus, the definition of a hydrologic regime should reflect the nature of the system's average trend, as well as the hydrologic variation. The approach for quantifying hydrologic regime varies with the different research intents. Some previous studies quantified the hydrologic regime by investigating the long-term or steady-state of a hydrologic system under an averaged external forcing (Peterson et al., 2012; Richter et al., 1996). Richter et al. (1996) examined the tipping point of a climate condition passing which the monthly and yearly stream flows were altered. This method can detect the long-term response of a hydrologic system to external disturbances, such as the dam and long-term groundwater pumping conditions. However, a short-term response of the system to disturbances cannot be captured and examined. Peterson et al. (2012) focused more on the shorter time scale analysis of a hydrologic system by looking at the shift of a steady-state groundwater condition under different short-term disturbances. However, most of the real-world systems are not reaching or even close to their steady-state due to the stochastic features of external forcing. Thus, some other studies quantified the hydrologic regime by estimating the averaged hydrologic states and fluxes over a certain period. For example, Zhang et al. (2019) quantified the coastal wetland hydrologic states by computing their daily-, seasonally-, and yearly-averaged values by considering the temporal variation of external climate forcing.

It is critical to define to what extent a change in hydrologic regime is "significant." The "significant" used in describing the change in hydrologic regime is not the same as the "significant" in statistics that helps quantify whether a result is likely due to the chance or some factor of interest (Montgomery et al., 2009). Statistically, when a finding is significant, it simply means one can feel confident that it is real, not only got lucky in choosing the sample. Here, the "significant" focuses more on describing the "big" change of a hydrologic regime that may temporally change the current hydrologic cycle of a system, or permanently alter the hydrologic functions of the system. There is still no consensus on what magnitude of change is a "significant" change because different coastal systems are different. A small change in one system may mean a big change in another system. Zhang et al. (2019) defined a "significant" change as the change of a hydrologic regime exceeded one standard deviation below or above its climatological mean. In addition, some other thresholds from practical or theoretical purposes are also applicable as the indicators for "significant" changes. For example, Tiner (2013) defined wetland as a landscape with a groundwater table within 0.3 m from the ground surface for at least 2 weeks in its growing season; it is thus reasonable to define the "significant" change of the groundwater table as the groundwater table is below 0.3 m from the ground surface in the growing season. The "significant" change could be also defined as the condition when the hydrologic change causes dysfunction of a coastal wetland ecosystem. For example, a "significant" change of surface water can be the condition when the ponded water causes the mortality of wetland vegetation, the damage of infrastructure, and the flooding of a coastal city within or near a coastal wetland domain.

3.3 The Quantification of Hydrologic Resilience

According to the definition of hydrologic resilience above, hydrologic resilience quantification should focus on: (1) the threshold intensity of climate disturbances that coastal wetland system could withstand without significant change in their hydrological functions, and (2) the rate of recovering their hydrological functions from disturbances to the pre-disturbance conditions. Due to the nonlinearity of the complex wetland system, one or several thresholds of climate disturbances/forcing may exist (Peterson et al., 2012), the hydrologic resilience of coastal wetlands may not be easily examined under a short-time series analysis. The characteristics of the hydrologic cycle of coastal wetland may not be captured under a short time period, thus a long time series analysis of the hydrological cycle (e.g., decades) is needed, such as years or decades (Zhang et al., 2019). All the components in the hydrologic cycle of coastal wetland, such as evapotranspiration, surface water depth, overland flow, channelized flow, soil moisture, groundwater level, and groundwater flow, should be able to indicate a part of the hydrologic resilience of coastal wetlands to climate disturbances because these components reflect the wetland hydrologic functions (storing and releasing water). As introduced above, the quantification of hydrologic resilience is the process of investigating (1) at what climate disturbance, the hydrologic cycle component/components can still vary within their regular variation range without "significant" change (e.g., one standard deviation deviates from their climatological mean) and (2) if a "significant" change occurs, how long does it take for the hydrologic component/components return to its prior-disturbance variation range? Depending on the different research purposes, a coastal wetland can be treated as a lumped system and quantify a systematic hydrologic response of this lumped system to climatic disturbances. In the meantime the spatial variation of hydrologic resilience can be also quantified, instead of having a hydrologic resilience for the whole system, if the spatial heterogeneity is an important to factor controlling the overall resilience of the system.

4 Case Study: Hydrologic Resilience of a Real-World Distributed Coastal Wetland System

4.1 Study Area

The case study presented in this chapter focuses on using a distributed-system approach to understand the hydrologic resilience of a coastal wetland system based on a 20-year hydrologic model simulation and in-situ observations of groundwater level, soil moisture, and evapotranspiration. The study site is located at the Albemarle-Pamlico peninsula of North Carolina with an area of 2784 km^2 managed as a wildlife reserve (35^{o}24′48″ N, 76^{o}40′15″ W—36°5′11″ N, 75^{o}40′33″ W) (Fig. 18.1). The wetland consists of 78% forested wetland and 3% emergent herbaceous wetland (Fig. 18.1). An eddy flux observation station was set up to measure energy, water, and carbon fluxes and associated meteorology (Aguilos et al., 2020). Several subsurface sensors were installed to measure the groundwater table dynamics and soil water content. Annual mean precipitation is about 1300–1400 mm, mean annual temperature is around 16.9 °C (1971–2000) (Aguilos et al., 2020; Miao et al., 2013), and annual actual evapotranspiration is about 700–800 mm (Aguilos et al., 2020), and the mean sea level increased by 0.083 m from 1995 to 2014 (NOAA, 2017). The groundwater table (GWT) of the forested wetland varied between 0.3 m below the ground surface and 0.3 m above the ground surface from 2009 to 2011 (Miao et al., 2013). The averaged summer and winter GWT of the herbaceous wetland is about 0.1 m higher and 0.02 m lower than those in the forested wetland, respectively (Zhang et al., 2018).

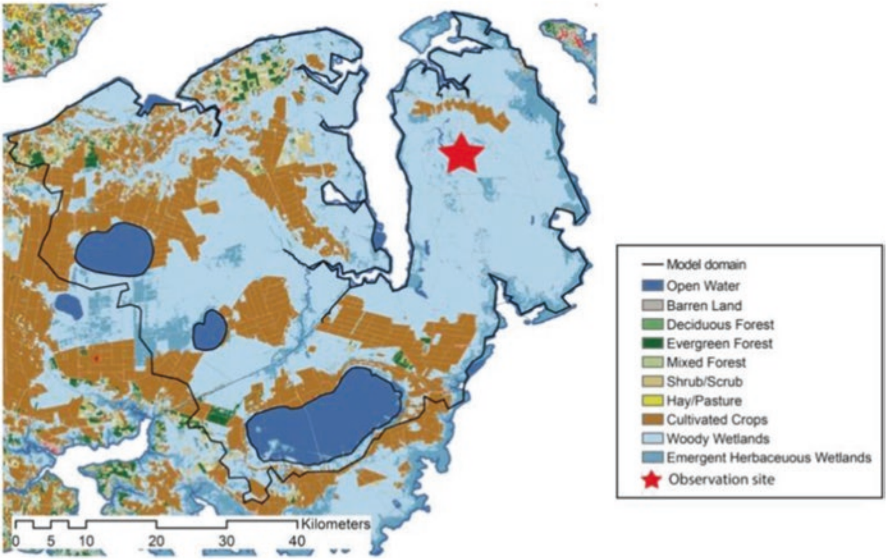

Fig. 18.1 The study area at the Alligator River coastal wetland in North Carolina, USA. The red star indicates the observation site (35°46′34″ N, 75°54′12″ W). The black lines indicate the model boundary (adapted from Zhang et al. (2019))

4.2 Model and Data

To capture the spatial heterogeneity of the coastal wetland in responding to climate disturbances, Zhang et al. (2019) implemented a physically based distributed hydrologic model, PIHM-Wetland, to simulate the change of surface water, unsaturated and saturated soil water, saltwater, and canopy water by simulating water exchange through canopy interception, infiltration, overland flow, channel flow, unsaturated water flow, saturated water flow, saltwater lateral flow, and evapotranspiration. PIHM-Wetland considers the hydrologic interaction between the upland river basins, coastal wetlands, and the ocean. The model was driven by the meteorological forcing from 1995 to 2014 from Phase 2 of the National Land Data Assimilation System (NLDAS-2) (Xia et al., 2012) and tide and sea level change from the same period from NOAA (National Oceanic and Atmospheric Association) tide and current observation (the Oregon Inlet Marina station, Station ID: 8652587). The soil and land cover parameters were derived from the national Gridded Soil Survey Geographic (gSSURGO) database (Soil Survey Staff, 2016) and the National Land Cover Dataset (NLCD) (Fry et al., 2011), respectively.

4.3 Quantification of Wetland Hydrologic Resilience

To characterize wetland hydrologic resilience, Zhang et al. (2019) used the following method: (1) the threshold intensity of climate disturbances that coastal wetland system could withstand without significant change in their hydrological function, and (2) the capability of recovering their hydrological function from disturbances to the pre-disturbance state. They also identified the change of the hydrological conditions as statistically significant when the change was at least one standard deviation above or below the climatological mean.

The proposed method in Zhang et al. (2019) emphasized the hydrological interactions among upland, coastal forested wetlands, coastal herbaceous wetlands, and the ocean, which together determine the hydrodynamics of coastal wetlands. They chose the groundwater table (GWT), overland flow rate (OFR), and water table of saltwater (ST) as indicators of wetland hydrologic resilience. Zhang et al. (2019) first identified climate variability and extremes (e.g., dry and wet years, large rainfall events, and droughts). Then, they quantified the hydrologic resilience by investigating the responses of GWT, OFR, and ST to climatic disturbances, such as drought, heavy rainfall, and sea level rise.

4.4 Identification of Long-Term Climate Disturbances

To better understand hydrological responses to climate disturbances, Zhang et al. (2019) classified the 20-year period into three dry years (1997, 2001, and 2007) and three wet years (1996, 2003, and 2009), where the annual precipitation anomaly is lower and higher than one standard deviation of the climatological mean precipitation (see Fig. 18.3). The remaining 14 years were the normal years. They also identified the heavy-rainfall events with a precipitation rate at the 75th percentile of the entire precipitation distribution, which is higher than 13 mm/day. There is no big variation of temperature, compared with the precipitation. The seasonal and annual variation of sea level was also analyzed. The seasonal sea level variation is relatively small (within 0.05 m). The annual sea level decreases in the first 7 years from 1996 to 2002, and then it gradually increased from 2003 to 2006. A clear drop in sea level was also observed in 2007 followed by a large increase in sea level from 2008 to 2014 (see Fig. 18.2).

4.5 Hydrologic Resilience to the Climate Variabilities

Zhang et al. (2019) analyzed the response of GWT to drought events with different durations at a daily scale. Figure 18.3 shows the lowest daily GWT of the forested and herbaceous wetlands within the continuous days of no rainfall for the wet and dry years, respectively. They found that the GWT of the forested wetland stays at a similar level in the wet years even when the duration of no rainfall reaches the maximum (9 days) (blue bars in Fig. 18.3a), which indicates that the forested wetland can absorb all of the drought disturbances in the wet years. Similarly, in the dry years, the forested wetland can absorb the drought disturbances when the duration of no rainfall is less than 6 days (orange bars in Fig. 18.3a). However, the GWT

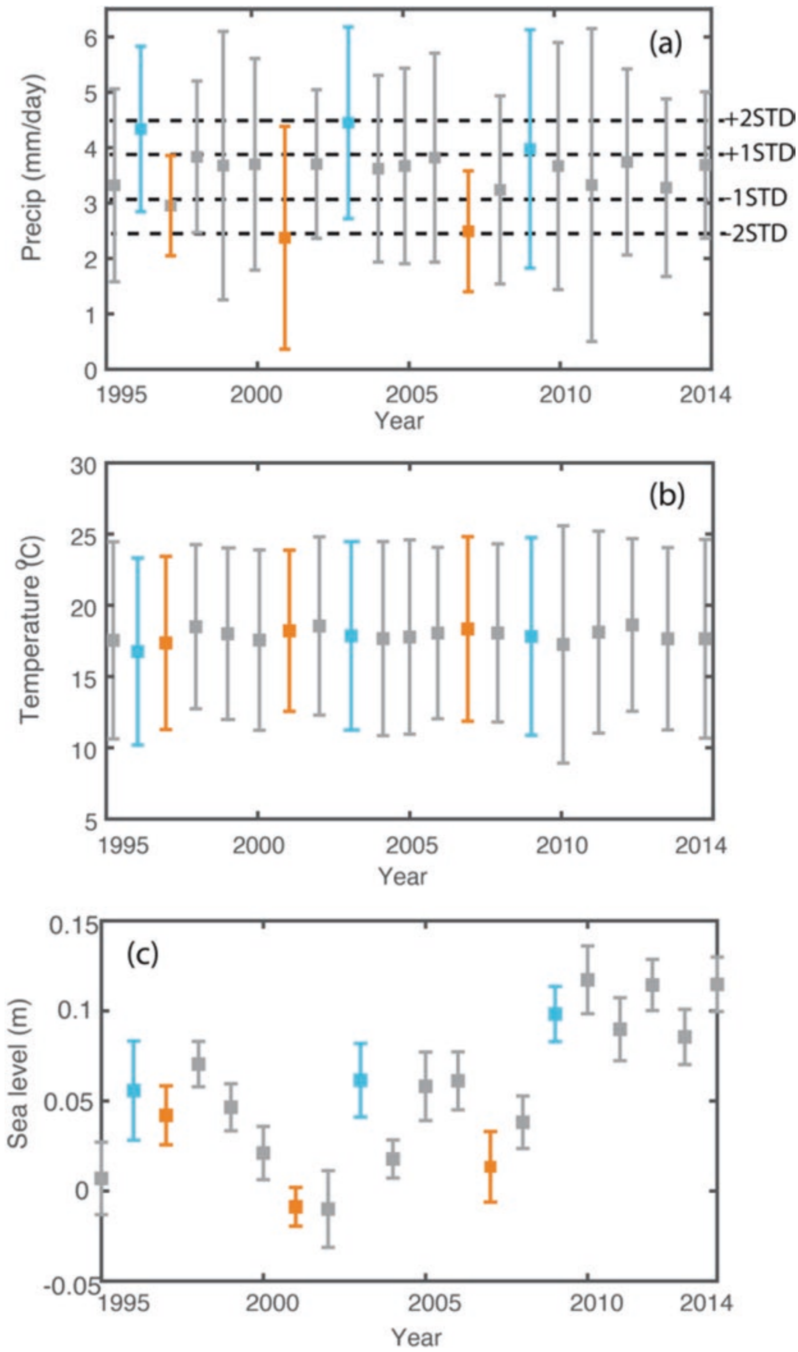

Fig. 18.2 Climate variability in annual (**a**) precipitation, (**b**) temperature, and (**c**) sea level. The orange bars indicate the dry years and the light blue bars are the wet years. (adapted from Zhang et al. (2019))

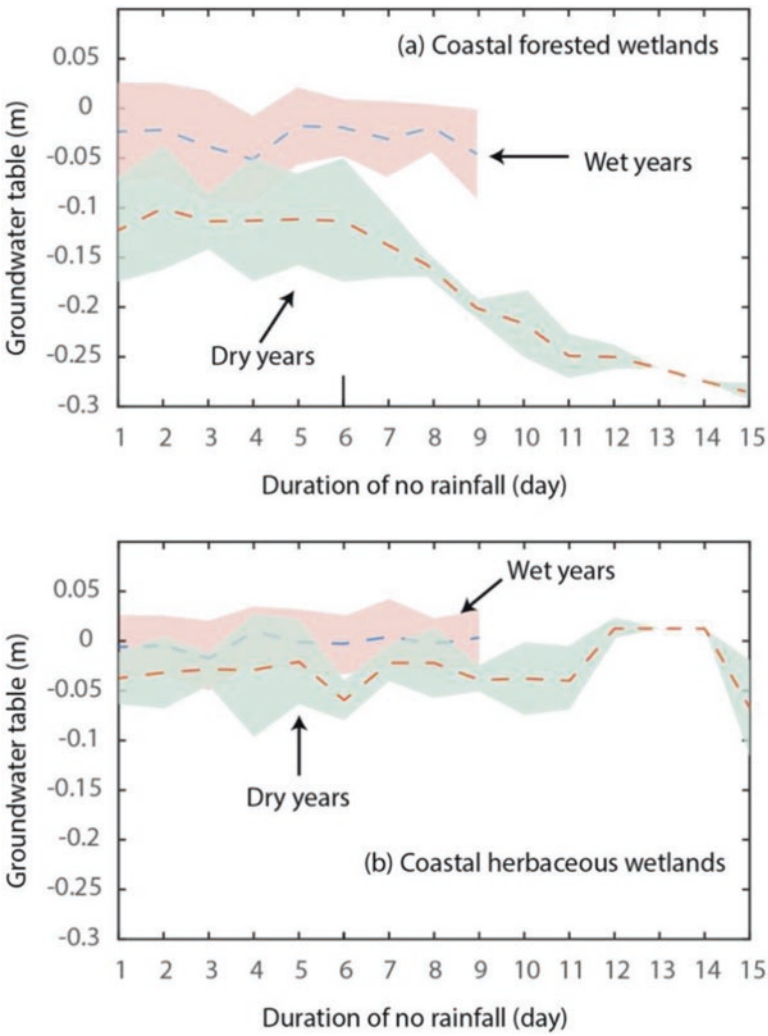

Fig. 18.3 The lowest daily GWT under drought events for (**a**) the forested wetlands and (**b**) the herbaceous wetlands. The blue and orange bars indicate the mean GWT and its one standard deviation for the wetland and dry years, respectively (adapted from Zhang et al. (2019))

dramatically decreases when the duration of no rainfall is greater than 6 days, which implies that the groundwater system of the forested wetland is not able to absorb those drought disturbances. Therefore, the resilience of the forested wetland to drought decreases after 6 days of no rainfall. For the GWT of the herbaceous wetlands (Fig. 18.3b), supported by the sea level, the GWT variations under drought events are small. No big drop of GWT is observed even when the duration of no rainfall reaches its maximum. Therefore, the herbaceous wetland is more resilient to drought, compared with the forested wetlands.

Zhang et al. (2019) also investigated the threshold response of overland flow to individual rainfall events on a daily scale (Fig. 18.4). In the dry years (Fig. 18.4b), almost no large overland flow occurred when rainfall was less than 30 mm/day because of sufficient soil water storage room for infiltration. However, a relatively large overland flow was observed in winter when GWT rose and soil water storage room decreased. In contrast, during the wet years, the overland flow rates were doubled or tripled, compared with the rates in the dry years in all seasons (Fig. 18.4b) due to limited soil water storage year-round. Therefore, for both the forested and herbaceous wetlands, the system is less resilient to rainfall in the wet years, while it is more resilient to rainfall in the dry years.

Last, Zhang et al. (2019) analyzed the saltwater table variation under sea level rise at the seasonal and interannual scales. The seasonal saltwater table variation was small (within 0.025 m) due to the slow response of the saltwater diffusion process to sea level change. Inter-annually, saltwater table variation was also small from 1995 to 2007, after which the saltwater table was elevated from 2008 to 2014. Therefore, coastal wetlands are more resilient to short-term sea level variation. However, a long-term sea level change has a dominant control on saltwater intrusion (Fig. 18.5).

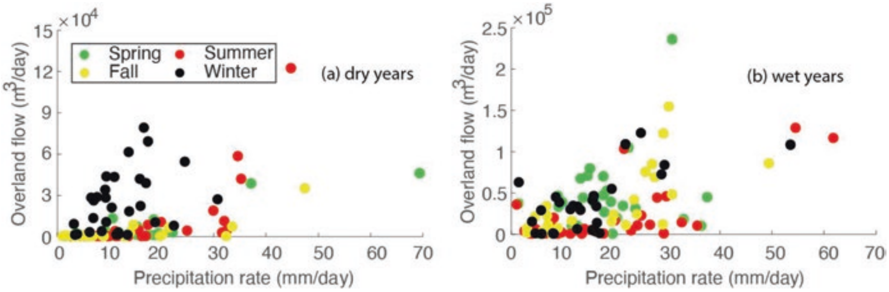

Fig. 18.4 Daily averaged overland flow rate as a function of precipitation rate for (**a**) the dry years and (**b**) the wet years. Dots of different colors indicate different seasons (adapted from Zhang et al., 2019)

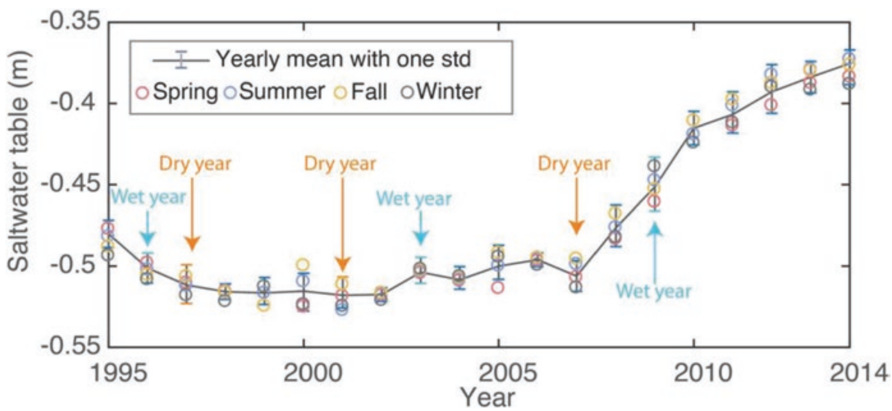

Fig. 18.5 Seasonal and yearly variation of the saltwater table from 1995 to 2014 (adapted from Zhang et al. (2019))

5 Conclusions

This chapter introduced the concept of coastal wetland hydrologic resilience: its definition, quantification method, related hydrologic processes, and climate impacts. Several key components have been highlighted that have not been well studied, such as the definition of hydrologic resilience, the identification of hydrologic conditions, the quantification method, and real-world applications. The case study described how to use a modeling approach to understand the spatial variation of hydrologic resilience in a real-world coastal wetland ecosystem. The selected metrics for quantifying hydrologic resilience to climate variabilities may apply to similar coastal wetlands in other regions.

This study identified several challenges in assessing coastal wetland hydrologic resilience: (1) identifying the tipping point of hydrologic states, passing which the hydrologic functions are significantly altered, (2) transforming hydrologic information (e.g., hydrograph) into resilience characteristics, and (3) quantifying the co-evolution of a system to better understand its hydrologic response. Future studies should focus on better integration of models and data to compile and extract information from different aspects of the hydrologic cycle at different scales. The development of high-resolution remote sensing data and machine learning techniques may be applied in the hydrologic resilience studies. Explicit integration of multi-scale, multi-process, co-evolving coastal hydro-eco-geomorphologic models for more accurate quantification of coastal wetland resilience is also important.

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Chapter 19
Perception of Vulnerable Ultra-Poor Women on Climate Change Impacts and Local Adaptation in a High Flood Prone Area of Bangladesh

Md. Shareful Hassan, Syed Mahmud-ul-Islam, and Mohammad Mahbubur Rahman

Abstract The contextual and risk perception about climate change and its consequences could help individuals respond appropriately and make timely adaptation actions. The level of perception or knowledge on climate change issues is often gender-sensitive, and it is usually less among vulnerable women. To this end, this study investigates different dimensions of risk perceptions on climate change among the ultra-poor women group within the high flood areas of Bangladesh. The study has used an empirical approach to collect primary and secondary data using both qualitative and quantitative research tools at the same time. According to the findings of the study, individual perceptions of climate change among women are relatively low. Nonetheless, they have observed significant changes in a variety of climatic variables over the last three decades. Furthermore, this study identified some major adaptation options, such as plinth raising, livestock rearing, homestead gardening, seasonal migration, and using indigenous knowledge, among others, to address the adverse effects of climate change-induced extreme events, such as flooding, at the local level. Respondents spent significant amounts of money from individual sources in the study area to implement these adaptation measures. A Structural Equation Modeling (SEM) is also used to comprehend any links between climate change understandings and other variables connected with the studied community. The SEM findings indicated that climate change would be a long-term challenge, and it is a strong predictor in this model, with standardized regression weight $\beta = 0.56$. Despite the respondent's lack of knowledge about climate change, it means

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that climate change is occurring and has become the most significant factor limiting cultural, economic, and environmental development in the study area.

Keywords Climate change · Vulnerable women · Perception · Adaptation · Bangladesh · High flood

1 Introduction

Climate change poses considerable uncertainty concerning both the intensity and the temporal or spatial pattern of its impacts on the individual's decision-making process (Woods et al., 2017). Research findings on how people act under high uncertainty conditions suggest that individuals consistently overlook the risk of a disaster affecting them, and these have profound implications (Grothmann & Patt, 2005). Contextual perceptions of risk are unconsciously chosen ideologies that facilitate an individual's way of life, as explained by cultural cognition theory (Lacroix & Gifford, 2018). Every individual has beliefs about how the world should be. Because some risks promote particular ideas more than others, individuals "selectively…attribute or deny the evidence of risk in patterns that match values that they exchange with each other" (Kahan et al., 2011). For instance, considering that egalitarians do not like unfair social disparities (Kahan, 2012; Kahan & Braman, 2003); and given that most people believe climate change risks to others around the world to be higher than the risks to themselves, it follows that egalitarians are more likely to be involved with climate change because it endangers their view of a socially fair and equitable society (Lacroix & Gifford, 2018).

Risk perception is a mental construct (Sjöberg, 2000). Human perception is exceptional since it makes it possible to distinguish between the nature of concrete, immediate threats, such as climate change, and the subjective perception of those threats (Rosa, 2003). For instance, even though anthropogenic global warming is one of the biggest global threats to human existence, risk assessments of global climate change vary considerably from one individual to another (Hine et al., 2013; van der Linden, 2017). Moreover, there is a substantial cross-cultural difference in the intensity of combined public concern and a general eagerness to address the problem. In the United Kingdom, Australia, and most of mainland Europe, climate change, for instance, has always been seen as a "substantial" problem. On the other hand, it has traditionally been gained lower attention in countries such as the United States, China, and Russia (van der Linden, 2017). Of that kind, prejudices can skew perceptions of risk, a key mechanism for motivating adaptive behavior. For example, studies of flood insurance purchases have shown that, even if the flood damage is severe, people prefer to disregard the possibility of flood risks when they have a low flood probability scenario (Woods et al., 2017).

The differential consequences of climate change on men and women emerge from diverse roles in society, how these roles are boosted or diminished by other aspects of injustice, perceived risks, and the nature of disaster response (Field et al., 2014). Vulnerability study results on climate change showed that the factors of men's and women's vulnerability and adaptation capacity were gender-sensitive and mediated by cultural, socio-economic, and political structures and processes (Carr & Thompson, 2014). Moreover, several socio-demographic variables, including gender, race, education, access to the property, and social networks, can be used to label the most vulnerable (Baptiste & Kinlocke, 2016). In general, women have often been perceived by their increasing dependence upon natural resources and increased poverty among the most vulnerable victims of climate change (Arora-Jonsson, 2011; Mainlay & Tan, 2012; Lawson et al., 2020). Poor women are the most vulnerable and most affected by climate change, especially in developing countries (Swai et al., 2012). Bangladesh, one of the developing countries from the global south, is at a high risk of frequent climatic disasters such as flooding, cyclone, riverbank erosion, sea-level rise, etc. Though natural disasters affect all population groups, some researchers have found gender-specific exposure and disaster effects. This vulnerability is more triggered by other social problems such as sexual integrity and poverty, mainly confronted by women and adolescent girls, making them further insecure and shocked (Azad et al., 2013). Therefore, women here are more susceptible than men to climate-related impacts because of their social condition, cultural norms, lack of access to and control over resources, and lack of participation in decision-making processes (Khan et al., 2010). Among other South Asian countries, the geographical context has made Bangladesh more vulnerable to seasonal flooding, causing tremendous loss of human life and property. An average of 844,000 million cubic meters of water runs across the country during the rainy season (May–October) through the three most important river systems—the Ganges, the Brahmaputra, and the Meghna. As a low-lying country where almost eighty percent of the landmass covers floodplain, it exposes to repeated floods (Dewan, 2015). The marginal and disadvantaged group of people, including the poor, physically challenged, and ethnic minorities, are the forefront victims of the aftereffect of any natural disasters, including floods. More precisely, among these groups of the marginal community, women, children, and adults' susceptibility are of the highest degree. However, individuals could play a significant role in responding to a changing climate and disaster situation (CCC, 2009).

For decades social scientists and environmental sociologists have researched gender dynamics in scientific understanding and the ecological problem. The results are a combination of robust designs as well as unresolved consequences. These consist of a multidisciplinary study exploring public opinion on climate change or global warming, a vital science-based environmental issue full of political controversy and moral concern (McCright, 2010). Most previous studies (e.g., Pearse, 2017; Swai et al., 2012; McCright, 2010) concentrated on gender relations of climate change, exploring vulnerability and adaptation in different contexts, and knowledge and social action targeting both males and females. However, there is hardly ever any study (e.g., Selm et al., 2019; Lawson et al., 2020) that focuses principally on women or women-headed households and their perspectives of basic understanding of climate change and knowledge of its adaptation and response options. Besides, less work is being done on a systematic public opinion analysis that explores the conceptual dimension of gender relations with climate change attitudes and beliefs (Eslamian et al., 2011). Conversely, researchers generally include gender as a statistical control in multivariate models and then only explain this variable's effectiveness in passing—often with little or no empirical discourse (McCright, 2010). A noticeable number of researches (e.g., Huq et al., 1999; Alam et al., 2017; Rahaman et al., 2019; Rahaman & Rahman, 2020) have assessed the implications of climate change in different sectors in Bangladesh. In contrast, the study on climate change impacts on ultra-poor women and their risk perceptions are less explored. Instead, most studies consider multiple groups of vulnerable populations in their studies (e.g., Haq & Ahmed, 2017). Thus, this study will examine the risk perceptions of these less explored population groups, particularly women.

Sirajganj district is historically known as one of the most vulnerable areas in Bangladesh that face frequent seasonal flooding and havoc visits. Sirajganj is inundated nearly each year, with the most drastic floods occurring in 1949, 1956, 1961, 1962, 1966, 1968, 1974, 1979, 1987, 1988, 1996, 1998, 2002, 2004, 2007, 2008, 2014, 2016, and 2019 (Ali et al., 2019). Khan et al. (2010) have shown that the intensity of extreme climatic events such as flooding, impact, and response depends on the socio-economic conditions among a vulnerable group of people, including the poor, ultra-poor, and wealthy class. Both the hard and soft adaptation knowledge is crucial to coping with the distractions caused by extreme disasters. A local community, affected by the unexpected conditions due to climate change, tries different alternatives and strategies to cope with it. Affected people adopt livelihood strategies using their indigenous knowledge and coping mechanisms. Among the strategies, diversification of livelihoods and cropping patterns, such as introducing floating gardening, poultry and duck rearing, cage aquaculture, building sea wave protection walls, pond or canal excavation, and dam construction, are remarkable, and mostly these are hard adaptation measures (Anik & Khan, 2012).

Women and women-headed households in rural areas like the Sirajganj district, in general, are more likely to experience more poverty than the urban areas and, at the same time, more vulnerable than men to various natural disasters, including flooding. Moreover, widowed women are supposed to be weaker in social safety and empowerment than those with a well-earning husband or rich and good family network. Women also have less socio-economic power compared to men. In village areas, men go to cities searching for jobs, leaving women in their home village. Women in the town often look after their families and work harder to feed their children or dependent. Thus, reasonably women are more likely than men to be experienced with local disasters in flood-prone areas. Therefore, climate change impacts affect vastly ultra-poor women in remote and rural flood-prone regions. The activities of women in the affected area are also noteworthy. Women are involved in cultivation, and post-harvest works along with men (NAPA, 2009). They are also taking part in tailoring, fishnet making, cattle farming, poultry, and handicrafts making. In rural communities, women overwhelmingly undertake the labor of collecting food, water, and energy resources for cooking that increase collection time. Women's activities contribute to their families' existence by ensuring food security (Nasreen, 2008, 2012). However, lack of access and ownership of land and wealth makes women vulnerable to economically challenged situations triggered by environmental stresses. Thus, knowledge and understanding of climate change and its impacts and response could be an essential tool for promoting soft adaptation strategies and improving their coping capacities in such rural flood-prone areas. This knowledge will also help them in keeping their families safe during the disaster period.

This study has been carried out to understand the perception and impact of climate change among ultra-poor vulnerable women and find out local adaptation options, particularly in the highly susceptible flood-prone areas like the Sirajganj district of Bangladesh. Along with other statistical analyses, Structural Equation Modeling (SEM) has been used to understand any links between climate change perceptions and other associated variables. Based on this study's background literature materials, this SEM will be a noble work as none of these studies addressed this issue in the Bangladeshi context. Therefore, this study will provide a proper guideline on using SEM for climate change studies in Bangladesh, particularly flood-prone areas.

2 Methods

2.1 Study Area

Chowhali Upazila under the Sirajganj district is one of the most vulnerable flood-affected areas in Bangladesh. This study was conducted in seven unions of the Upazila; most of the unions are flood affected. This Upazila lies between 24°01′N and 24°17′N latitudes and between 89°41′E and 89°59′E longitudes. The entire Upazila covers 21,039 hectares area (Fig. 19.1). The Jamuna River passes through the Upazila that brings ample bank erosion, causing the displacement of many human settlements. Hassan and Mahmud-ul-islam (2016) conducted a remote sensing study using three multi-date Landsat imageries. It estimated that about 1340-hectare areas had been eroded between 1989 and 2015 in different parts of the entire study area. This zone is mainly selected as the study area due to its high vulnerability to flood, river erosion, and climate change's adverse impacts.

2.2 Data Collection and Analysis

In this research, both quantitative and qualitative approaches were applied to explore the perception of different vulnerabilities of vulnerable women due to climate change in the study area. In the quantitative approach, a mini-structured questionnaire with 20 key questions related to the study's primary objectives was used. The survey collected responses from 200 climate-vulnerable ultra-poor women in seven

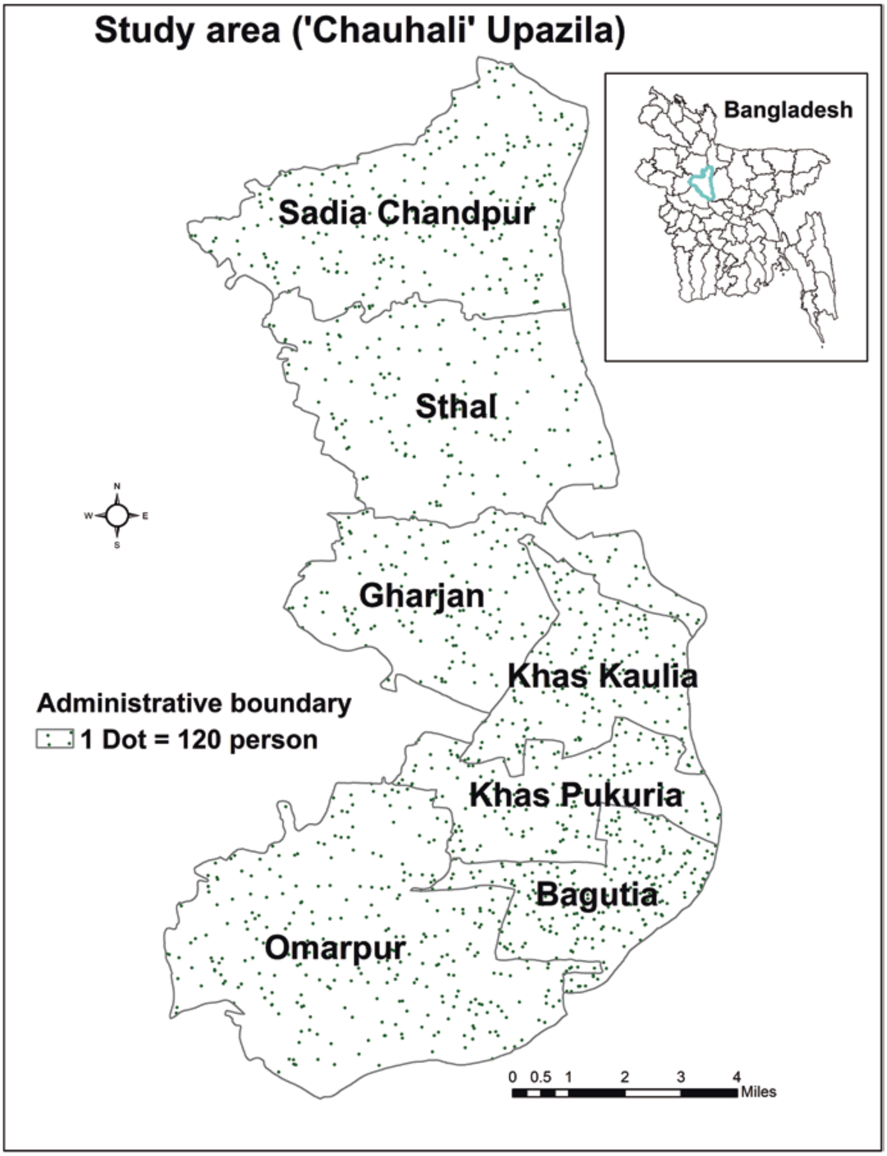

Fig. 19.1 Location map of the study area

unions of the Upazila. The study undergoes a random sampling method to extract 200 respondents, following a 95% confidence level with a 5% margin of error. The average sample size of each union was 30 climate-vulnerable women with having similar socio-economic status and criteria. These specific criteria were: (1) suffer daily food insecurity, (2) no land or less than 0.15 acres, (3) deplorable housing condition, (4) women-headed household, and (5) no active male income earner. In the qualitative data collection method, ten Key Informant Interviews (KIIs) were also conducted from schoolteachers, Union Parishad members, Union Parishad chairpersons, and elite persons who know the environment, climate change, and overall socio-economic status of the study area. The survey's primary focus was to define which climate change variables are impacting respondent's livelihood and socio-economic parameters and how to mitigate and adapt to climate change impacts locally. The data collection took place in the study area from February–March 2019 with the help of ten data collectors, who were appointed locally due to familiarity with the study area. Before collecting responses from respondents, two-day training was conducted on the whole questionnaire to minimize possible non-sampling errors. After receiving and cleaning all the feedback, SPSS version-23 was used to analyze the collected data. Moreover, some significant descriptive statistics such as mean value, total number, range, regression, percentage, and standard deviation were produced to analyze the surveyed data.

Structural Equation Modeling (SEM) is a widely used statistical modeling tool in social science research where a combination of path analysis, factor analysis, and multiple regressions is prevalent to delve into the different latent and apparent relationship of variables (Hox & Bechger, 1999). One dependent variable—'climate change is true (CC_is_True)' has been used to perform an SEM in the study. Additionally, four independent variables—adequate knowledge of climate change (CC_Knowledge); the reason for climate change (Reasons_of_CC); is it a long-term problem (It_is_a_problem); and the role of the local government (Role_of_local_GoB) had also used following a path model using SPSS software. This equation is an excellent way to conduct and show multiple regression models that permit dichotomous variables (Boon, 2016).

3 Results

3.1 Socio-Economic Profiles

In this study, only female respondents were counted for the survey. The total respondents were aged between 20 and 60 years old. About 47% of the respondent's age was between 20 and 35 years. The interviewee's second majority age group was 35–45 years old, 41% of the total respondents.

Women can be the best way to emphasize adaptation to climate change impacts (UNICEF, 2016). In this study, the educational status of the respondents portrays a poor picture. Only 25% of the respondents completed primary education. Most interviewees (43.7%) did not finish their primary school, while just 18.7% of the interviewees could only sign their names. The highest literacy rate was among 12.5% who completed secondary education. Thus, about 67% of women were most vulnerable due to a lack of primary education. Boon (2016) argued that the perception of climate change can increase with proper education and training.

Most of the respondents were housewives accounting for 49%. The next dominant group had either small poultry or did cattle raised at the household level. Only 8% of the respondents were engaged in tailoring at the community level. 40% of the interviewees were landless, and 7% of respondents live in *khash* land.[1] About 34% of respondents had marginal households, and 19% had small families.

3.2 Perceptions of Climate Change

The study shows that only 37% of the respondents were concerned with climate change's general concept (Fig. 19.2). The rest of the 63% never heard about climate change. When the respondents familiar with the topic asked about the source of the knowledge of climate change, a significant number (55%) replied NGO as a source, followed by TV (26%) and radio (19%). This study reveals that direct education, training, or communication positively impact educating vulnerable poor women on climate change-related issues. In addition to this finding, most of the respondents did not have proper scientific explanations and climate change results.

3.3 Major Changes in Climate

Figure 19.3 demonstrates the main climatic changes over the last 30 years noticed by the respondents. All the respondents observed irregular and less rainfall (Fig. 19.3) in the study area, while 93% said rain was not in time. The overall

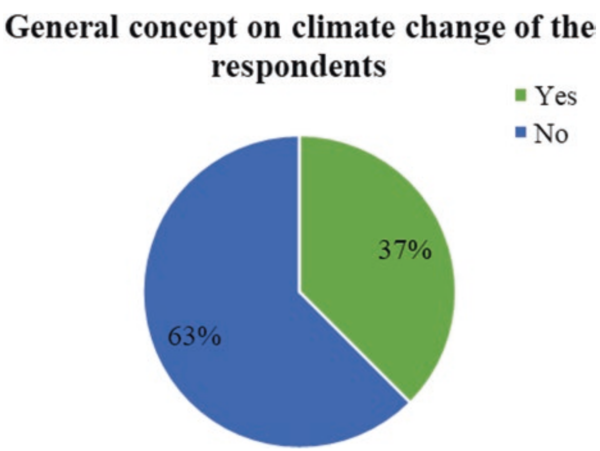

Fig. 19.2 Respondent's general concept about climate change

[1] Government owned fallow land.

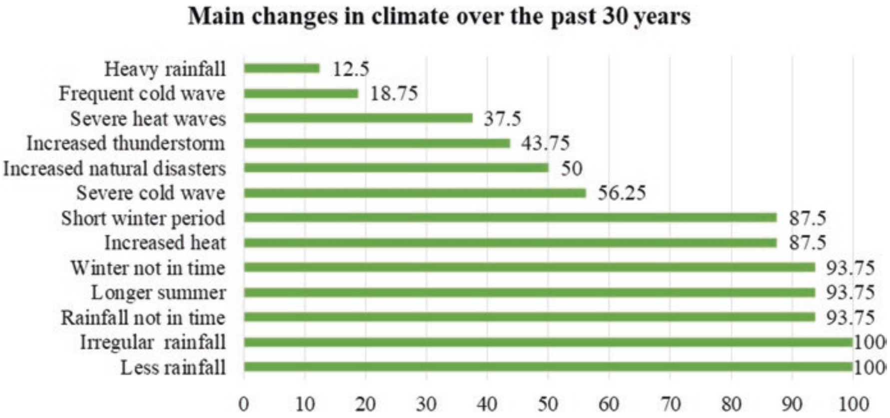

Fig. 19.3 Main climatic changes observed by the respondents

climate change scenario in the study area is exposed to less rainfall and increasing temperature trend during the past 30 years. 93.7% of the respondents replied about a more extended summer period, while 87.5% talked about a shorter winter period. 93.7% of the interviewees found that winter does not appear timely over the last 30 years, whereas 56% observed severe cold wave conditions during winter. 37.5% of the respondents experienced severe heat waves during the summer. Half of the interviewees witnessed the increasing natural disasters during the last 30 years.

3.4 Major Changes in the Ecosystem and Environment

The impacts of climate variability and change in the study are severe, shown in Fig. 19.3. Based on this figure, the development of the overall ecosystem and environmental sustainability is in danger that may affect the socio-economic and agriculture areas also. All of the respondents perceived drought conditions during the dry season. About 93.8% of the interviewees witnessed river erosion and mentioned lowering the groundwater level (Fig. 19.4). Half of the respondents realized the loss of natural resources over the last 30 years. Many interviewees (87.5%) claimed that there was less abundance of flora and fauna, indicating the loss of species. Approximately 81% of respondents witnessed less water in the river and wetlands. About 43.75% of respondents mentioned floods as significant adverse impacts. Heavy rainfall is another negative consequence during the last 30 years, referred by 25% of respondents. Thirty one percent of the interviewees indicated the increasing trend of waterborne diseases as major public health issues in the study area.

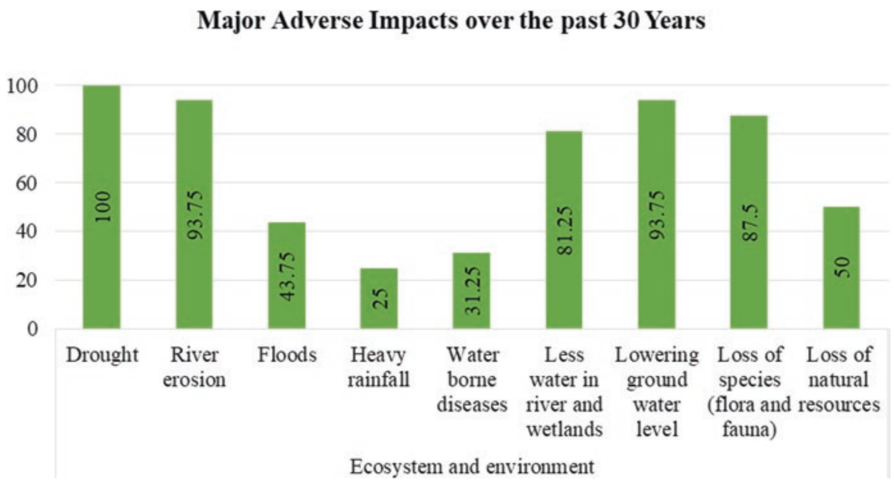

Fig. 19.4 Major adverse impacts on the ecosystem and environment

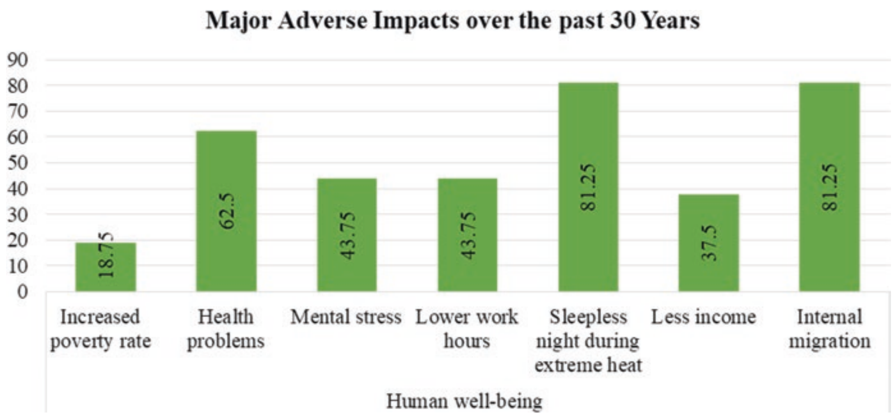

Fig. 19.5 Major adverse impacts on human well-being

3.5 Major Changes in Human Well-Being

Climate change and its consequences not only have effects on the environment but also human well-being. Eighty one percent of the respondents suffered internal migration due to poverty and family demands (Fig. 19.5). The same number of respondents experienced sleepless nights due to extreme heat conditions, which resulted in less body stamina and affected the laborious job. 62.5% of the respondents answered health-related problems like diarrhea, fever, and other air- and waterborne diseases in the study area. About 43.75% of the respondents got lower work hours due to adverse impacts of climate change, and a similar percentage mentioned mental stress in their daily life. As a result, less income from fewer

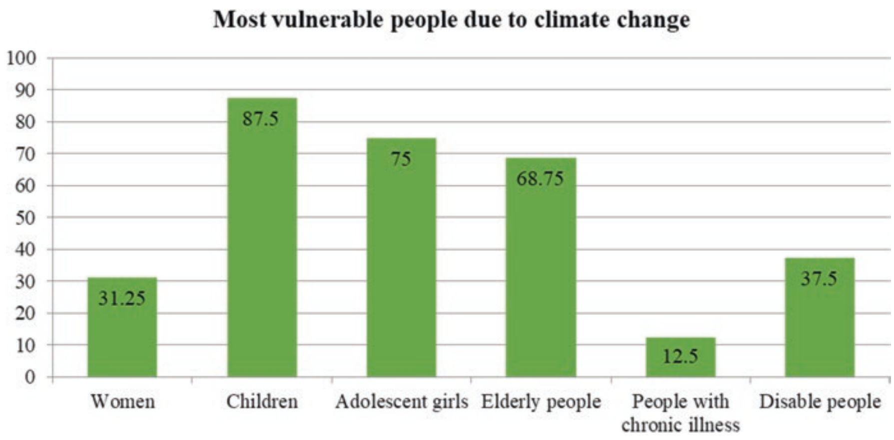

Fig. 19.6 Different climate change vulnerable groups

working hours was also identified by some respondents (37.5%). Therefore, this study's results reveal that the poverty situation can be a dangerous and increasing trend because about 19% of the interviewees believed this is happening in their area.

Figure 19.6 represents the percentage of a different group of people that are the most vulnerable in Bangladesh due to climate change effects. Among the vulnerable groups, children are the most affected, 87% of the total people affected. Adolescent girls and women are also vastly affected. Illness is also on the top list.

3.6 Major Changes in Agriculture

As an agricultural country, the effects of climate change on agriculture are one of the most significant concerns. All the respondents agreed to the point that climate change has an impact on the loss of soil fertility and increased crop production cost (Fig. 19.7). All interviewees also opined that plant or agriculture lands go underwater during flooding and sometimes covered with sand. The next significant adverse impacts are crop failure, which was opined by 87.5% of the respondents. About 75% of the respondents also indicated a loss of crop yields as an initial impact. About 37.5% of respondents pointed out irrigation problems, and 18.7% noticed the unknown plant diseases. One-fourth of the interviewees mentioned that the food crisis exists in the study area.

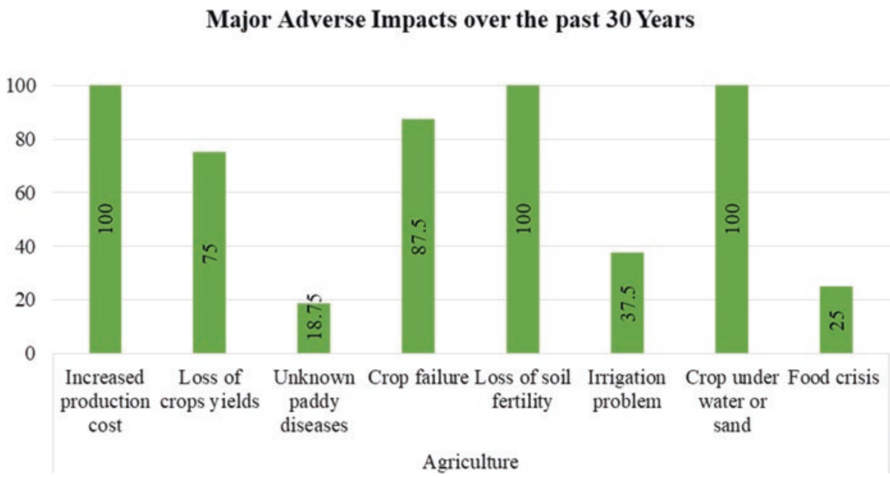

Fig. 19.7 Major adverse impacts on agriculture

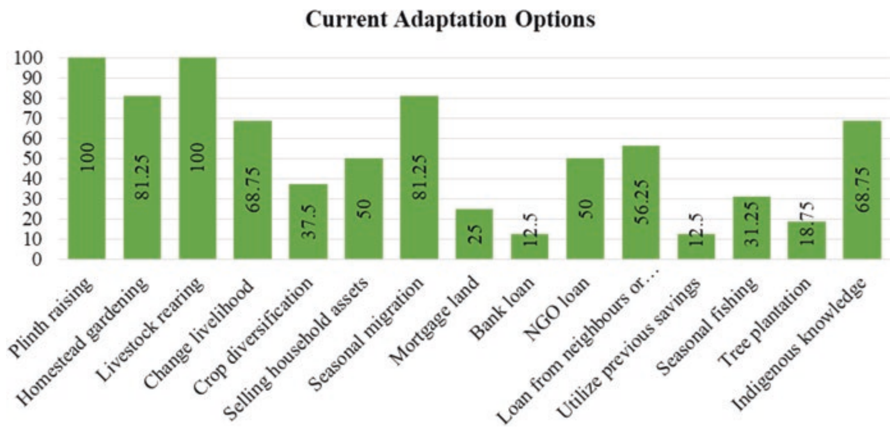

Fig. 19.8 Present climate change adaptation options

3.7 Local Adaptation to Climate Change

Figure 19.8 shows the current adaptation options for climatic impacts. Plinth raising (100%), livestock rearing (100%), homestead gardening (81.25%), and seasonal migration (81.25%) are popular adaptation options in the study area. Other options include the change of livelihood, taking a loan, using indigenous knowledge, crop diversification, selling household assets, mortgaging land, a loan from NGO, tree plantation, and seasonal fishing. People affected by the climate change consequences have tried many ways of adapting by spending their own money.

3.8 Investment for Local Adaptations

To apply local adaptation options to climate change, about 32% of the respondents spent 3500 BDT ($45) or more, 18% spent 3000–3500 BDT ($38–45), 27% spent 2500–3000 BDT ($32–38), 16% spent 2000 to 2500 BDT ($25–32), and 7% of the affected people spent 1500 to 2000 BDT ($20–32) once in the study area. These costs include recovery actions after any climatic strike like the flood, riverbank erosion, and drought condition. This expense also includes migration to other places due to the impact of climate change.

The results of Structural Equation Modeling (SEM), which included one dependent and three independent variables, reveal that about 49% of the variance (R2) evidence the existence of climate change in the study area. It means that a sizable portion of possible influences impacts climate change by some significant variables used in this model. Figure 19.9 shows climate change will be a long-term problem, which showed a sharp predictor in this model considering standardized regression weight $\beta = 0.56$. Climate change knowledge was a very small predictor, standardized regression weight of which was $\beta = -0.52$, in this model. It means, despite inadequate expertise on climate change of the respondents, climate change is happening and becoming the worst factor delaying cultural, economic, and environmental development in the study area.

Table 19.1 reveals that the respondent's climate change knowledge and problems of climate change are statistically significant at $P < 0.05$. It means that the respondents realized climate change is true, which will be impacted long-term on their socio-economic and cultural lives. Moreover, they believed that it is happening due to not only anthropogenic but also other natural reasons. In addition to this finding, the role of local government and climate change causes did not have any significant influences on climate change. Consequently, this statistical result shows that climate change is an emerging situation that can affect the local livelihoods, agriculture,

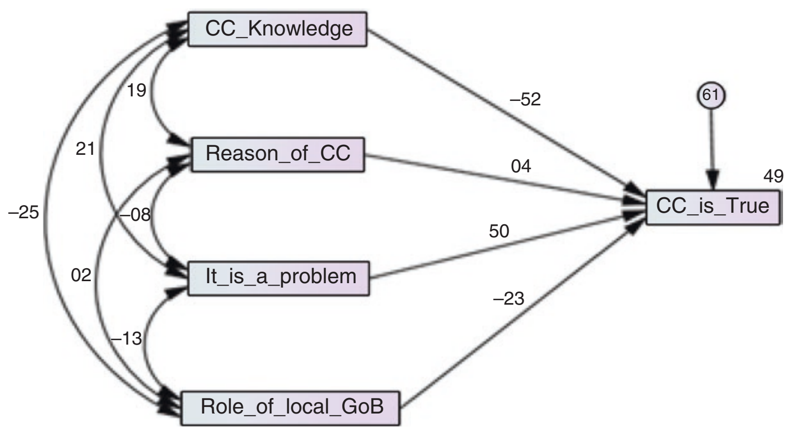

Fig. 19.9 The SEM model structure and its pathways

Table 19.1 Model outputs derived from the Structural Equation Modeling (SEM)

Dependent variable		Independent variables	Estimation	Standard Error (SE)	Critical Ratio (CR)	*P**
CC_is_True	←	CC_Knowledge	−0.651	0.178	−3.664	0.027
CC_is_True	←	Reasons_of_CC	0.058	0.216	0.267	0.789
CC_is_True	←	It_is_a_problem	0.523	0.128	4.098	0.019
CC_is_True	←	Role_of_local_GoB	−0.349	0.209	−1.675	0.094

*Sig value $P < 0.05$

economy, food security, and women empowerment. The local government's role is instrumental in identifying existing climate change problems and developing local adaptation action plans in their Annual Development Program (ADP). Different frontline workers of the government, along with NGOs, schools, youth, and civil society movements, can play a significant role in enhancing the knowledge on climate change for the local community.

4 Discussion

The study shows that the traditional understanding of climate change is concerned only by a small number, whereas the majority of women respondents do not know the word. The primary sources of knowledge gathered on climate change were the local stakeholders, including government, NGOs, and the conventional media such as radio and TV. The area has experienced notable shifts in different climate and weather conditions, including erratic and excessive rainfall, shorter winter and longer summer seasons, summer heat stress, cold winter, and monsoon floods, and a steady trend in different natural disasters in the recent decades. Such changes in climate and environment have increased the severity and frequency of the natural disasters such as floods, erosion, drought, and so on. Almost all of the ultra-poor participants experienced river erosion by the Jamuna River. It forced several hundred people to move away from their land of origin. Approximately 80,690-hectare lands had eroded along the 240 km Jamuna River in between 1973 and 2009 (Shaw et al., 2013). It destroyed many properties and made the respondents suffer economically. These events also contributed to increased waterborne diseases and depletion of natural resources and eventually impacted local population livelihoods, including women at risk. Women choose the alternative forms of living, for example, livestock raising, poultry, home gardening, and shift in livelihoods. Sometimes they move seasonally to big towns in search of work and take a loan or even sell the household property to cope with the adverse situation. Cannon (2002), Sultana (2010), and Khalil et al. (2020) indicated the same pattern of male members relocating from local areas to the closest cities to seek jobs. Abedin et al. (2013) spoke about multi-strategies such as child-education, storage of essential items, borrowing money, selling and mortgaging properties, relocation and finding alternative jobs, and so on. Khalil et al. (2020) also found that women work as day laborers, make crafts, and catch fish and crabs and other non-traditional jobs, to provide their families with livelihoods.

This study is the advanced research of climate change to understand the perceptions and impacts in this particular flood-prone area and shows a low perception strategy among the target group of affected people. Few climate-vulnerable ultra-poor women were concerned with climate change issues. Both government and NGO can play a significant role to bring awareness to them. To reduce the impacts of climate change, the National Plan for Disaster Management (2008–2015) formed a Disaster Management Committee for five administrative levels (District, upazila, union parishads, municipalities, and City Corporation) to mitigate the climate change impacts. Based on the Bangladesh Climate Change Strategy and Action Plan (BCCSAP-2009), the government set six key priorities/pillars to guide the integration of climate change issues into the main development frameworks to make a holistic effort at different ministerial levels. Already the National Adaptation Programs of Action (NAPA) have been published and started implementation with its primary goal of reducing the effects of climate change and promote sustainable development at central to community levels (NAPA, 2009). Based on different substantial pieces of evidence and studies, NGOs are the principal source of transferring knowledge about climate change to grass-roots people. They can add-on the climate change as an essential cross-cutting issue in their all of the development projects to mitigate the impacts of climate change. Many NGOs in Bangladesh are working on climate change adaptation issues focusing on life-skills and income generation activities for improving household and community development (Lönnqvist et al., 2010).

Electronic media can play a vital role to provide the information about climate change. Media can promote the climate change policies through proper research, live documentary, roundtable discussion, special supplementary, and features (Haque et al., 2010). Therefore, it is essential to make and provide the sufficient information on the climate change issues and adaptation processes for community people through electronic media. Mujaffor (2011) argued that growing awareness and dissemination on climate change issues through different media channels can play a crucial role in improving sustainable development at the community level.

The findings of Structural Equation Modeling (SEM) are significant in the study because local government institutions and officials do not have adequate management and coordination skills to tackle different impacts of climate change. Moreover, various government initiatives like Sustainable Development Goals (SDGs), National Adaptation Plan (NAP), National Biodiversity Strategy and Action Plan, National Adaptation Programs of Action, National Action Programme for Combating Desertification, Bangladesh Capacity Development Action Plan, National Sustainable Development Strategy, National Climate Change Strategy, and Action plan, National Sustainable Development Strategy should have vital roles in enhancing climate change knowledge and adaptation to rural and urban communities. The following recommendations can be useful adaptation measures depending on the outcomes of this study:

- Introducing the human security framework in the policymaking to adapt to climate change.
- In national climate change policies, the programs should essentially include gender perspective adaptation policies.
- Ensuring women's participation in climate change dialogue and decision-making at local, regional, and national levels.
- National Adaptation Programme of Action (NAPA) should be revised and include a gender perspective, especially for ultra-poor women.
- Encouraging more research on the gender-specific vulnerabilities of climate change.
- Policies can be categorized based on the climate hazard types and affected areas.
- Policies and legislation also should focus on the sustainable development goals.
- Initiate adaptation funds for the most affected areas and most vulnerable people to climate change.

5 Conclusion

This study explores the different perceptions of climate change and its adaptation options from ultra-poor women in the study area using a set of quantitative and a few KIIs data. Along with some descriptive statistical analyses, this study conducted a sophisticated Structural Equation Modeling (SEM) to delve into different internal and apparent relationships between some fundamental variables standard for the climate change studies. This study reveals that the perception of climate change at participants' level is relatively low (63%), but they have observed the significant differences in climatic parameters over the past 30 years. To tackle these changes and impacts, they adopt some local indigenous methods to improve the existing ecosystem and environment, agriculture, human well-being, and overall socio-economic developments. As a result, they had to invest in implementing these adaptation processes ranging from $20–45 at the household level. From the SEM results, climate change is real and happening in this study area. Therefore, the roles of local government, along with other development actors, can incorporate the existing policies into any regional planning and developments in the study area. The main limitation of this study was the low sample size and not using other secondary information.

Further research on this similar issue may have a robust sample size with mixed-method data collection and analysis. However, this study can be used as technical guidance for analyzing the similar ecosystem data in Bangladesh and other areas. Local government, NGOs, and other development actors may use these findings for preparing any development initiatives in the study area related to the climate change and environmental studies.

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Chapter 20
Climate Change Adaptation and Resilience on Small-Scale Farmers

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Abstract Smallholder agricultural activities are susceptible to risks and uncertainties compounded and affected by climate change in intensity, frequency, and scope. Risks affecting crop yields and livestock survival are most important for smallholders, as they tend to consume a significant part of their own production. Local farmers have learned to live with the uncertainties of a changing climate, coping and adapting by building a memory of past events, accepting the reality of unstable systems, and increasing their ability to learn from shocks and crisis. Diversification of livelihoods is often used to reduce risks and increasing options in the face of increased climate hazard. Community-based monitoring and indigenous observations provide important impetus to close the gap between local impacts and adaptations and global science. Vulnerability of smallholder farmers is seen by their exposure to climate hazards, as they depend on climate-sensitive rainfed agriculture. However, the smallholder systems exhibit resilience to climate change, registered by their ability to deal with the shocks and hazards over time. Such resilience comes through development of various adaptive capacities, enabling the farmers to withstand the vagaries associated with uncertainties of a rapidly changing climate. Options to cope and adapt to change on smallholder farms often include climate-smart agriculture, off-farm livelihood options, and guided interventions by national governments, e.g., promotion of drought tolerant crop varieties.

Keywords Smallholder farmers · Adaptation · Adaptive capacity · Resilience · Climate change

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1 Introduction

Agriculture plays a huge role in ensuring the food security, job creation and generating income to farmers at local scale as well as globally. However, it can be affected by climate change. Human activities such as the burning of fuels, deforestation, and urbanization can contribute to greenhouse gas emissions, thus influencing climate change (Michalak, 2016). About 1.5 billion population in sub-Saharan Africa is expecting agriculture to play a huge role in feeding and enhancing food security by 2050 (FAO, 2007). However, due to climate change, achieving this goal will be a challenge. Crop yields are expected to drop by 2050 due to climate change and variability unless farmers adopt and use the mechanisms that will assist in adapting to climate change to enhance food security (Aggarwal et al., 2018). Smallholder farmers are more vulnerable to climate change because of the high poverty rate and high dependency on rainfall for sustainable agriculture.

2 Evidence of Climate Change and Its Impact on Smallholder Agriculture

Climate variables such as temperature, erratic rainfall, and extreme weather events affect the agricultural production severely. These factors affect pest population, pest distribution, pest behavior, and pest migration rate (Durak et al., 2016). Poikilothermic pests are the most affected by climate change and are more adaptable to increased temperatures than any other pests (Durak et al., 2016). Smallholder farmers are already vulnerable to such pests' damage and due to increased temperatures, they are expected to be more vulnerable to increased pest infestations. This has become a major problem in enhancing food security and sustainable agriculture due to lack of resources to manage these problematic pests.

As the vagaries of climate change and variability continue to unfold, it is the smallholder farmers who bear the brunt of nature's wrath (Parnell & Walawege, 2011). Smallholder farmers lack the necessary resource endowments to be able to effectively cope and adapt to rapid changes in the weather. Apart, from low resource endowment, these smallholder farmers also largely depend on climate-sensitive rainfed agriculture to sustain their livelihoods (Jiri et al., 2017). With increasing ambient average day temperatures, cooler night and winter temperatures, and poorly distributed rainfall, these small farmers have to drastically evolve and adopt new ways of farming and living. Such adaptation is not easy. It has to span from what the farmers are used to do but often venture into unchartered waters of adaptation beyond the individual and community levels. As usually reported, smallholder farmers have been coping and adapting to climate change since time immemorial (Ubisi et al., 2017). Such ways of coping, adaptation, and resilience need to be unpacked and documented. There are coping and adaptation strategies that are specific to a locality, but there are also some which are broad. Commonly, indigenous knowledge systems are believed to be specific, while scientific and meteorological models tend to be robust and need downscaling. However, some indigenous knowledge systems are robust, and there efforts to downscale the climate models to be effective at the local level (Nkomwa et al., 2014).

The impacts of climate change are often glaring at the local level, with loss of livelihoods being the eventual evidence. These impacts range from loss of agricultural productivity, for both crops and livestock, to loss of water and forest resources, due to temperature and rainfall variations (Muller, 2009). Crop yields have continued to decline, even with the “climate-smart crops” being developed and promoted in places. Droughts have become more frequent, particularly over southern Africa, causing devastating loss of life and livelihoods (Lobell et al., 2008). As a result of climate change, various biophysical risks are going to change, most of them in an uncertain way. Measuring these risks and impacts is often a complicated and difficult process as each component of the system will react differently, hence changing relationships within the system, at the local, national, and international levels.

3 Concept of Adaptation

Adaptation defines the processes of deliberate change in response to shocks and risks (in this case resulting from climate change) and other changes that affect the lives of people and communities (Below et al., 2010). The causes of these changes are usually very difficult to precisely identify. Successful adaptation is those actions that decrease the vulnerability of the smallholder farmers and increase resilience, in response to the shocks and risks. The vulnerability of the smallholder farmers depends on the degree of exposure to the climate risk or shock; and on the sensitivity of the system, their livelihoods are dependent such as rainfed agriculture; the already acquired adaptive capacity; and already acquired resilience (Berkes, 2007). For most smallholder farmers, whose lives depend on rainfed agriculture and the natural resource base, successful adaptations help to build resilience and decrease vulnerability to multiple threats. In relation to smallholder farming systems, it would be of interest to analyze the relationship between autonomous, locally driven adaptation and managed policy-driven adaptation. Local level coping and adaptation strategies are often seen as reactive, while policy-driven adaptations are seen as planned.

3.1 Local Forms of Adaptation

Smallholder farming communities, particularly in the global south, have been using a variety of strategies including indigenous knowledge systems and genetic diversity to adapt to climate change and variability (Padulosi et al., 2011). This has helped define types of effective and sustainable climate change adaptation. For example, smallholder farming communities have always protected wetlands which act as floodwater reservoirs. This brings to the fore what has been recently coined as "ecosystem-based adaptation." This approach tends to increase the local resilience and adaptive capacity when managed appropriately. There is also evidence that ecosystem-based approaches can be cost-effective and, concurrently, generate the social, economic, and environmental co-benefits (Valdivia et al., 2010).

The other approach has been termed "community-based adaptation," owing to it being a community lead process, based on community priorities, needs, knowledge, and capacities, which help the people to plan and cope with the impacts of climate change and variability. Community-based adaptation is often practiced reducing the impacts of vulnerability to farmers and also to assist farmers in becoming more resilient to climate change. It helps in boosting farmers adaptive capacity in order to improve the livelihoods and to enhance agricultural sustainability by implementing techniques and strategies to adapt to climate change (Gero et al., 2011). However, when implementing this approach would be inadequate to engage the community without adequate knowledge and understanding of the strategies to be used.

3.2 Why Adapt?

Climate change continues to impact the livelihoods at various levels of society. The smallholder farmers are hardest hit as, in most cases, they depend on climate-sensitive rainfed agriculture. Climate and weather extremes such as droughts, heat-waves, and flash floods already create widespread problems for smallholder farming communities (Stringer et al., 2009). In the absence of adaptation, these challenges will grow as the climate change increase the intensity, frequency, and duration of these extreme events. These impacts would be costly to attend to in the future. The impacts of climate change and variability are most acutely felt at the local level (Gbetibouo et al., 2010). This positions the smallholder farmers at the front line of having to deal with the climate change impacts. This creates the need and opportunity to reduce the vulnerability through adaptation planning at the local level. Action that is taken now to reduce vulnerability to current and future climate impacts may also lower the costs of those impacts by reducing financial losses and reducing the disruptions to livelihood processes. Furthermore, the range of coping and adaptation options may be more when preparing for, rather than reacting to, climate impacts (Rhodes et al., 2014).

3.3 Constraints to Adaptation

Climate change may happen rapidly or severely, that adaptation becomes difficult. Adaptation may be limited by the threshold of the climatic shock. These limits may be ecological, economic, physical, societal, or technological in nature. In order to reduce the adverse effects resulting from climate change, farmers need strategies to adapt to climate change impacts. However, this becomes more difficult due to lack of resources, lack of risk exposure awareness (Elum et al., 2017), poor service delivery from extension services and other organizations, poor technological facilities and norms and beliefs of farmers (Otitoju & Enete, 2016). Africa is expected to be exposed to increased water stress by 2020 and this will affect crop yields (Parry et al., 2007). Although smallholder farmers are battling to adapt to climate change impacts, in some African countries, farmers minimize climate impacts by changing crop planting dates, planting drought-resistant crops, and also irrigating their crops to improve yields (Bryan et al., 2009).

4 Resilience Building

In the context of smallholder agriculture, resilience entails the ability to survive and sustain livelihoods in the face of climate change and variability. Building resilience to climate change and variability should begin by building resilience through sustainable management of natural resources and ecosystem restoration (Gitz & Meybeck, 2012). Interventions, defined as building resilience, largely depends on the nature of the shock and risk. Some risks such as plant pests and livestock diseases resilience building would focus on early warning and action to prevent the spread of the risk (Fig. 20.1; Pasteur, 2011). However, this would need appropriate

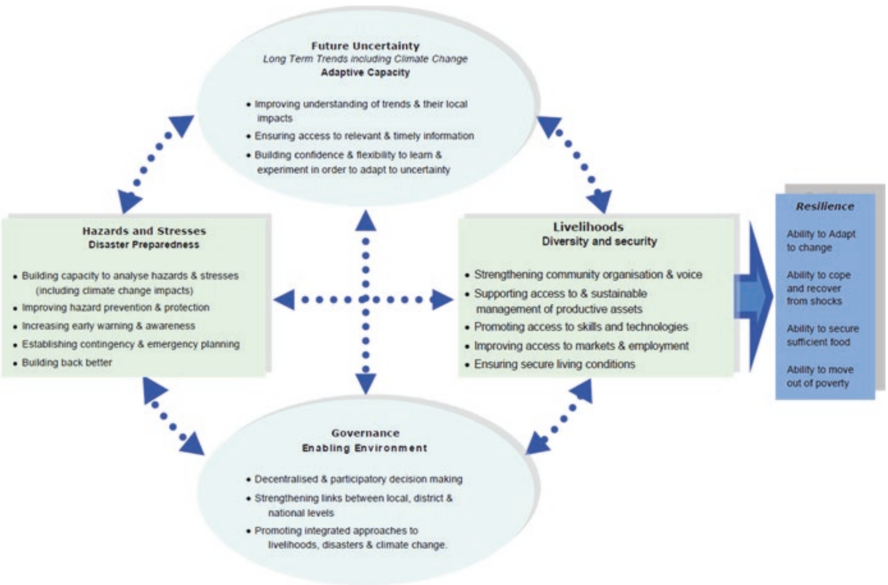

Fig. 20.1 Resilience framework (adapted from Pasteur, 2011)

equipment and tools, policies, and institutions to be in place. For crop seeds, for example, there would need to preserve genetic resources, and then making them accessible when needed. It should be noted that extreme climatic events significantly change the decision environment and a typical government response would be to institute implementation of robust policies, which may not be optimal in normal circumstances, but which avoids negative outcomes.

The Intergovernmental Panel on Climate Change defines resilience as “the ability of a system and its component parts to participate, absorb, accommodate or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration or improvement of its essential basic structures and function” (Seipt et al., 2013). The continued upsets in temperatures and rainfall, negatively affecting the productivity of crops and livestock, affect food security. The uncertainty in the prediction of climate shocks and events increases the sensitivity of ecosystems and communities (Gitz & Meybeck, 2012). Climate change introduces the new uncertainties, modifies shocks and risks, vulnerabilities and the conditions that help the resilience of agricultural systems. Building resilience has to start with reducing vulnerabilities, as there is generally a negative correlation between the two (Gitz & Meybeck, 2012). The complication in this relationship is the problem of the time dimension, and the need to deal with uncertainties. This means that the resilience of agricultural systems cannot be an event but should happen over time, often with uncertain outcomes. This is what defines adaptive capacity. Adaptive capacity is a dynamic notion which denotes the capacity of a system to adapt in order to be less vulnerable (Aymone Gbetibouo & Ringler, 2009). This capacity is determined by the interaction of biophysical, economic, social, and economic factors that shape vulnerability though exposures and sensitivities. In essence, coping and adaptations are manifestations of adaptive capacity. It can be interpreted that increasing resilience can be achieved by reducing vulnerabilities (reducing exposure and reducing sensitivity) and increasing adaptive capacity. It is critical, therefore, to reduce the transmission of shocks between different types of risk, between scales and between domains and their interactions to negate cumulative effects so as to achieve better resilience.

The dynamic nature of agricultural systems poses the challenge of prescribing certain resilience building options. To ensure resilience, actions that build resilience in agricultural systems must be considered through time and taking into consideration future uncertainties (Table 20.1). Agricultural practices such as climate-smart agriculture (CSA) may help increase the resilience of smallholder agricultural systems (Stringer et al., 2012). CSA is multi-faceted but aims to increase agricultural productivity and incomes, as well as increasing resilience of ecosystems and livelihoods to the climate change and variability. In the longer term, CSA also helps to reduce greenhouse gas emissions. The effectiveness of CSA is driven by its consideration of context-specific and locally adapted actions and interventions, along the whole agricultural value chain. If promoted at the local level, this practice can strengthen the local knowledge base on sustainable strategies, and improve on financial and policy options to enable communities and countries to meet their food and nutritional security goals (FAO, 2010). Some of the key strategies that can be

Table 20.1 Suggestions on building smallholder farmer resilience at local level

Resilience building strategy	What can be measured as enabling information	Pathways for building resilience	Measurable outcomes
Access to localized, relevant, accurate data	Downscaled climate modelling and up-to-date climate change scenarios	Scientific and academic community and stakeholders consolidate and downscale research	Availability of data
Optimal activities in the face of climate change	Vulnerability and risk assessments Relevant downscaled climate modelling, weather and seasonal forecasts	Institutional social and safety nets, essential services, and emergency response services	Improved long-term stability against shocks and stressors Early warning systems operational at local level
Informed decision making	Downscaled climate modelling analytical tools to map impacts and weigh benefits and trade-offs	Engagement with climate information producers and knowledge brokers to discuss needs and availability of information	Useable and reliable climate change information available for use by policy makers and planners at the local and national level
Promotion of innovation and local research	Scenarios of future agroclimatic conditions Principles, practice, and case studies of resilient options available for farmers	Research programs specifically targeting climate resilient crops for expected conditions	Climate resilient crops developed and being trialled
Trained practitioners	Key skills required for climate resilient systems	In-service training to fill skills gaps in current agricultural practitioners	Courses that support climate resilience
Food security and farming	Principles, practice, and case studies of climate-smart options for different crops for different cropping systems	Promotion of climate-smart agriculture via extension, courses, and other information options Financial support and other incentives available for climate-smart agriculture	Farmers adopting climate-smart agriculture

used by smallholder farmers to develop the resilience and adaptive capacity are shown in Table 20.1. Success and continued adaptation are defined by these factors.

Building resilience around local woodlands, forests and trees in smallholder communities requires a basket of actions (Leeuwen et al., 2013). These may include the conservation, management, and use of the natural forest resources to reduce risk on the forest and people vulnerable to climate change. For example, the local folks in most indigenous communities use indigenous knowledge systems to predict seasons and forecast season quality through the use of tree phenology and animal behavior. Preserving these trees would ensure the perpetuation of use of indigenous knowledge in such communities (Njiraine & Ocholla, 2010). However, it also becomes a challenge when prolonged droughts, due to climate change, destroy the forest resources, often changing animal behavior and migration patterns, useful for indigenous predictions.

At the policy level, strategies to build resilience must combine a set of specific policies aimed at addressing certain categories of risks and vulnerabilities. Policies to help smallholder farmers should aim at building economic resilience at the farm level through increasing incomes and promoting diversification (Ifejika Speranza and Deutsches Institut für Entwicklungspolitik, 2010). Other measures could also include actions to prevent loss of productive assets, such as feedbanks for livestock during a drought or measures that help a quick recovery, such as ensuring availability of seed. The effectiveness and efficiency of risk management policies depend on other enablers such as favorable policies, support institutions, effective coordination and appropriate infrastructures, such as transport and markets (Pye-Smith, 2011).

4.1 Measuring Resilience

Resilience analysis is concerned with the ability of households or communities to adjust their livelihoods after disturbances (Osman-Elasha, 2006). To analyze resilience, therefore, both ex-ante actions that reduce continued risk and ex-post actions that help households and communities after a crisis occurs must be considered. This will lead to the most effective combination of short-term and long-term strategies for building the adaptive capacity and resilience, moving the families and communities out of the traps of food and nutritional insecurity. For smallholder farmers, four basic tenets determine their resilience to food security shocks as a result of climate change and variability (Solh & Van Ginkel, 2014):

1. access to water, healthcare, and energy
2. social safety nets, e.g., food assistance
3. assets, e.g., land, livestock
4. access to food (and income)

An analysis of these factors can give a quantitative score of resilience for each household. Further analysis of these pillars could also indicate which pillar needs to be strengthened to further build resilience. For example, analyzing how and why people in a certain location became food insecure may suggest ways of preventing this from happening in the future. Interventions that are made can then be tailored to enhance the people's ability to manage risk, climatic or otherwise, over time, leading to a reduction of the need for humanitarian assistance over time. Generally, vulnerability assessments and resilience assessments often compliment, rather than being seen as alternatives. However, the important difference is that vulnerability analysis tends to measure the susceptibility of farmers to damage when exposed to shocks, while resilience analysis pinpoints the specific factors that make households resilient, giving decision makers clear indications of where to intervene (Care

International, 2009). Policy interventions resulting from resilience analysis would lead to measures such as the promotion of climate-smart agriculture (CSA) and radical agricultural innovation systems. The main limitation to recommendations from a resilience analysis is usually financial, often addressed through private sector partnerships.

Policy measures that promote resilience in the smallholder farming sector often should go beyond the agriculture facet. Non-agricultural interventions are often important to enhance the effectiveness of these measures. Investments in infrastructure, developments of credit markets, enhancement of health facilities, and addressing other institutional constraints would support challenges in the face of climate change and variability. Safety nets for vulnerable smallholder farmers are a priority in the policy. Most of the smallholder farmers are not able to adapt and benefit, even when prospects are enhanced. For such smallholder farmers, safety nets to support production and consumption are required. Such decisions can be made based on the results of resilience analysis (Food and Agriculture Organization, 2013).

5 Conclusions

There are so many uncertainties in the way that climate change will, directly and indirectly, affect and impact the agricultural and food systems, as well as increasing related vulnerabilities. This makes building resilience of the individuals and communities central to risk-preparedness for future changes. Such resilience options need to be explored at the ecosystem (biophysical), economic, social and institutional levels, as well as at the various scales of operation and implementation. However, there can be an interaction between domains and scale of resilience implementation. For effective resilience building, it is important to identify and monitor potential shocks, risks, and vulnerabilities. This will allow early actions to be taken and avoid cumulative and long-term effects. There is also a need to increase the adaptive capacity of smallholder farmers and systems, to be able to recover from shocks and to prepare for future climate change. Disasters result from the impact of hazards on vulnerable communities, people with fragile livelihoods and who are inadequately prepared, not only from hazards themselves. Therefore, disasters are not inevitable and farmers do not have to be helpless. Action can be taken to build resilience to hazards and strengthen adaptive capacity to further climatic shocks. Farmers have traditionally adapted to the climate risk by diversifying across crops and risk management options. Farmers generally diversify their production systems by employing activities that are less sensitive to drought and/or temperature stresses and activities that take full advantage of beneficial climate conditions. For example, farmers time their planting and inputs based on their best estimates of the cropping season; and they reduce risk exposure by diversifying their livelihoods. Farmers diversify their cropping practices using a mix of crop species both in space and time (e.g., intercropping of different crops species, strip cropping and double cropping), growing different cultivars at different sowing dates and farm plots; combining less productive drought-resistant cultivars with high-yielding but water-sensitive crops. Nevertheless, managing droughts effectively in the vulnerable areas requires diversifying livelihood strategies and income generating options within and outside agriculture especially into income generating options through non-farm enterprises and employment opportunities. This will require the greater investments in infrastructure, road networks, electricity, communication, and market development. It is important that extension officers in African countries should be well informed about climate change and its impacts and also how to adapt to these changes to reduce vulnerability. There needs to be a strong link between research organizations and extension by the relevant institutions active at a country level. Workshops and formal meetings should be held to share information to extension officers so that they should give it with smallholder farmers. In order for the smallholder farmers to adapt to climate change, more experimental researches should be conducted on the farm, for farmers to see, look, and learn through experience.

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