Food and Agriculture
Organization of the
United Nations

BUILDING RESILIENCE INTO WATERSHEDS

A SOURCEBOOK

Mountain Partnership

Building Resilience into Watersheds

A sourcebook

Food and Agriculture Organization of the United Nations

Rome, 2023

Required citation:
FAO. 2023. *Building Resilience into Watersheds – A sourcebook*. Rome. https://doi.org/10.4060/cc3258en

ISBN 978-92-5-137347-7

Cover photograph: Mountainous agriculture and forestry system in Japan
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Content

Foreword

The magnitude and frequency of hazards linked to climate variability and extremes has grown in the last decade. Annual occurrence of disaster today is found to be more than three times that of 40 or 50 years ago. Increased risk exposure is a new reality and the impacts of climate change will exacerbate it.

Wildfires, extreme weather, desert locust swarms, and emerging biological threats like the COVID-19 pandemic are threatening agrifood systems and people's lives and livelihoods, especially in rural areas. These hazards have interacting and cascading negative effects can last for many years.

People's ability to cope with and recover from the impacts of hazards is closely associated with the ability of the ecosystems they depend on to withstand natural and anthropogenic impacts. Building the resilience of people and ecosystems in the face of climate-related hazards therefore is a priority for natural resources management.

For 65 years, the Food and Agriculture Organization of the United Nations (FAO) has been at the forefront of developing and implementing landscape and natural resource management solutions that are people- and livelihood-centred.

This publication provides a framework for strengthening the integration of risk considerations into all aspects of watershed management processes, with the aim to increase the resilience of local communities.

In presenting existing tools and approaches for building resilience at the landscape level, this publication stresses the need for the formulation and implementation of cross-sectoral policies and investments to coherently address the new risks imposed by climate change.

It is our hope that users of this publication will apply and tailor the approaches presented here to the needs of their own communities and landscapes to develop more sustainable watershed management practices. This would reduce the impact of climate change, and creating more resilient livelihoods for all, thereby moving towards achieving the United Nations 2030 Agenda for Sustainable Development.

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Acknowledgements

This document is based on the work led by Yuka Makino, FAO, with inputs and support from Antoine Libert, Mashauri Muliro, and Jos Timmerman, FAO consultants.

FAO experts provided their inputs during the peer review, including Stephan Baas, Rebeca Koloffon, Peter Moore, Ewald Rametsteiner, Laura Russo, Mette Wilkie and Daowei Zhang. Thanks go also to the international experts who participated in the peer review process: Emmanuel Cheo, United Nations University (UNU); Maxime Souvignet, United Nations University Institute for Environment and Human Security (UNU-EHS); Nanco Dolman, Royal HaskoningDHV; Ansgar Fellendorg, United Nations Environment Programme (UNEP); Luca Fe D'Ostiani, FAO; Thomas Kohler, Centre for Development and Environment (CDE); Josef Krecek, Czech Technical University in Prague; Stefan Schneiderbauer, Global Mountain Safeguard Research (GMSR); Giacomo Teruggi, World Meteorological Organization (WMO); Zenaida Willison, United Nations Development Programne (UNDP); and Ken Zielke, Symmetree Consulting Group.

Gratitude is extended to Hans Schreier, University of British Columbia, for his revisions and for providing specific inputs on disaster risk management measures.

Many thanks to Samantha Abear, Enrico Aloi, Allison Bozzi, Alton C. Byers, Alex Chepstow-Lusty, Clare Pedrick and Azul Popper for editing, Barbara Hall for editing and proofreading and to Roberto Cenciarelli for the graphic design and layout.

Abbreviations and acronyms

FAO	Food and Agriculture Organization of the United Nations
GAR	Global Assessment Report on Disaster Risk Reduction
GIS	geographic information system
IPCC	Intergovernmental Panel on Climate Change
LID	low impact design
$\mathbf{M_w}$	Moment magnitude (earthquake scale)
NGO	non-governmental organization
NOAA	National Oceanic and Atmospheric Administration
OECD	Organisation for Economic Co-operation and Development
PGA	Peak Ground Acceleration (earthquake scale)
PGIS	Participatory Geographical Information System
SDG	Sustainable Development Goal
SLM	Sustainable Land Management
SPEI	Standardized Precipitation-evapotranspiration Index
UNDRR	United Nations Office for Disaster Risk Reduction
UNFCCC	United Nations Framework Convention on Climate Change

About this sourcebook

Purpose and scope

The purpose of this sourcebook is to provide advice on how to incorporate disaster risk reduction and resilience building into the watershed management process. As an increasingly heavier toll is exerted on agriculture and food systems by drought, floods, wildfires, and other extreme events, adopting risk reduction and management practices must become an integral part of watershed management. While the steps involved to incorporate resilience building are similar to those routinely carried out in integrated watershed management, this sourcebook stresses the importance of understanding disaster and climate risks, adopting a landscape approach and targeting vulnerable groups (e.g. women, youth, Indigenous Peoples, others) at all stages of planning and implementing watershed management.

This publication contributes to FAO's work in developing guidelines, policy briefs and handbooks that provide decision-makers, field technicians and development practitioners with data-driven, up-to-date recommendations on key issues related to watershed management and sustainable development.

Previous FAO publications on the subject have included a number of guides and handbooks related to integrated watershed management and its practice (FAO, 1998, 2005a, 2006, 2017, 2019a). The publications include discussions on climate change and agricultural management, as well as the impact of disaster risk reduction in agriculture on local and national scales (FAO, 2008, 2014a, 2018a, 2019b, 2021). Other field guides have been produced on the topics of risk reduction in agriculture (FAO, 2015) nature-based solutions for agricultural water management (FAO, 2018b), and the role of forests in landslide risk reduction (FAO, 2013a) and flood risk reduction (FAO, 2005b.

A free e-learning course "A guide to developing a resilient watershed management plan" (FAO, 2020a), developed as a companion to this sourcebook is also available.

This publication is based on a stocktaking of best practices, approaches and lessons learned in the incorporation of risk into integrated watershed management from a landscape perspective while emphasizing that all elements of the constituent landscape (including livelihoods, land use, ecosystem services, infrastructure and customary management practices) are taken into account.

This sourcebook fits into FAO's commitment to global processes, such as the Sendai Framework for Disaster Risk Reduction 2015–2030 (Target E) and the Paris Agreement while also contributing to the overall achievement of the 2030 Agenda for Sustainable Development and its Goals.

Intended users

This sourcebook is primarily aimed at practitioners in the field of landscape and watershed management who desire to integrate climate change and disaster risk management approaches into their traditional programme portfolios. It is designed to be user-friendly and accessible to readers with different background knowledge and/or experience. National governments, local government experts and community specialists may find the sourcebook of use for its step-by-step descriptions of designing and implementing watershed management programmes in the face of a changing global climate and associated increase in hazard risks.

How to use this sourcebook

The sourcebook provides an overview of the steps required to build resilience in the watershed management process. It sets out the building blocks that together form a coherent guide to developing a resilient watershed management plan, as well as its implementation, monitoring and evaluation. Users should bear in mind that the elements presented here should be tailored and adapted to each particular situation.

The sourcebook deliberately offers generic recommendations, rather than delving into specific methods or tools. Recommended reading and materials are suggested at the end of each chapter for users interested in further information.

The chapters of the sourcebook can be summarized as follow:

Chapter 1: Main concepts and definitions related to resilience and watershed management stresses that resilient watershed management routinely incorporates the landscape, climate change, and risk perspective into its research, analysis and implementation processes. Resilience is the ability of a community to "bounce back" from an unanticipated and extreme weather event or natural hazard, in part *because they were prepared to do so*. "Landscape approach" refers to the inclusion of all aspects of land use and societal needs, from the highest snow-covered mountains to the coastal plains, in the analysis of disaster and climate-related risks conducted. Resilient watershed management promotes the integration of the physical and social sciences, the experience and knowledge of local people, and contains an emphasis on long-term sustainability within the programme planning and implementation processes.

Chapter 2: Enabling environment for effective implementation of resilient watershed management describes the policy, legislative and institutional conditions that are required for resilient watershed management to be able to achieve its full potential of environmental, economic, and social benefits. Ensuring an enabling environment entails that:

- existing policies are relevant to watershed management, including climate and disaster risk management, and involve climate-proofing of policies and land-use planning mechanisms;
- legislation regarding watershed management is supportive of resilient watershed management approaches;
- supportive institutional arrangements, including local participation, communication, capacity development and coordinating mechanisms, are in place;

- information necessary for sustainable development, climate and disaster risk management, and climate change adaptation is available; and

- financial arrangements are in place, including a budget, cost recovery and mainstreaming of risk-related costs, to enable the implementation of the resilient watershed management goals, objectives and activities, as well as the monitoring and evaluation systems as defined in the resilient watershed management plan.

Chapter 3: Stakeholder engagement focuses on how effective stakeholder engagement facilitates the collection of information and sharing of ideas and expertise. The stakeholder analysis phase of planning focuses on identifying key groups, who could benefit from risk aversion actions, and/or who are responsible for implementing the activities. Integrating the risk perspective into the stakeholder engagement processes recognizes that various stakeholders are affected and respond differently to the impact of disasters and climate change. Explicit recognition of this diversity will strengthen resilient watershed management strategies, along with individual stakeholder engagement.

Chapter 4: Perform risk assessment describes how to integrate risk management considerations into overall watershed management, in order to assess the risks at hand. Climate and disaster risk assessment involves identifying different degrees of risk and taking account of their potential impacts, as well as the likelihood of their occurrence. Climate and disaster risk assessment also acknowledges that hazards cannot be prevented, but focuses on how to reduce exposure to them while lessening the vulnerability of those who live in hazard-prone areas, as well as to their livelihoods. This assessment can serve to identify and delineate risk hotspots within the landscape and isolate *risk reduction opportunity areas* during the management plan development process. The importance of identifying these areas, where interventions – such as erosion control, revegetation and drainage – will have the strongest potential for reducing risks to downstream populations and infrastructure, is underscored throughout. Risk assessments can be performed not only using sophisticated technologies, such as geographic information systems (GIS), but through community consultations alone, or some combination of both.

In **Chapter 5: Measures and strategies for resilient watershed management** are summarized as: prevention and mitigation; preparedness; and response, recovery and reconstruction. Risk management emphasizes the need for an integral and long-term vision of risk, which goes beyond relief and reconstruction, and which underscores the importance of prevention and mitigation. The goal is to identify a set of integrated measures that can be combined to form the resilient watershed management plan.

Chapter 6: Monitoring and evaluation for resilient watershed management explains the need to identify the appropriate indicators, information and data sources to determine the impact and effectiveness of the risk reduction measures implemented under the resilient watershed management. In order to determine the effectiveness for risk reduction, it is important to monitor the impact on each aspect of risk: extent of hazard, reduction of exposure to the hazard, reduction of vulnerability to the hazard and the increase in capacity to address the hazard. Once this data is collected, it is important to analyse and communicate it to all the stakeholders and where necessary, modify or add further risk reduction measures to ensure the effective reduction of risk.

Chapter 7: Conclusion recaps the steps in the cycle that make up the watershed management planning process.


Sacred Valley in Peru
©Andy Salazar/Unsplash

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Main concepts and definitions related to resilience and watershed management

Alpaca in the Plurinational State of Bolivia
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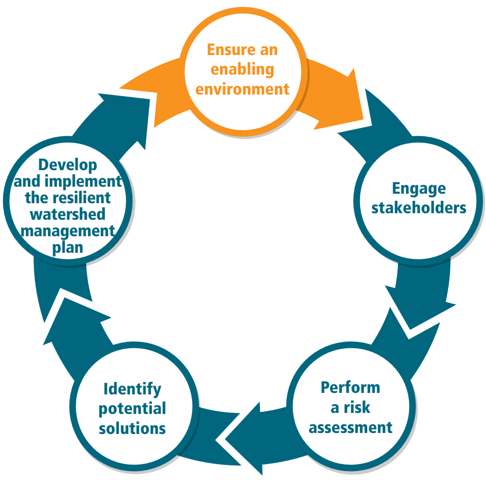
1. Main concepts and definitions related to resilience and watershed management

1.1 Introduction

This chapter describes the main concepts and definitions that help understand the resilient watershed management approach. Building resilience in integrated watershed management planning and implementation requires the incorporation of a risk perspective at all steps of the watershed management cycle (see Figure 1.1).

The landscape and ecosystem-based approaches and climate mitigation and adaptation measures in watershed management are discussed. The importance of assessing the vulnerability and capacity of the different stakeholders is highlighted.

Figure 1.1: The resilient watershed management cycle

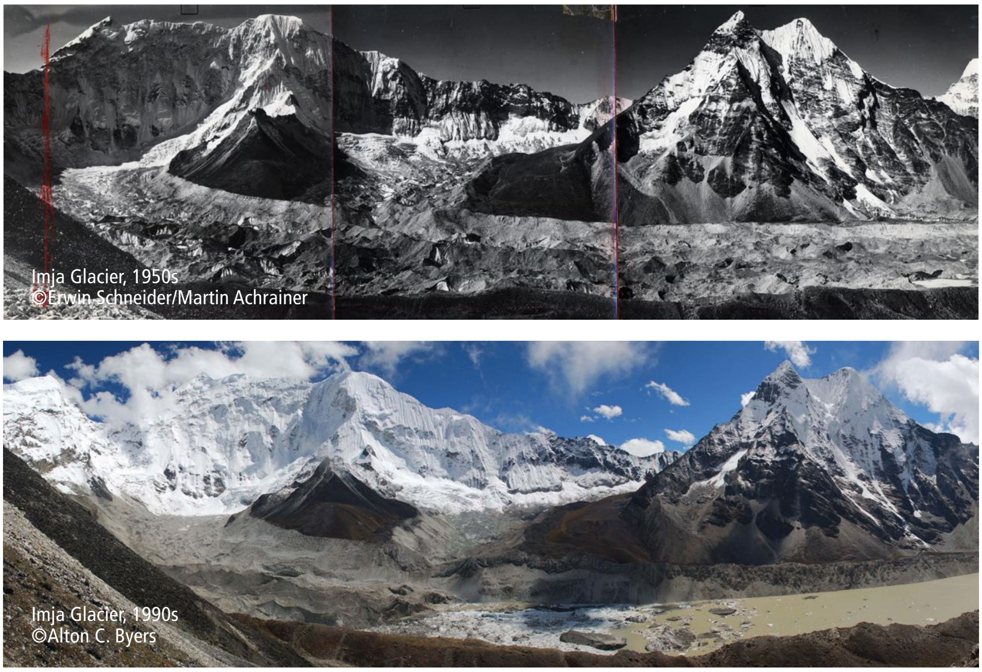


Source: Author's elaboration

1.2 Principles of resilient watershed management

Over the past 20 years, there has been a sustained rise in the frequency and intensity of climate-related disasters, such as floods and droughts. In 2017 alone, nearly 100 million people were directly affected by natural hazards, 78 percent of which were the result of floods, storms or droughts (CRED, 2018). Agriculture absorbs a disproportionate share of disaster impacts: between 2008 and 2018, the agricultural sector in developing countries absorbed 23 percent of all damage and loss caused by medium- to large-scale climate-related disasters (FAO, 2021). All over the world, rural communities are at higher risk of experiencing the negative effects of the increase in the frequency and intensity of extreme weather-related and climate-induced events observed over the past decades (see Figure 1.2 and 1.3).

Figure 1.2



Top: High mountains have been particularly vulnerable to the impacts of climate change. This photograph shows the Imja Glacier, Mount Everest region, Nepal in 1955, which at that time was covered with debris.

Bottom: In the early 1960s, small meltwater ponds began to form near the terminus of the Imja Glacier, which by the 1990s had coalesced to become a small lake. However, by 2013, when this photograph was taken, the Imja Glacier had produced a large and dangerous glacial lake susceptible to periodic glacial lake outburst floods.

Figure 1.3: Community with high exposure and vulnerability located in the floodplain and immediately below a large landslide area in Uttarakhand, India

The photos were taken from across the Mandakini River (left) and from the top of the mountain immediately above the site of a landslide (right).

Understanding disaster and climate risks

Understanding and managing risks of extreme weather and climate events are central to watershed management. Disaster risk is the interaction between hazards, the exposure to them, the vulnerability of a livelihood or a system such as a watershed, and the capacity of the people, community and/or institution to bounce back after the exposure.

Highlands in Ethiopia
©Rob Marchant

BOX 1.1
Basic climate and disaster risk definitions

Capacity refers to the combination of all the strengths, attributes and resources available within an organization, community or society to manage and reduce disaster risks and strengthen resilience (UNDRR, 2019a).

Climate is the long-term average of weather, typically averaged over a period of 30 years (IPCC, 2013).

Climate risk refers to the consequences, likelihoods and responses to the impacts of climate change and how societal constraints shape adaptation options (Eckstein *et al.*, 2018).

A disaster is a serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts (UNDRR, 2019a).

Disaster risk is the potential loss of life, injury, or destroyed or damaged assets that could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity (ibid.).

Exposure is the situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas (ibid.).

Hazard is 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 (ibid.).

Resilience is the 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 through the preservation and restoration of its essential basic structures and functions using risk management (ibid.).

Vulnerability refers to the conditions determined by physical, social, economic and environmental factors or processes that increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards (UNDRR, 2019a). Vulnerability must be understood within a holistic approach that recognizes the sensitivity or fragility of the system, embedded within a social dimension (e.g. gender, health and education), economic dimension (e.g. income and wages), physical dimension (e.g. roads, houses and railways), cultural dimension (e.g. indigenous knowledge, artefacts, cultural practices and norms), environmental dimension (e.g. ecosystem functions and services, watersheds and pollution) and institutional dimension (e.g. governance and laws) as well as within the dimension of resilience (IPCC, 2019).

Notes

1. United Nations Office for Disaster Risk Reduction. 2019a. *Terminology on disaster risk reduction*. Cited 25 October 2022. www.unisdr.org/we/inform/terminology

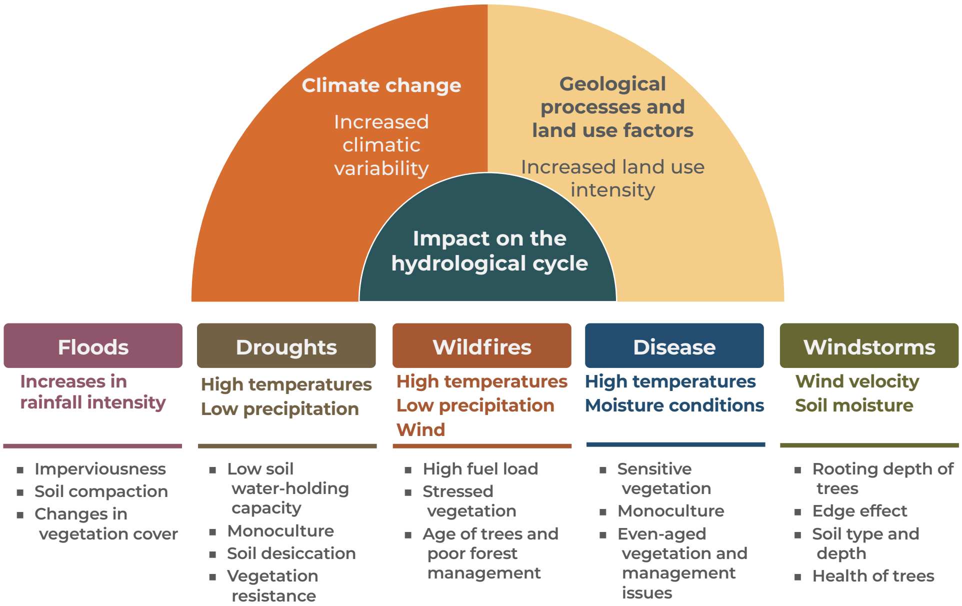
2. Intergovernmental Panel on Climate Change (IPCC). 2013. Climate change 2013: The Physical Science Basis. www.ipcc.ch/site/assets/uploads/2018/03/WG1AR5_SummaryVolume_FINAL.pdf

3. Eckstein, D., Kunzel, V., Schafer, L. & Winges. M. 2018. *Global Climate Risk Index 2020. Who suffers most from extreme weather events? Weather-related loss events in 2018 and 1999 to 2018*. Berlin. www.germanwatch.org/en/cri

4. Intergovernmental Panel on Climate Change (IPCC). 2019. *IPCC DDC glossary*. Cited 25 October 2022. www.ipcc-data.org/guidelines/pages/glossary/index.html

Climate change is expected to affect the frequency and magnitude of hazards. Recent evidence shows that many of the climatic events interact: for example, when a drought causes wildfire that is followed by a rainstorm event. Figure 1.4 presents some of the hazards to be considered in resilient watershed management. They are among the most important ones impacting agriculture and natural resources management in watersheds.

Figure 1.4: Main hazards to be considered in watershed management



Source: Author's elaboration

Designing measures for disaster risk reduction needs to be based on hazard risk assessment in the area considered. A commonly used approach for hazard identification and risk prioritization requires that the type of hazard and its potential impacts are to be identified first. This is followed by a specific assessment of where and to what extent people, infrastructure, livelihoods and the environment are vulnerable. The next step is to determine the probability and frequency of occurrence of the identified hazard. Then, a risk assessment needs to be carried out to decide how much effort should be made to minimize the risk. When a number of risks are identified within the watershed, then it is necessary to prioritize the risk.

Only after such a risk assessment is made can the most appropriate protective measures to prevent or minimize the impacts be selected. These measures include structural, non-structural, nature-based solutions and institutional, legislative, regulatory and policy measures that will be highlighted later in this sourcebook. These are the key elements to build resilience into watershed management.

BOX 1.2
Selecting climate adaptation measures

After the identification of the hazard and its frequency and magnitude, the analysis of what could be exposed to the hazard is carried out to develop measures for lowering the exposure. For example, if a particular area is found to have a high level of exposure to landslides, adaptation activities may include evacuation plans and drills, relocation of people living there, and land-use planning to ensure that the land-use activities do not aggravate or induce the hazard, or expose critical infrastructure to it. Other reforestation activities should be carried out and cropping patterns/farming systems adjusted to reduce erosion and ensure appropriate drainage.

Another step is to understand the vulnerability of the people who are exposed to the hazard. Vulnerability is related to the sensitivity of the social system and to its capacity to anticipate, cope with, and recover from a disaster event.

Individual, community and institutional vulnerabilities are linked to, among other things, the available knowledge of risk reduction methods, the existence of risk reduction and disaster preparedness measures, as well as to socioeconomic factors such as poverty and inequitable social dynamics.

Developing the capacity of each individual to protect themselves from climate and disaster risk may include activities to improve livelihoods and the ability to anticipate, cope with, and recover from disasters.

Developing capacity at the community level entails community organization for disaster preparedness activities, such as early warning systems, contingency budgeting, land-use planning, integration of risk into rural development planning, and community savings and credit systems.

Developing the institutional capacity to address and manage risks involves, among other things, the institutionalization of risk reduction into local, regional and national planning and budgeting, and the implementation of regulations and laws to prevent construction and settlement in high-risk areas.

Source: Author's elaboration

Figure 1.5 provides an example of how the evaluation of flood risks in a mountain community can be carried out. Initially, the sensitivity, adaptive capacity and vulnerability of people and infrastructure to flooding events are identified. If communities have low adaptive capacity, their vulnerability is higher. If the adaptive capacity is high, the community has greater potential to cope.

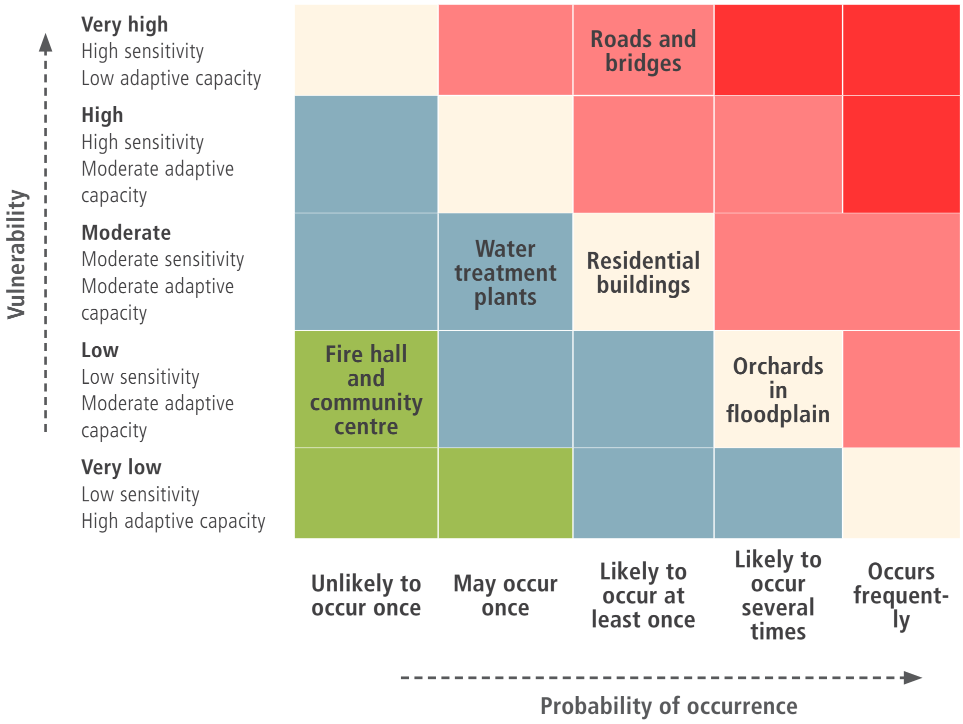
Then, the flood hazard is prioritized based on the level of vulnerability and the probability of such an event to occur. The upper right corner of the matrix in red is where the vulnerability and the probability of occurrence of the event are both high, indicating a priority risk.

Figure 1.5: An example of identifying the sensitivity, adaptive capacity and vulnerability of flood risks in a community

Sensititvity, adaptive capacity and vulnerability assessment for flood risks

Risks of flooding	Sensitivity	Adaptive capacity	Vulnerability
Damage to roads, buildings and bridges	High	Low	Very high
Damage to water treatment plants	Moderate	Moderate	High
Risk to life in rivers	Very high	Low	Very high
Risk to agricultural land activity	Moderate	High	Moderate
Damage to fire hall, hospital, community centre	Low	Moderate	Low

Example of flood risk assessment in a community



Source: Adapted and modified from Gorecki, K, M.Walsh, J. Zukiwsky. 2010. District of Elkford, Climate Change Adaptation Strategy. Zumundo Consultants |Report, 80 pp. www.cakex.org/sites/default/files/documents/get.pdf

This approach can be used for each type of hazard caused by climatic events (flood, droughts, fires, windstorm and disease) or triggered by earthquakes, or a combination of poor land management and climate factors.

Once the risks are prioritized, the appropriate processes of building resilience into watershed can be pursued. Many of the protective or preventive measures are well documented and have proved effective. For their implementation, it is important to overcome the institutional obstacles that relate to governance, policies, legal constraints and stakeholder involvement.

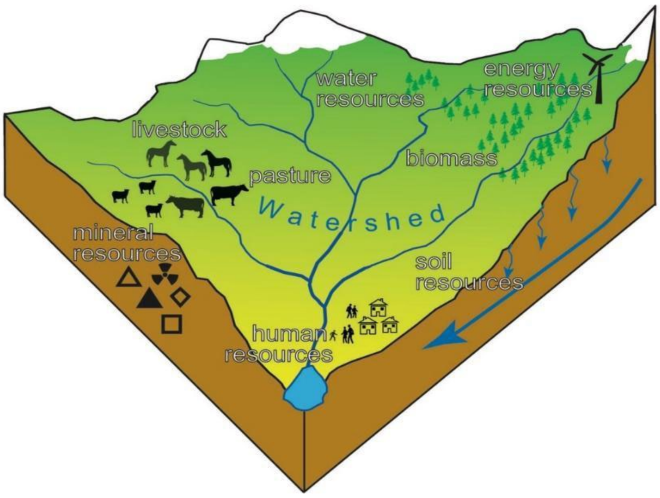
Chapter 4 presents a detailed framework for risk assessment and Chapter 5 highlights some effective structural and non-structural options for building resilience.

Integrated watershed management

A watershed is the geographical area drained by a watercourse. The concept applies at various scales – for example, from a farm drained by a stream (a micro-watershed) to a large river basin (or a lake basin).

A river basin usually comprises a complex system of watersheds and micro-watersheds crossed by, and draining into, a major river and its tributaries, generally from higher elevation, or source, to the river's mouth. A lake basin may be defined as a geographic land area draining into and containing a lake. Since soils and vegetation are linked to the water cycle, watersheds are an optimal planning unit for integrated water and land resources management (FAO, 2019a), as they encompass the entire landscape within a drainage area (Figure 1.6).

Figure 1.6: Components of a watershed



Source: GEO. 2014. *What means the term IWM?*. Cited 20 June 2019. www.geo.fu-berlin.de/en/v/iwm-network/learning_content/introduction_iwm/definition/index.html

BOX 1.3 Principles of integrated watershed management

1. Geographical scale – The watershed should be the planning boundary for integrated watershed management, and should be at an appropriate scale to address the issues under consideration in a way that recognizes its connectedness to upstream and downstream watersheds. (see Figure 1.7).

2. Ecosystem approach – An interconnected process should be considered that uses the best available knowledge, considers cumulative impacts, and promotes watershed and sub-watershed approaches.

3. Interdisciplinary analytical approaches – These should integrate the physical and social sciences in the watershed assessment, planning and problem mitigation process.

4. Adaptive management – Flexible and continuous improvement and adaptation of approaches, policies and management should be undertaken by incorporating new knowledge and innovative design, practices and technology.

5. Integrated approach – Land, water and infrastructure planning, investment and management should consider the direct, indirect or potential impacts and their interdependencies.

6. Cumulative impacts – Planning should consider cumulative effects on the environment and the interdependency of air, land, water and living organisms.

7. Precautionary principle and "no-regret" actions – Caution should be exercised to protect the environment when there is uncertainty about environmental risks.

8. Proactive approach – Environmental degradation should be prevented. It is better for the environment and more cost-effective to prevent degradation than to restore it afterwards.

9. Shared responsibility – The responsibility for policy and programme development and implementation should be shared within the mandate of all actors at the appropriate scale.

10. Engaging Indigenous Peoples and local communities – Integrated watershed management processes should recognize and duly support the identity, culture, knowledge, traditional practices and interests of local communities and Indigenous Peoples by enabling their meaningful participation.

11. Valuing local people's knowledge and experience – These should be incorporated into the watershed management assessment, planning and problem mitigation process.

12. Sustainable development – The right to development should be fulfilled to equitably meet economic and societal needs while not compromising the environment for present and future generations.

13. Natural capital – This should be protected and managed to reduce short- and long-term negative financial impacts. Natural systems provide goods and services of environmental, economic, social, cultural and spiritual value.

14. Identifying risk reduction opportunity areas – This should take place during the management plan development process, in order to pinpoint remedial activities (drainage, revegetation, land-use changes), whose implementation will have the greatest likelihood of protecting and benefiting people and their assets downstream.

Source: Adapted from Canadian Council of Ministers of the Environment (CCME). 2016. Summary of integrated watershed management approaches across Canada. 27 pp. www.ccme.ca/files/Resources/water/water_conservation/Summary%20of%20Integrated%20Watershed%20Management%20Approaches%20Across%20Canada%20PN%201559.pdf

Resilient watershed management is practised at a landscape scale and builds on integrated watershed management by adding the risk perspective to the principles of integrated watershed management (see Box 1.3).

Figure 1.7: Landscape scale of the impacted area of Kedarnath Uttarakhand, India (elevation 3 553m)

After multiple cloud bursts triggered a glacial lake outburst flood (GLOF) in June 2013 (Left). Closer view of the settlement below the glacial lake (Right).

Incorporating climate change and risk perspectives into watershed management entails assessing the implications of disasters and climate change on any planned development action in all areas and sectors (such as agriculture, livestock, forests, fisheries, energy, transport, water supply and sanitation, health, biodiversity and conservation).

Incorporating flexibility into watershed management systems can help to strengthen the watershed's resilience to future risks. One particular example of flexibility in resilient watershed management is the use of structural measures designed to fail, for instance, levees that can be removed in the event of a flood to submerge the surrounding farmland. However, such a system should be linked to an insurance programme for the affected farmers. This example also illustrates the importance of combining structural and non-structural measures (see Chapter 5). In addition, nature-based solutions (such as ecosystem conservation and restoration) can serve to enhance long-term resilience in the face of hazards (Sonneveld *et al.*, 2018). Positive impacts on watershed inhabitants can include flood protection solutions for downstream inhabitants, reduced sediment loads, enhanced recreational services, and clean drinking water.

Resilient watershed management integrates the principles of climate change adaptation (see Box 1.4) and mitigation by ensuring that risk reduction processes take into account potential long-term risks.

BOX 1.4 Key principles for climate change adaptation

Adaptation needs to be sustainable – Adaptation responses should not add to climate change or limit the mitigation efforts. In addition, they should not reduce the ability of other parts of the natural environment, society or business to carry out adaptation elsewhere (for example, using groundwater for irrigation in dry regions, which causes a declining groundwater level and limits the available amount of drinking water). Where possible, adaptation efforts should be fostered that enhance the capacity of natural systems to boost resilience by buffering climate risks.

Work should be carried out in partnership – Identify and engage with affected actors (for example, from public authorities, non-governmental organizations and businesses) at all relevant levels, and ensure that they are well-informed and encouraged to work on adaptation.

Adaptation needs to be evidence-based – It should make full use of the latest research, data and practical experience so that decision-making is well-supported and informed.

Climate and non-climate risks should be managed using a balanced approach – Climate change is only one aspect of multiple stresses that influence social, natural and economic development. Adaptation must therefore take a holistic approach, which includes managing both climate and non-climate risks.

Risks associated with past and current climate variability and weather extremes must be addressed – This should be the starting point for anticipatory actions to address risks and opportunities associated with longer-term climate change. It is important to ensure coordination and close synergies with disaster risk reduction/management.

The responses to climate impacts should be prioritized – For example, this can be achieved by focusing more attention on sectors that are most affected by the weather and climate, i.e. those that have long-term lifetimes or implications, and where significant investment is involved or high values are at stake, or where support for critical national infrastructure is involved.

Adaptation should be tailored to the scale required by the climate change challenge (for example, national/sectoral/cross-border) – Solutions need to be modified for individual situations while also addressing responsibilities and financing.

Adaptation should be flexible – Although there is still uncertainty over the future climate, we should consider options now in certain fields (for example, in sectors with long-term planning horizons) and make decisions that can be adjusted easily. Thus, the value of no-/low-regrets and win-win adaptation options in terms of cost-effectiveness and multiple benefits should be recognized, as well as the value of a phased approach to adaptation.

Adaptation needs to be transparent – The effects of various adaptation options should be fully communicated, both in the short and long term while providing as much detail as possible. Adaptation decisions are also value-laden, for instance, regarding the level of risk to be accepted. It is therefore crucial that decisions are made transparent in order to agree on solutions that are fair and balanced.

Adaptation decisions should be reviewed continuously – This is aims assess their effectiveness, efficiency, equity and legitimacy so as to gradually improve them according to the evolution of evidence and knowledge on climate change impacts. This requires monitoring and re-evaluations of risks.

Source: Climate-ADAPT. 2019. Key principles for adaptation. Cited 28 June 2019. https://climate-adapt.eea.europa.eu/knowledge/tools/adaptation-support-tool/key-principles

Strengthening resilience involves working across different scales of space (international, national and local) and time (short-term priorities and long-term goals) with a diversity of stakeholders (from government, civil society, academia and local communities) (UN, 2018). Building a resilient watershed involves working towards sustainable land-use and water management, fostering the provision of ecosystem services and supporting climate-smart livelihoods, in collaboration with local inhabitants. It also involves recognizing their needs and rights while reducing climate and non-climate risks.

The landscape approach in watershed management

Although there is no precise limit to its geographical coverage, a landscape tends to cover a large spatial scale and integrates a diversity of land-use activities, from urban spaces to rural communities, from pastures to forest management, and from mountain slopes to river basins. A landscape may consist of one or more watersheds. According to FAO,

> *A landscape approach deals with large-scale processes in an integrated and multidisciplinary manner, combining natural resource management with environmental and livelihood considerations. The landscape approach also factors in human activities and their institutions, viewing them as an integral part of the system rather than as external agents.* (FAO, 2019c).

The landscape approach is essential in identifying *risk reduction opportunity areas*. These areas may not immediately be in a highly hazardous zone or an evident risk hotspot, but interventions at these sites, such as flood, erosion or avalanche control, or draining a glacial lake upstream, will have strong potential for reducing risks in other locations. As such, these actions will lower the risk for people, their assets and infrastructure downstream.

The knowledge and expertise of local people in the background research, development, implementation, and monitoring and evaluation of the watershed plan need to be routinely incorporated in the resilient watershed management process. Local people are familiar with their natural and social landscapes, and are often in the best position to clarify climate change impacts, hazard risks and prospective remedial solutions.

Ecosystem-based approach to building resilience

Healthy ecosystems play an important role in safeguarding development gains and in building resilience against disasters and global environmental change (PEDRR, 2016; FAO, 2019a). Ecosystems that become degraded generally do so as a result of land-use changes that influence or alter water retention, recharge and run-off capacities, such as floodplains covered with infrastructure, silted wetlands, or deforested hillslopes surrounding the floodplain, which may in turn intensify the severity of a natural hazard. These factors can also reduce the ability of landscapes and societies to absorb the shocks caused by hazards (UNISDR, 2015a).

The degradation of ecosystems is an important driver of vulnerability to natural hazards and other weather extremes, and the unsustainable use of ecosystem services is limiting the ability of ecosystems to regulate climate change (IPCC, 2012, 2014, 2018; IPBES, 2019). The role of ecosystems in reducing disaster risk is often overlooked, and instead engineering solutions are used such as dyke construction to protect against floods or sea rise. The ecosystem-based approach provides sound management practices for natural resources, which in turn offer "no-regret" solutions to most natural hazards and climate change problems.

In developing measures to mitigate the risks in a watershed, existing ecosystems should be viewed in terms of their capacity to reduce vulnerability while the restoration or upgrading of such ecosystems need to be considered. In addition, nature-based solutions may be scaled up in view of their contributions to reducing disaster risks.

BOX 1.5 Definition of ecosystem services

Ecosystem services refer to the benefits people obtain from ecosystems. These include: provisioning services such as food, water, timber and fibres; regulating services that affect climate, floods, disease, waste and water quality; cultural services that provide recreational, aesthetic and spiritual benefits; and supporting services such as soil formation, photosynthesis and nutrient cycling.

Source: Millennium Ecosystem Assessment (MA). 2005. Ecosystems and human well-being: Synthesis.Washington, DC, Island Press. www.millenniumassessment.org/documents/document.356.aspx.pdf

Ecosystems, such as wetlands, can be heavily damaged by hazards. The result can be a serious disruption in ecological balance, or the transformation of one ecosystem into a completely different regime. When local inhabitants depend on goods and services from these damaged ecosystems, their livelihoods may be impaired, along with their capacity to cope with and recover after a disaster event. Ecosystem-based approaches in risk management therefore include maintaining or restoring ecosystems to an optimal ecological state, protecting them, especially those that provide high value in terms of ecosystem services, from being damaged by hazards, and using ecosystems as nature-based solutions that naturally "engineer" landscapes in order to help lessen the impacts of hazards.

Ecosystems provide three essential benefits for risk management: protection or buffers against natural hazards (for example, vegetation cover against erosion and landslides); reduced exposure (for example, floodplains cushion elements-at-risk against flooding); and livelihood sustainability for the population living in the watershed (for example, through the provision of basic needs such as food, water and shelter) (PEDRR, 2016).

Identifying *risk reduction opportunity areas*, or areas within the watershed where interventions will have the greatest potential to reduce risks for downstream populations and infrastructure, is a key component of the resilient watershed management approach.

Incorporating gender into risk assessment and management

Concerns about gender should occupy a central position within vulnerability assessments and risk management in general. Mainstreaming gender ensures that adaptation mechanisms reduce existing injustices, as well as other underlying drivers of people's vulnerability to natural hazards and climate change. Understanding how gender shapes people's vulnerability is therefore a critical step in resilient watershed management. This is because socioeconomic factors such as poverty, unequal power relations between women and men, and cultural norms tend to intensify gender-specific vulnerabilities.

Women may face additional barriers in terms of adapting to livelihood disturbances, since they may have less access to alternative sources of income. Indeed, many societies assign the role of family caregivers to women, with the result that the family may be more affected when women can no longer carry out related tasks.

Several general examples of gender gaps include:

- unequal access to and use of productive resources and agricultural inputs;
- unequal tenure security and related investments in land and improved technologies;
- unequal access to credit;
- informal institutional constraints that affect farm/plot management;
- unequal access to advisory and extension services, and training programmes; and
- unequal access to knowledge and information (FAO, 2018c).

The above gaps may reduce the capacity of women to anticipate, cope with and recover from current and future risks. For women to have equal access to and control over water resources for food security and livelihoods, they must be involved in decision-making and priority-setting on on an equal footing as men (FAO, 2010).

The first step towards integrating a gender perspective into risk management is to recognize that men and women experience disaster risk differently. One way to do this is to ensure, as much as possible, that the data collected from watershed communities are sex-disaggregated. Next, a gender analysis should be conducted to understand social differences and examine power dynamics and roles within societies. This also helps to gather information on needs and priorities, as well as providing access to resources and services (FAO, 2016), in order to design and implement differentiated measures that contribute to reducing the community's vulnerabilities in the face of risks.

Recognizing vulnerable groups

Indigenous Peoples and local communities as well as smallholders, poor urban populations, people with disabilities, youth, children and elderly people potentially represent particularly vulnerable groups who may face additional barriers in managing risk.

In addition, Indigenous Peoples, local communities and linguistic and/or ethnic groups may face specific vulnerabilities. For example, formalized risk information, such as plans, vulnerability maps and even legislation, is typically prepared by national or subnational organizations, many of which are dominated by non-Indigenous decision-makers; Indigenous Peoples often do not have adequate opportunities to participate in their design, implementation, monitoring and evaluation (PAHO/WHO, 2015). Resilient watershed management should therefore take into account these groups and their specific experiences and perception of risk, as well as their vulnerability, and diverse copying and adaptive capacities.

In the analysis of vulnerability, it is also critical to recognize the inherent capacities of people, communities and institutions, and build on them, which is covered in the stakeholder analysis in Chapter 3.

1.3 Further reading

- On further watershed-related programmes and experiences, see *Watershed management in action – Lessons learned from FAO field projects*. www.fao.org/3/a-i8087e.pdf

- Integrated Water Resources Management (IWRM) is widely discussed in the literature. A good entry point is the Global Water Partnership. www.gwp.org/en/GWP-CEE/about/why/what-is-iwrm. Another source is Snellen, W.B. & Schrevel, A. 2004. *IWRM: For sustainable use of water – 50 years of international experience with the concept of integrated water management*. www.fao.org/ag/wfe2005/docs/IWRM_Background.pdf

- On incorporating climate change considerations into watershed management, see FAO, 2012. *Mainstreaming climate-smart agriculture into a broader landscape approach*. www.fao.org/docrep/016/ap402e/ap402e.pdf; or Joosten, K. & Grey, S. 2017. *Integrating climate change adaptation and mitigation into the watershed management approach in eastern Africa – Discussion paper and good practices*. Addis Ababa, FAO. www.fao.org/3/a-i7489e.pdf

- See also United Nations Economic Commission for Europe (UNECE). 2015. *Water and climate change adaptation in transboundary basins: Lessons learned and good practices*. No. ECE/MP.WAT/45. Geneva. www.

unece.org/fileadmin/DAM/env/water/publications/WAT_Good_practices/ece.mp.wat.45_low_res.pdf.

- The ecosystem-based approach is extensively discussed in WWAP (World Water Assessment Programme)/UN-Water, 2018. *The United Nations World Water Development Report 2018: Nature-based solutions for water*. Paris, UNESCO. http://unesdoc.unesco.org/images/0026/002614/261424e.pdf. This report from Sonneveld *et al*., 2018. *Nature-based solutions for agricultural water management and food security* gives more detail about agricultural water management and food security. www.fao.org/3/CA2525EN/ca2525en.pdf

- See also Renaud, F.G., Sudmeier-Rieux, K., Estrella, M. & Nehren, U., eds. 2016. *Ecosystem-based disaster risk reduction and adaptation in practice*. Advances in Natural and Technological Hazards Research. Springer International Publishing. www.springer.com/la/book/9783319436319.

- Information and examples on ecosystem services and in particular on the water-food-energy-ecosystem nexus can be found at www.unece.org/env/water/nexus and in UNECE, 2007. *Recommendations on payments for ecosystem services in integrated water resources management*. Geneva, United Nations Economic Commission for Europe. www.unece.org/index.php?id=11663

- Much information on water can be found in FAO, 2018c. *Guidance note on gender-sensitive vulnerability assessments in agriculture*. Rome. www.fao.org/3/I7654EN/i7654en.pdf. Other entry points are: www.fao.org/land-water/water/watergovernance/water-gender/en

- www.fao.org/land-water/water/watergovernance/water-and-poverty/en.

- Information on sustainable land management (SLM) can be found in the World Overview of Conservation Approaches and Technologies (WOCAT)'s Global SLM Database. Together with partners, WOCAT has developed a framework and standardized tools and methods for documentation, monitoring, evaluation and dissemination of SLM knowledge. The database contains over 1 500 SLM practices from all over the world. www.wocat.net/en/global-slm-database

River in India
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Green canyons surrounding a stream in Iceland
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2

Enabling environment for effective implementation of resilient watershed management

2. Enabling environment for effective implementation of resilient watershed management

White Lake in Kazakhstan
©Mark Nikulin

2.1 Introduction

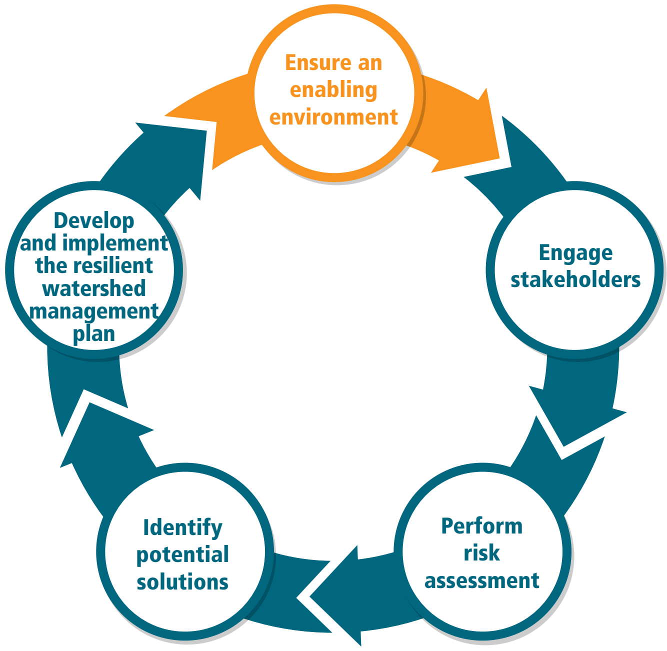
An enabling environment is understood as the context in which individuals and organizations function, including the institutional set-up with implicit and explicit rules, power structures, and the policy and legal environment (FAO, 2010). Ensuring an enabling environment is the first step in the watershed management planning process (see Figure 2.1).

Risk governance is the system of institutions, mechanisms, policy and legal frameworks, and other arrangements to guide, coordinate and oversee risk reduction and related areas of policy (UNDRR, 2019a).

Resilient watershed management requires the integration of diverse policies and legal frameworks, so that they complement and do not contradict each other.

Changes to the enabling environment may involve policy reform, new legislation, strategic exercises in country planning and prioritization, and changes to incentive systems. How these are set in place will eventually define the effectiveness of risk governance. For instance, the cross-sectoral strategies put in place at different levels of government are likely to lead to effective risk governance if their implementation takes into account local communities' priorities and context. This includes the types of hazards to which they are exposed, their level of vulnerability and preparedness, and their perception of risk, including their adaptive capacity to climate change. As set out in the Sendai Framework for Disaster Risk Reduction, Priority Action 1: "Policies and practices for disaster risk management should be based on an understanding of disaster risk in all its dimensions of vulnerability, capacity, exposure of persons and assets, hazard characteristics, and the environment" (UNISDR, 2015a).

Figure 2.1: The resilient watershed management cycle



Source: Author's elaboration

For ensuring an enabling environment, it is necessary to assess and adapt the following:

(a) policies in place that are relevant to resilient watershed management, including disaster risk management, and involve climate-proofing of policies and land-use planning mechanisms;

(b) legislation regarding the various aspects of resilient watershed management;

(c) institutional arrangements, including participation and communication, capacity development and coordinating mechanisms;

(d) information needed for sustainable development, disaster risk management, climate risk management and climate change adaptation;

(e) financial arrangements comprising budget allocation, cost recovery and mainstreaming of risk-related costs, so as ultimately to be able to implement the resilient watershed management measures, including the resilient watershed management plan. These financial arrangements also need to take into account equitable access to finance and contribution by local communities.

2.2 Policy analysis

Existing policies in place in a country can be found in the formal documents that contain current and future strategies. Various departments within the government are usually involved in watershed management, disaster risk management, climate risk management, and climate change adaptation and mitigation, and they all must be identified.

National and local policies, strategies, investments and legislation are often compartmentalized, and there is little integration of priorities among sectors (disaster risk management, climate change mitigation and adaptation, and agriculture).

The policy analysis helps to identify potential gaps and obstacles, and should also account for multisectoral interventions at local, national, or transnational levels (FAO, 2006).

For a transboundary watershed, landscape management is carried out in the context of understanding the national riparian policies and laws of the different countries involved, as well as the potential policy gaps and obstacles between them.

Policies in the field of land-use planning, disaster risk management, environmental protection, natural resource management, rural development, infrastructure development and health management have long sought to manage the risks associated with short-term, seasonal and inter-annual climatic variability.

Policy analysis should also include an assessment of the way that the policies can be reviewed or updated to take into account long-term climatic change and the associated risks. This approach is also referred to as "climate-proofing" of policies. In addition, the process should ensure that the risks and opportunities originating from natural hazards and climate change are fully embedded into national and local policies, strategies and budgetary processes. Furthermore, it should provide recommendations for viable public and private investment opportunities. Lastly, the policy analysis should support the identification and prioritization of short- and long-term climate change adaptation and mitigation strategies within the disaster risk management framework.

2.3 Legislation analysis

The key aspect of ensuring the effective implementation of resilient watershed management is that risk needs to be considered in the planning of all sectors, including water, agriculture, rural development, infrastructure, roads and forestry. Each sector needs to integrate considerations for risk preparedness, risk reduction, contingency planning and budgeting. The primary consideration for any spatial planning such as construction of roads, hospitals and agricultural fields needs to be based upon a hazard and risk map, as well as an assessment. Particular attention should be paid to the different scales of legislation and the potential complementarity or conflict between subnational jurisdictions, national legal frameworks and international law (Libert Amico, Ituarte-Lima and Elmqvist, 2019).

For instance, the planning of the location of schools can consider multipurpose use as an emergency shelter and being located in low risk areas. Additionally, the grounds can be made slightly lower than the areas surrounding it so that the grounds can be used as a flood water overflow area. In other cases, rural development plans should include risk reduction activities as an integral part of the plan to ensure the protection of livelihoods and assets.

Table 2.1 provides a non-exhaustive list of questions to inform an analysis of the legal framework in relation to disaster risk management.

2.4 Institutional capacity analysis

A clear attribution of the roles and responsibilities of each institution is essential in the face of disaster risks and extreme weather events.

The analysis of the enabling environment includes assessing the capacity of institutions to fulfil their role in the resilient watershed management plan. Care should be taken to ensure that all parties involved have a similar level of understanding of the diverse disaster risks involved, and of the impacts of climate change on the watershed system and the livelihoods within it.

An essential component of the capacity assessment is to determine the existing coordination, information and financial flow mechanisms from community, regional and national levels to reinforce transparency, accountability and participation in the process.

Figure 2.2: Community consultation, Huaraz, Peru, 2014

The analysis should include source of information and how the information is communicated. This includes exploring how communities have historically addressed and communicated risks.

In the case of limited information availability, it is important to identify what information is available that can be helpful in developing and implementing a set of resilient watershed management strategies (see Chapter 6). For example, one resilient watershed management plan outcome could be the improvement of its monitoring and information systems.

Table 2.1 provides a non-exhaustive list of questions to inform the analysis of the information system related to disaster risk management.

2.5 Financial system analysis

The analysis should begin with the assessment of existing planning mechanisms such as rural development, forest management, agricultural extension, local development and disaster management. Each of these planning mechanisms will have a mechanism for budget allocation.

The analysis should also include the existence of local financial mechanisms, such as community saving and credit systems or microcredit schemes, and synergies between the public and private sectors that generate a return on investment.

The costs of implementing the risk management measures are determined by the type of risk reduction measure identified/selected. Depending on the level where the measure has its impact – international, national, subnational or local – efforts should be made to include budgets and economic incentives in the relevant programmes for this purpose. As such, the costs should be part of the regular budget while taking into account the operation and maintenance expenses, where relevant. In order to favour cross-sectoral collaboration, existing budgets from diverse sectoral departments can be merged to fulfil the goals of addressing climate and disaster risk reduction. For instance, farming subsidies from the agricultural department can be combined with reforestation budgets managed by the forestry department to create biological corridors in agricultural spaces, or soil retention barriers for slope agriculture.

National-level hazard and risk mapping is usually borne by the national agency responsible for disaster risk management or GIS mapping. However, the cost of local or watershed level planning and implementation is borne by the relevant local/regional government agency, included in the local-level rural development plan, infrastructure development plans, natural resources management plans, and agricultural development plans. At the farmer level, where it requires the adaptation of techniques or behaviour, it is the responsibility of the individual who can be assisted by technical advisory services. A very important aspect of resilience building is ensuring access to finance to the local communities, such as establishing savings and credit systems in communities who have limited access to conventional banks or agricultural cooperatives.

The analysis of financial arrangements should take into consideration the actual land and water users (communities, businesses and service providers) and their share of the financial burden, since it is often these stakeholders who benefit the most from sound watershed management. Financial as well as ecological sustainability can be improved by recognizing natural resources, such as water, as an economic good, and by recovering the costs to the extent possible from the users. In addition, compensation or payments to the upstream region for basin management may be used as a method to reduce or avoid water-related disasters downstream. Payments for such benefits (or compensation for costs) from disaster risk management or climate risk management measures could be made in the context of cooperative arrangements (see Chapter 5). Cost recovery from water users is an important funding source that can be directly linked to the intensity of water usage. As a result, users tend to become more aware of the risk consequences of their activities, which in the long term can mitigate or prevent overexploitation of the resource (Timmerman and Bernardini, 2009).

Table 2.1 provides a summary list of questions that can be used to inform the financing mechanism analysis relevant for watershed management.

Table 2.1. Key questions for an enabling environment for resilient watershed management

Country setting	
Policies	Does the country have a disaster risk management policy? If so, does this policy consider water-related disasters and disaster risk in watershed and/or land-use planning? Has the country taken steps towards integrating international commitments in relevant fields, such as disaster risk reduction (e.g. Sendai Framework), mainstreaming biodiversity and ecosystem services (e.g. Convention on Biological Diversity), climate change mitigation and adaptation (e.g. nationally determined contributions to the United Nations Framework Convention on Climate Change)?
Legislation	Is there an updated legal framework on climate change and disaster risk management? Which agencies are responsible for the implementation of the legislation? Is there a requirement to conduct national disaster risk assessments? Are there any legal obligations by agencies to consider the results of the risk assessment in their overall planning?
Institutional arrangements	Are there vertical and horizontal coordination mechanisms or incentives that foster policy alignment, complementarities and cooperation across central and subnational governments and different government sectors for including risks in their specific sectors?
Information management	Is there a national body that coordinates water, climate and risk information, or are there separate bodies?
Finance	Are funds assigned to risk-sensitive planning? Does the country have specific resilience programmes that can include watershed management? Are there emergency funds available that could be complemented with investments in prevention and mitigation?
Engaging stakeholders (see Chapter 3)	
Policies	Do policies consider consultations, local participation and feedback on programmes, and multistakeholder consultation bodies?
Legislation	Is there clear land and forest tenure in the watershed? Are there mechanisms to solve land-use and water-related disputes? Does the country practise free, prior and informed consent with Indigenous Peoples and local communities?

Country setting	
Institutional arrangements	Are mechanisms in place for civil society participation in decision-making? Is there a clear distribution of attributions and powers related to disaster risk management between national and subnational governments? What social and informal networks exist in the communities?
Information management	Is transparent information on climate change and risk indicators accessible to the general public? Are public hazard and land-use maps available? Can local stakeholders submit relevant information to update these information systems? Is a risk education and communication strategy in place? Are capacity development campaigns in place or information needs assessments available? What mechanisms do communities use to communicate risk with each other?
Finance	Is a budget assigned to facilitating participation in risk and watershed management? Are there existing community savings and credit systems or access to microcredit? What kinds of social safety nets exist? What kinds of income generation activities exist?
Assess risk (see Chapter 4)	
Policies	Do land-use management plans, as well as land and forest classification processes, consider watershed management, risk management and climate change? Are explicit measures in place to identify access to land and water services by vulnerable groups, such as Indigenous Peoples, refugees, migrants and the homeless?
Legislation	Are building codes in place and are reviews of building codes based on updated information required by law? Do zoning regulations exist based on risk or hazard? Are there regulations that assign roles and responsibilities on risk management from the national level to municipalities to villages? Do local and regional development plans require the inclusion of risk assessment and risk mitigation measures?
Institutional arrangements	Are there coordination mechanisms to support the prioritization of risk reduction measures in public expenditure? Are there dedicated regulatory agencies/bodies in charge of enforcement and compliance for land use, water resources, water services and risk management? What are the local social networks and institutional capacities available for risk management?
Information management	Who is responsible for conducting climate and risk modelling? Is there a nationwide hazard map? Is up-to-date information on hazards, exposure and vulnerability available to the general public? Is the disaster risk management information system harmonized, standardized and coordinated across relevant agencies and responsible authorities? Are there real-time data and do they guide decision-making? Do livelihood strategies consider a gender perspective, or specific vulnerabilities and coping capacities of vulnerable groups? How do communities communicate with each other during disaster events?
Finance	Are data on public spending and private investments available in the watershed? Are there existing community savings and credit systems or access to microcredit? What kinds of social safety nets exist?
Develop risk reduction measures (see Chapter 5)	
Policies	Do policies consider the need to prioritize prevention and mitigation over response and recovery? Do policies incorporate preparedness measures?

Country setting

Legislation	Are there regulations for the accountability of risk transfer and insurance operations? Is there any disaster preparedness legislation?; Is there any disaster response legislation? Is there any regulation to mandate resilience-building in programmes?
Institutional arrangements	Does contingency planning consider watershed management issues? Are there multistakeholder decision-making bodies where implementation arrangements for prioritized measures can be deliberated and clearly assigned? What community organizations or community systems exist for risk reduction? What existing community mechanisms can be adapted for risk reduction?
Information management	Does the country have an early warning system in place? Are there methods for evaluating risk reduction and management measures already in place? How is risk information collected, communicated and evaluated among local, regional and national institutions? How is risk information shared among community members? What kinds of hazards have the community been exposed to in the past? How did the community respond to the disaster events? What risk reduction strategies have the communities developed in the past? What is the community perception of risk, and what risks do they find relevant? Which assets are exposed to the most risk?
Finance	Are risk transfer and insurance mechanisms in place? Are there financial mechanisms to access risk transfer mechanisms? Are there existing community savings and credit systems or access to microcredit? What kinds of community-level safety nets exist?
Develop and implement the resilient watershed management plan; monitoring and evaluation (see Chapter 6)	
Policies	What mechanisms exist for ensuring the development, implementation and monitoring of the resilient watershed management plans? Is risk management integrated into the local, regional and national planning of forest, agriculture, rural development, infrastructure, etc.?
Legislation	Are there mechanisms in place for updating the legal framework grounded on risk-based watershed planning? Who is mandated to conduct the hazard and risk assessments?
Institutional arrangements	As part of the implementation arrangements of the resilient watershed management plan, which bodies can monitor the plan implementation? Which agencies are responsible for implementation of the plan? How will the coordination between the agencies be conducted? What are the roles of the communities?
Information management	Which monitoring and evaluation systems are in place regarding climate change and risk policy, planning and implementation at local, regional, and national levels? How is information on risk shared and stored at the local, regional and national levels? How and where can local, regional and national institutions access hazard and risk information? How will the impacts of the risk reduction measures be fed back to the planning process?
Finance	Is there a budget allocation for implementation of the resilient watershed management plan at local, regional and national levels? Are there provisions made in the rural development, forestry, agriculture, etc. plans to include funding for risk management measures? Are there existing community savings and credit systems or access to microcredit? What risk transfer mechanisms exists at local, regional and national levels?

Source: Based on Organisation for Economic Co-operation and Development (OECD). 2018. *Implementing the OECD Principles on Water Governance. Indicator framework and evolving practices*. www.oecd-ilibrary.org/environment/implementing-the-oecd-principles-on-water-governance_9789264292659-en

2.6 Expected outputs

The final result of this step is an enabling environment analysis report that describes the current situation and its potential gaps and obstacles. The report should include recommendations for:

- new or improved policies;
- new or improved legislation;
- new or improved institutional arrangements;
- improved information management; and
- possible financing mechanisms and budget allocations for resilient water management.

2.7 Further reading

- Guidance on governance analysis related to disaster risk reduction and climate change adaptation convergence is provided in the discussion paper: Bojić, D., Baas, S. and Wolf, J. 2019. *Governance challenges for disaster risk reduction and climate change adaptation convergence in agriculture. Guidance for analysis.* Governance and Policy Support. Discussion paper. Rome. FAO. Licence: CC BY-NC-SA 3.0 IGO. www.fao.org/3/ca5389en/ca5389en.pdf for the entire report
- For a general overview of important issues in watershed governance, see the water governance programme of the Organisation for Economic Co-operation and Development (OECD): www.oecd.org/water/regional. Practical suggestions for applying the OECD governance principles are provided in *Improving governance in transboundary cooperation in water and climate change adaptation* (Timmerman *et al.*, 2017).
- With regard to floods, the rapid legal assessment tool (RLAT) (www.floodmanagement.info/publications/policy/ifm_legal_aspects/Legal_and_Institutional_ Aspects_of_IFM_En.pdf) enables a team of experts to test a country's existing legal frameworks for compatibility with the concept of integrated flood management, and to initiate and guide an appropriate reform process.
- In cases where tenure rights play an important role in the watershed, the following can provide guidance: FAO, 2012a. *Voluntary guidelines on the responsible governance of tenure of land, fisheries and forests in the context of national food security*. Rome. www.fao.org/3/i2801e/i2801e.pdf

- On financing, a comprehensive overview is provided in World Bank and UNECE, 2019. Financing climate *change adaptation in transboundary basins: Preparing bankable projects*. http://documents.worldbank.org/curated/en/172091548959875335/pdf/134236-WP-PUBLIC.pdf. Another entry can be found in Ramirez, J. & Hernandez, E. 2016. *Innovations for inclusive agricultural finance and risk mitigation mechanisms – The case of Tamwil El Fellah in Morocco*. FAO/ADA. www.fao.org/3/a-i6166e.pdf

Villagers in India
©Dinesh Singh Pundir

Black-necked crane on Tso Kar Lake in Ladakh, India
©Amar Paul Singh


3
Stakeholder engagement

3. Stakeholder engagement

Andean Plateau in west-central South America

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3.1 Introduction

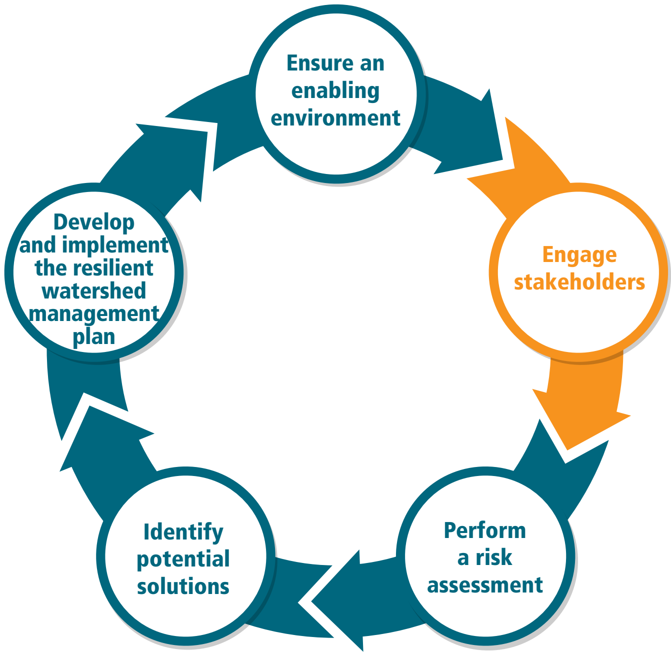
Engaging stakeholders is a standard component of the watershed management planning process (see Figure 3.1).

The objectives of engaging watershed stakeholders include:

- recognizing that coping capacities are diverse among stakeholders; for instance, some stakeholders may mobilize unique resources and networks in order to respond to adversity;
- identifying sections of the population who are particularly vulnerable to disaster and climate change (for example, the elderly, single mothers or linguistic minorities) and who may require differentiated and specific measures to reduce their vulnerabilities in the face of disaster events;
- mobilizing support from diverse sectors of society and technical backgrounds in the landscape for ongoing risk management initiatives; beyond simply responding to emergencies, risk management lays emphasis on constant efforts towards reducing vulnerability and strengthening coping capacities;
- incorporating local knowledge of the landscape, climate change impacts, issues and prospective solutions into the design of the resilient watershed management plan, since local people tend to possess a vast knowledge of these factors through decades of living and working in their regions; and
- identifying *risk reduction opportunity areas* within the watershed in question where interventions or mitigation activities will have the

greatest potential for reducing risks to downstream populations and infrastructure.

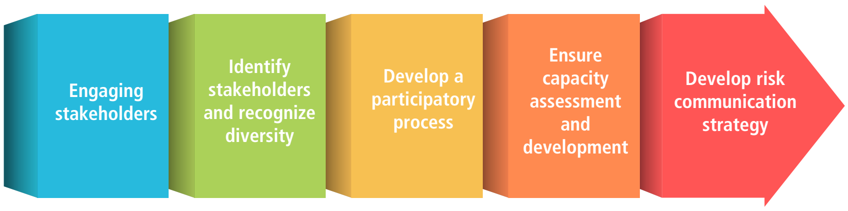
Figure 3.1: The resilient watershed management cycle



Source: Author's elaboration

The process for engaging stakeholders starts by identifying relevant stakeholders for the landscape or watershed, with a focus on particularly vulnerable populations. After a thorough stakeholder analysis, the process of planning how the stakeholders will participate is developed. Given the diversity of stakeholders, especially with regards to vulnerability and perspectives of disaster risk and climate change, capacity assessment and development is needed to support the participatory process. Finally, this participatory process goes hand in hand with an ongoing communication strategy to mainstream all information and considerations throughout the decision-making process that takes place in the watershed.

Figure 3.2: Participation and communication framework



Source: Author's elaboration

3.2 Ensuring stakeholder engagement

The emphasis on a people-centred, bottom-up approach, based on the understanding that local communities possess skills, experience and traditional and current environmental knowledge, can be of critical importance for the successful implementation of resilient watershed management programmes.

Table 3.1 presents some key elements related to stakeholder engagement. A successful stakeholder engagement process for resilient watershed management can help stakeholders to obtain the "triple dividends" of resilience (Tanner *et al.*, 2015), namely to:

- avoid losses from disaster events;
- stimulate economic activity to reduce vulnerability; and
- develop co-benefits, or uses, of a specific disaster risk management investments.

To obtain these dividends, it is important to ensure that resilient watershed management systems reflect the values of the local stakeholders, thereby increasing their ownership of risk management processes and initiatives. Stakeholder engagement in resilient watershed management should therefore take the results from the stakeholder mapping and make sure that it acknowledges the following:

- diversity;
- different social values;
- capacities of people and institutional mechanisms for collaboration; and
- availability of local knowledge from all stakeholders that complements the scientific data obtained, to reduce vulnerability and strengthen resilience.

Careful consideration should be given to designing mechanisms that ensure social inclusiveness and equitable representation of all stakeholders within planning and decision-making processes, including socially and economically disadvantaged or marginalized groups (FAO, 2017). As highlighted by the United Nations Global Assessment Report on Disaster Risk Reduction 2019 (UNDRR, 2019b), involving a range of stakeholders avoids creating new risks while reducing risk behaviour (e.g. building in flood-prone areas) and providing novel solutions to issues due to different perspectives. Proper stakeholder engagement also allows for strategies to be implemented and prioritized at the local level, without being completely dependent upon formal government structures. This element is important since risk is not defined by territorial or political divisions.

Multistakeholder processes are often complex and time-consuming. Given the rapid rise in extreme events, it is crucial that they are conducted efficiently. Arriving at consensus during negotiation requires important leadership skills and depends on a careful selection of the stakeholders (Schreier and Kurian, 2014).

Stakeholder mapping

The landscape approach should dictate the level at which the stakeholder mapping is carried out.

Stakeholders should include national and local authorities, and where relevant, established transboundary bodies and platforms, infrastructure management agencies (water, energy, land and transport), productive sector entities, including associations and businesses (natural resource management, agribusiness, forestry, fisheries, construction, tourism, mining, health and disaster risk management), civil society, the media, academia, minority groups and others (UNECE, 2015).

Several resources are available for the selection of approaches and tools for stakeholder mapping, such as interviews with key informants or focus groups (FAO, 2017).

Building resilient watershed management requires facilitating community-based risk management discussions within identified hotspots. These are defined here as those features or regions within a watershed where management interventions would result in the most tangible improvements in a landscape's condition, for instance, the installation of a warning system for averting a massive loss of lives downstream. In parallel with the stakeholder analysis at the larger landscape scale, local-level stakeholder mapping exercises can assist in identifying local stakeholders who hold responsibilities in watershed management. Those identified may include subnational institutions, user associations, management committees and producer organizations, as well as stakeholders who face specific disaster risks. This community-level stakeholder mapping can assist in identifying communities or community-based associations with whom to carry out the community multi-hazard risk assessments.

Issues that should be analysed and explained to the stakeholders include those related to the allocation of land and water rights, and the potential/anticipated impacts of climate change, biodiversity loss and land degradation (UNECE, 2015; IPBES, 2019). At the community level, it is particularly important that the stakeholder analysis rigorously identify the different ways in which sectors of society or diverse members of the community can participate in natural resources management and decision-making since this may reveal different coping capacities or increased vulnerability.

Table 3.1: Engaging stakeholders for resilient watershed management

Stages of resilient watershed management	Priority stakeholders to be involved (not an exhaustive list)	Information provided and issues of interest
Engaging stakeholders to create an enabling environment (Chapter 2)	Emergency response and disaster prevention institutes	Powers and attributions in disaster risk management
	Government ministries that influence landscape management (water, agriculture, forestry, environment, finance, energy and mining)	Policies and legislation Inter-institutional collaboration mechanisms (special programmes, cross-sectoral funds, etc.) for multilevel coordination
	Budget management institutes	Budgets for watershed management Special funds or emergency budgets that could be used for preventing disaster risks
	Land-use planning bodies and technical agencies (e.g. meteorological institutes, statistics institutes and research centres)	Baseline information used for landscape and watershed planning, for example whether institutes refer to the same hazard and risk maps for land-use planning and issuing permits and concessions.
Engaging stakeholders in climate change sensitization and risk assessment (Chapter 4)	Formal and informal community leaders (authorities, elders, etc.), opinion leaders, local business owners Community-based organizations and watershed management committees	Local knowledge on climate change, terminology and impacts; landscape and ecosystem approaches; watersheds and environmental risks; existing adaptation mechanisms; capacity development needs and development plans; institutional and community collaboration
	Women, youth, elderly, Indigenous Peoples and migrants	Resource mapping; climate change impacts; disaster history; vulnerability and exposure assessment. Power dynamics that influence equity and vulnerability; coping mechanisms mobilized; identification of possible solutions
	National institutes with personnel in the watershed; subnational government institutes	Development plans Disaster risk management plans and prevention mechanisms. Mechanisms developed to integrate the various plans into a comprehensive development plan
	Technical agencies (e.g. meteorological institutes), universities and research institutes, and statistics institutes	Data on local environmental and social conditions (hydrology, soils, precipitation, poverty, infrastructure, land use and land cover); up-to-date information on hazards, exposure and vulnerability assessments; maps and GIS of the region

Stages of resilient watershed management	Priority stakeholders to be involved (not an exhaustive list)	Information provided and issues of interest
Stakeholder engagement in identifying measures for resilient watershed management (Chapter 5)	Formal and informal community leaders (authorities, elders, etc.), opinion leaders and local business owners	Local stakeholders are well positioned to inform on potential prevention and mitigation measures based on pre-existing strategies and local conditions, especially since they are the ones who will implement the selected measures
	Government institutes in charge of watershed planning (water, agriculture, fisheries, forestry, infrastructure or spatial planning ministry)	Budget allocation and policy priorities (e.g. emphasis on prevention rather than emergency response)
	Technical agencies and research centres	Suitability of measures; perform cost-benefit, effectiveness and efficiency assessments
	Community-based organizations and watershed management committees	Existing management measures; sustainable development needs; potential combinations of livelihood strategies
	Local and international NGOs	Capacity development plans and sustainable development initiatives
	Planning institutes at national and subnational levels	Planning design and approval
Engaging stakeholders in the resilient watershed management plan, and monitoring and evaluation (Chapter 6)	Government coordination and budget management	Plan approval and publication
	Formal and informal community leaders (authorities, elders, etc.), opinion leaders and local business owners Local organizations, NGOs and user committees	Plan consultation and validation; implementation and monitoring mechanisms, roles and responsibilities
	Watershed management institutions	Maintain monitoring information and facilitate periodic evaluations
	Watershed management committee and local associations	Participate in monitoring system design; collect and analyse information

Source: Author's elaboration

3.3 Developing a participatory process

BOX 3.1
Integrating risk management into watershed management committees

Watershed management committees have become a key tool in organizing user participation in watershed management. Although a variety of community-based organizations or user associations may already exist and may even be more relevant to the specificities of the local context, watershed management committees have proved to be a practical tool in institutionalizing user participation because they have often been recognized in national legislation (e.g. water law).

Watershed management committees rarely include an explicit recognition of risk management needs. Recommendations for integrating disaster risk management into watershed management committees (FAO, 2017) include the following:

- Seek representation from the diversity of local stakeholders, actively providing spaces for women, youth and Indigenous Peoples while recognizing diversity in land tenure (for instance, private owners and resource usufruct rights) and land uses (for example, nomadic versus sedentary populations).
- Watershed management committees should actively engage local inhabitants and users of the different components of the landscape, for example, forests in the upper portion of the watershed or the water users further downstream. Such representation at the landscape level facilitates an integral perspective of risk management, beyond water quality or flooding, in order to address additional issues such as ecosystem services and the intrinsic links between livelihoods, forests, agricultural spaces and water.
- Build on existing structures – Before creating new watershed management committees, verify that the social and policy environment is conducive to the formalization of watershed management committees, which may be recognized in national law. Existing risk management legislation at national or subnational levels may also make space for watershed management committees as user representatives at the landscape level.
- Build on existing processes – Seek to include existing community-based organizations and user groups in order to build on present social ties and organizational relationships. This approach may help to ensure that groups and associations persist beyond the initial time frame of the resilient watershed management plan formulation.
- Ensure coordination with existing risk management mechanisms and committees (for instance, civil protection committees, disaster risk reduction committees, community monitors, as well as national security authorities). This approach will enable watershed management committees to have a mutual interest, which can be synchronized with risk management realities. Such coordination can be sought through the institutional recognition of watershed management committees as local representatives in risk management bodies created by national policy.
- Recognize that field facilitators or community mobilizers are indispensable for engaging local populations. Field technicians play a double role of helping resilient watershed management goals to be practical on the ground, but also – and most importantly – by ensuring that local knowledge and the needs of communities inform the design and implementation (from the ground up) of the resilient watershed management measures, and often in the local language.

Notes:

1. FAO. 2017. *Watershed management in action – Lessons learned from FAO field projects*. Rome. http://www.fao.org/3/a-i8087e.pdf

Participatory risk mapping

A participatory geographical information system (PGIS) is particularly designed to facilitate community discussions and bottom-up planning (NOAA, 2015). A PGIS also facilitates the representation of local people's spatial knowledge using two- or three-dimensional maps. These risk maps can be used to facilitate decision-making, as well as to support communication and community advocacy. PGIS often relies on the combination of expert skills with local knowledge (Willemen *et al.*, 2014).

Participatory risk mapping includes the mapping: of (i) existing physical resources such as roads, schools, hospitals, houses, and community centres; (ii) natural resources including agricultural land, water sources; (iii) the history of past disasters such as former landslides and extent of flooding, location of vulnerable populations, evacuation routes used during prior disaster events; and (iv) markets and other community resources. The participatory method in developing the map aids in identifying the critical infrastructure that needs to be protected or reinforced; and the agricultural land, houses and/or the people potentially exposed to the hazard and are vulnerable. This in turn will help identify the possible risk reduction and mitigation measures at both the landscape and individual scales. The participatory risk map also helps determine the appropriate evacuation routes and methodology (see Figure 3.2).

Figure 3.3: Participatory mapping of evacuation routes based upon vulnerability assessments, Tamil Nadu, India, 2017

Effective PGIS practice should be user-driven/user-centred and ethically conscious to avoid increasing the vulnerability of people, misusing their knowledge, and even disempowering them. It is therefore necessary to communicate any possible risks to communities regarding this knowledge-sharing exercise. In the case of Indigenous communities, this should be carried out through a free, prior and informed consent process. Negative mapping impacts may include issues related to boundaries and conflicts, sharing and presenting local knowledge, and documenting sensitive information (IFAD, 2009).

PGIS approaches ensure that communities take as much control as possible over decision-making processes, managerial power and responsibility during all the different stages involved. The success of this process is also dependent on facilitators who understand the local contexts as well as resilient watershed management, and can establish good working relationships with communities.

The participatory risk assessment process often includes the following activities:

- as initial stakeholder workshop to present the process goals as well as the participation plan;
- community visits and activities such as meetings, focal groups and semi-structured interviews and community-based risk assessment workshops; and
- a presentation of results to watershed stakeholders, including community representatives in a workshop to communicate and validate the results of the process, including a community hazard map, vulnerability and capacity assessment, and potential risk management measures proposed.

3.4 Capacity assessment and development

Increasing the capacity to address the hazard, reduce exposure and reduce vulnerability ultimately reduces risk. Capacity assessment must systematically assess the existing capacity and gaps of institutions and communities to: (i) identify, monitor and address hazard; (ii) determine the extent of exposure and ability to reduce exposure to the hazard; and (iii) analyse extent of vulnerability and design and implement vulnerability reduction measures. Table 3.2 provides an example of how capacity can be assessed at different levels.

FAO provides several examples of capacity development assessment tools, including questionnaires (FAO, 2012). The capacity assessment is followed by capacity development intervention planning.

The Sendai Framework for Disaster Risk Reduction highlights children as among the most vulnerable groups who must be empowered to prepare for natural hazards and who play a vital role in preventing and reducing disaster risk (UNISDR, 2018). As such, education in the formal sector should be supported by education in non-formal and informal settings, including clubs and other civil society fora. Actors responsible for formal education, as well as those in non-formal and informal settings, should therefore be prepared to cooperate.

Capacity development should be tailored to the local realities of the watershed and the landscape, and be linked to the risk assessment and proposed risk management measures (see Chapters 4 and 5). Existing watershed management committees or other user groups may be the target group for risk-specific training. Developing local skills for implementing good practices in risk and climate change adaptation and mitigation techniques (such as soil conservation, agricultural diversification, water turbidity monitoring, establishing drainage system, savings and credit systems and adult literacy programmes) may create suitable spaces to discuss the risks and potential hazards with local inhabitants and stakeholders. In addition, intervening actors (state authorities and external actors) may also benefit from capacity development to better understand the livelihoods, local cultures, norms and habits within the watershed, thereby making collaboration more effective.

The assessment of capacity is conducted during the vulnerability assessment process (see Chapter 4).

Table 3.2: Capacity assessment

Dimensions	Capacity areas	Existing situation (current level of knowledge)	Desired situation (desired level of knowledge)	Capacity development needs/gaps
Enabling environment (policy level)	Are there policy priorities and legal frameworks supporting resilient watershed management?			
	Are authorities committed to implementing resilient watershed management? If so, how is this reflected in terms of accountability?			
	Are specific budgets and resources allocated to watershed and climate risk management at the relevant level?			
	Are national/local agencies mandated to implement watershed and climate risk management programmes independent of political influences?			
	Are there documented procedures or standards for climate risk management programme implementation? Are there systems to monitor and evaluate the implementation?			

Dimensions	Capacity areas	Existing situation (current level of knowledge)	Desired situation (desired level of knowledge)	Capacity development needs/gaps
Organizations (institutions at national and local levels)	Which organizations have a mandate for watershed management? Do they include recognition of climate risk management and climate change adaptation and mitigation? Are their mandates clear? Who is responsible for collecting and monitoring hazard information? Who conducts hazard and risk modeling?			
	Do the organizations have the know-how to design, implement, monitor and evaluate climate risk management programmes carried out in watersheds?			
	Are there any interagency processes, groups or other coordination mechanisms? What are their strengths and weaknesses?			
	Are staff of local and national implementation bodies adequately trained or prepared? To what extent do staff have the necessary skills to carry out implementation functions?			
	Do national and local implementation bodies have access to climate risk management information, watershed indicators, innovations and good practices?			
	How do competent authorities and competent bodies share information with each other?			

Dimensions	Capacity areas	Existing situation (current level of knowledge)	Desired situation (desired level of knowledge)	Capacity development needs/gaps
Communities and/or individuals (household level)	What skills and competencies exist in coping with disaster and climate-related risks (access to information, knowledge of safety measures, emergency actions, vulnerability reduction measures, possible protection measures, livelihood activities and community organization)?			
	Are there any social protection measures especially designed to support individuals in implementing climate risk management measures?			
	Are there training/ learning opportunities for the public at large?			
	Do individuals have access to funds for implementation of risk management measures?			

Source: Based on FAO. 2012. FAO approaches to capacity development in programming: Processes and tools. Learning module 2 – capacity development. Rome. www.fao.org/3/a-i2531e.pdf

3.5 Risk-based communication strategy

A risk-based communication strategy for resilient watershed management may include diverse components, such as environmental education campaigns (for instance, on key species for the biodiversity of the watershed and its ecosystem services), art contests (such as a photography competition that allows local users to submit photographs of their watershed from their own hand-held devices), and online surveys to take stock of local perceptions of disaster risks and climate change. Simple signs and pictures painted on walls in villages can also be used to ensure transparency. Other ideas include designing smartphone apps that facilitate exchanges based on watershed identities, or open markets to exchange local produce and raise awareness of agrobiodiversity.

Developing an interactive website to enable the public at large to access data will help to make the information more readily available and support the necessary capacity development. An established data management system that is open to the public also sustains the long-term vision necessary in disaster risk management and climate change. For example, future risk management initiatives may refer to the baseline and build upon previous processes. Moreover, such a system will enhance public support for joint activities. A useful feature is an online GIS portal, which can provide near real-time information based on data collected at the watershed level (such as terrain, slope, soil texture, moisture, infiltration rate and soil capability, evapotranspiration, land use and land cover). This technology can subsequently support resilient watershed management decision-making across institutions at national and subnational levels.

A successful watershed risk communication strategy uses a mix of tactics and approaches, including but not limited to:

- public relations;
- media communication;
- social media and digital platforms;
- mass awareness initiatives;
- social mobilization;
- community engagement; and/or
- strategic partnerships with key public and private agencies, health care providers and the media.

3.6 Expected outputs

The expected outcome of this step is a stakeholder engagement strategy, which includes:

- a stakeholder analysis that identifies key partners and actors while recognizing stakeholder diversity;
- a participatory process plan with stakeholder representation;
- a capacity development plan; and
- a watershed risk communication strategy.

Since stakeholder engagement is a continuous process throughout the watershed management cycle, these outputs will be constantly updated and adapted to match the evolving needs and local priorities.

3.7 Further reading

- A comprehensive overview of making participation work can be found in the report, *Learning together to manage together – Improving participation in water management* (Ridder, Mostert & Wolters, 2005). On education, a report from the United Nations Economic Commission for Europe (UNECE, 2009) provides first insights. *Learning from each-other: The UNECE strategy for education for sustainable development*. www.unece.org/environmental-policy/education-for-sustainable-development/education-for-sustainable-development-esdpublicationshtml/education-for-sustainable-development/2009/learning-from-each-other-the-unece-strategy-for-education-for-sustainable-development/docs.html

- See also: FAO. 2005. *How to do participatory policy development*. Rome. www.fao.org/3/ak483e/ak483e02.pdf

- Practical technical guidance for vulnerability assessment with a forest- and tree-related component is provided in FAO. 2019. Climate change vulnerability assessment of forests and forestdependent people – A framework methodology, by Meybeck, A., Rose, S. and Gitz, V. FAO Forestry Paper No.183. Rome, FAO.

- A practical guide for stakeholder analysis is the 2016 World Bank report, *Public-private dialogue (PPD) stakeholder mapping toolkit. A practical guide for stakeholder analysis in PPD using the Net-Map method*. http://documents.worldbank.org/curated/en/842721467995900796/pdf/106395-WP-PUBLIC-PPD-Stakeholder-Mapping-Toolkit-2016.pdf

- Information and tools for capacity development can be found on the FAO Capacity Development webpage: www.fao.org/capacity-development/en

- See also**:** International Federation of Red Cross and Red Crescent Societies (IFRCRCS). 2013. *Public awareness and public education for disaster risk reduction: Key messages*. Geneva. www.ifrc.org/PageFiles/103320/Key-messages-for-Public-awareness-guide-EN.pdf

- On partnering for building resilience, see also: United Nations. 2020. *United Nations Common Guidance on Helping Build Resilient Societies.* New York (UN). https://unsdg.un.org/sites/default/files/2021-09/UN-Resilience-Guidance-Final-Sept.pdf

Laspur Kumrat trai in northern Pakistan
©Shams Uddin

4

Perform risk assessment

Ala Kul lake in the Kyrgyz Republic
©Altynai Taalaibek Kyzy

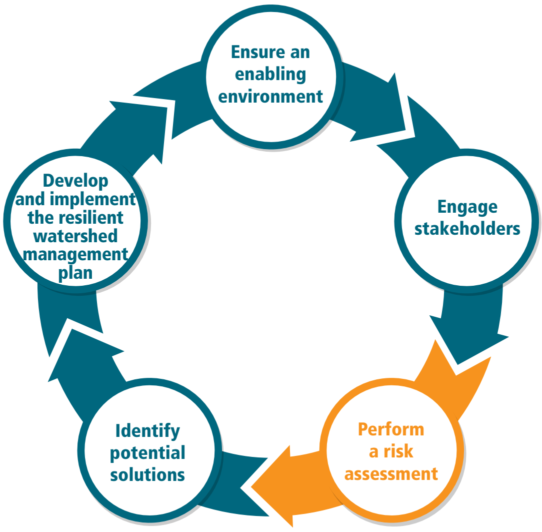
4. Perform risk assessment

4.1 Introduction

A risk assessment is an essential step in ensuring that appropriate and effective risk reduction measures are identified to be included in the resilient watershed management plan (see Figure 4.1).

Risk assessments are normally commissioned by national institutes or international institutions. However, they could also be developed within and across sectors at national and subnational levels, in partnership with sectoral ministries and local stakeholders, to produce a more field-based and participatory version. The scale of the risk assessment usually begins at national, regional, landscape, local and watershed levels. The scale, scope and level of detail should be in line with other assessments carried out for the development of the resilient watershed plan.

Figure 4.1. The resilient watershed management cycle



Source: Author's elaboration

Risk assessments can also be used to routinely integrate risk considerations into other areas relevant to resilient watershed management, including the agriculture, energy and communication sectors.

Adopting a landscape perspective to risk management entails considering the diverse components of the landscape, from water catchment areas in the highlands to agricultural spaces, livelihood strategies, urban water use and waste, and ecosystem services. The involvement of all stakeholders in the risk assessment process is of critical importance, especially local people who often possess a broad knowledge of a particular region's vulnerabilities, risks and remedial solutions (Watanabe *et al*., 2016). Ground truthing of GIS results is a highly recommended step. Analyses should also be repeated after any new disaster event.

4.2 Risk assessment components

Risk is a function of hazard, exposure, vulnerability and capacity. As capacity increases, a community's sensitivity to hazards, exposure and vulnerabilities decreases, because the community becomes stronger and more resilient to change.

According to the United Nations Office for Disaster Risk Reduction (UNDRR, 2019b), the disaster risk assessment process includes

> *the identification of hazards; a review of the technical characteristics of hazards such as their location, intensity, frequency and probability; the analysis of exposure and vulnerability, including the physical, social, health, environmental and economic dimensions; and the evaluation of the effectiveness of prevailing and alternative coping capacities with respect to likely risk scenarios.*

Risk assessment comprises the following steps, each of which is explained in greater detail later in this chapter:

1. **Hazard assessment:** This assessment determines the frequency and magnitude of specific hazards. The frequency reflects the repetitiveness of a particular hazard within an established period, usually expressed as the return period. It expresses the probability of occurrence of the particular hazard within a given time period in a specific location. The magnitude, meanwhile, reflects the severity or the potential damaging impact of the hazard. A hazard assessment is therefore intended to inform decision-makers, planners and the public on how often an event of a given magnitude is likely to occur in a given time interval and in a defined geographical area.

2. **Exposure assessment:** This determines the extent to which elements-at-risk (such as people, infrastructure, housing, production capacities, livelihoods and other tangible human assets) fall within the geographical range of impact of a specific hazard. Measures of exposure can include the number of people, livelihoods, area of farmland, number and types of critical infrastructure, and other tangible assets located in a hazard-prone area. In some reference materials, exposure is considered a component of vulnerability. However, in line with the risk conceptual definition used in this sourcebook, exposure is taken as a stand-alone component of risk.

3. **Risk hotspot identification and prioritization:** The overlay of the resulting hazard and exposure maps (Steps 1 and 2) delineates specific areas considered hotspots, or areas that are identified as being highly exposed to hazards and at the greatest risk of experiencing them. Once risk hotspots have been selected, further in-depth analysis needs to be conducted to formulate the appropriate interventions. The prioritization of risk hotspots can be determined by a cost-benefit analysis.

4. **Risk reduction opportunity areas:** As part of the risk hotspot identification process, risk reduction opportunity areas may also be identified that are of particular importance to the success of the resilient watershed management plan. These are entry points as shown by analysis to contain the greatest potential for responding to the interventions or treatments recommended, such as afforestation, construction of gabions structures to divert river flow, among others, which in turn will provide the highest level of risk reduction and safety for downstream populations and infrastructure.

5. **Vulnerability assessment:** Detailed vulnerability assessments are conducted in the prioritized risk hotspots. This assessment encompasses the notion of susceptibility in the face of specific hazards. Susceptibility refers to the multifaceted nature of vulnerability. It is underpinned by societal conditions and processes, viewed from a multidimensional approach (considering physical, social, cultural, environmental, economic and institutional dimensions), which increase the vulnerability of the community/system or watershed to negative impacts. Capacity assessment is conducted together with the vulnerability assessment. It assesses the existing capacity of the people and institutions to address the various aspects of risk, and measures their inherent and existing resilience.

6. **Risk analysis:** This process is carried out to evaluate the likelihood of a disaster and to qualitatively and quantitatively determine the anticipated loss and damage from the occurrence of a specific hazard or several hazards (multi-hazards).

Composition of the risk assessment team

Establishing an assessment team from the outset will help to ensure quality assessments. It is essential that the assessment team meet with relevant stakeholders in order to obtain the approval of the assessment, the scales of intervention, and to establish and clearly define the roles and responsibilities of the diverse actors involved in the assessment. The team composition should be determined based on the circumstances surrounding each assessment (ACAPS, 2016), and should immediately clarify:

- the objectives and scope of the assessment;
- the type of information to be collected;
- the sources of information;
- the data collection methods chosen;
- the in-country resources available; and
- the security conditions.

Team members should have expertise in a range of disciplines (for instance, community consultation and facilitation, landscape management, watershed management, climate change, natural hazards, meteorology, hydrology, limnology, ecology) and tools (modelling and GIS). The team should also possess knowledge about the national, regional and/or local situation, demonstrating experience in participatory processes while being sensitive to gender, poverty and other issues. Knowledge of relevant sectors such as agriculture, energy, tourism and industry is an additional requirement.

The first assignment of the assessment team will be to facilitate discussion among stakeholders about the objectives, information requirements and geographical scope of the assessment. Once the assessment and the analysis plan (including tools, sampling and report format) are agreed on by all, additional human resources will be required to support the assessment at different steps of its implementation.

Qualitative and quantitative assessment methods

Risk assessments may adopt quantitative or qualitative methods, or both, as they are generally complementary.

Quantitative risk assessments are mostly used to analyse the potential cost of physical damage and loss. They may involve scenario analyses based on past hazard events or conducted through the use of natural hazard models that can help to assess the probability of events of varying magnitude in the future (probabilistic approach). The approach may also be deterministic, attempting to assess the impact of any given hazard scenario. For example, wildfire computer models can now perform spatially explicit fire simulations for fire simulation for heterogeneous fuels while mapping wildfire behaviour characteristics across large landscapes (UNISDR, 2017a). Quantitative methods may prove costly and time-consuming, and their reliability is only as good as the data fed into them, which is often a problem in data-deficient rural areas of the world.

An example of an open-source and easily available quantitative method is the index for risk management, which uses statistical data to calculate an overall risk score for countries based on their dimensions, categories and components of risk (Marin-Ferrer, Vernaccini and Poljansek, 2017).

Qualitative risk assessment methods may be used when there are time and resource constraints. They may also be applied in cases where there is insufficient information regarding the frequency and intensity of a hazard, or when the exposed assets under investigation, or their level of vulnerability, are difficult to quantify. This approach particularly applies to risk assessments focusing on the social perceptions of risk, as well as on the economic and environmental dimensions of household and community risks (ADB, 2017a).

Generating data for qualitative indicators calls for participatory methodologies, including focus group discussions, individual interviews, and surveys measuring perceptions and opinions of both men and women. Subsequently, computer-assisted qualitative data analysis software can be used to facilitate research of subjective information, such as perceptions, narratives and discourse.

Defining focus and scale of the assessment

Risk assessments can be conducted for single and multiple types of hazards. Even if the focus is on a specific location, they should be conducted at a landscape level, so that risks that may originate outside the area of interest are also taken into account. Multi-hazard risk assessments are usually considered best practice at the landscape level. Multi-hazard assessments also consider the cascading effects of hazards.

Risk assessments can be conducted at national level to coordinate efforts with central government institutions and their land-use planning, and at the subnational scale, involving jurisdictions below the central government, such as provinces, districts, municipalities, communes and wards. In these subnational initiatives, it is important that attention be paid to the issues involved in multilevel governance and to coordinate among different levels of government, from local to national (see Chapter 2).

Since long-term interventions may be needed to increase the resilience of the poorest and most vulnerable populations, risk assessments should be an integral component of development planning at the community level.

The time frame for a risk assessment should be defined from the outset. The scale and focus should be clearly established, with uncomplicated definitions of participant contributions and responsibilities, as well as the time and space dimensions to be considered in the assessment.

4.3 Hazard assessment

Resilient watershed management lays emphasis on recognizing different types of natural and climate change-related hazards, their direct and indirect impacts on a landscape, and their cascading effects within the watershed. For example, a drought leads to loss of crops, but also to loss of wetland vegetation, which leads to reduced water retention when the rains start, causing much greater soil erosion and flooding. Indeed, one hazard may easily trigger another, so that an earthquake followed by heavy rains may lead to landslides, thereby requiring a multi-hazard perspective (UNDRR, 2019a).

Table 4.1: Different types of hazards

Types of Hazards	Origin	Examples	Multi-hazard considerations for watersheds
Geophysical	Internal earth processes	Earthquakes and tsunamis, volcanic eruptions, mass movements or landslides, snow and mud avalanches	Hydro-meteorological factors are important contributors to the exposure of geophysical hazards (e.g. strong rainfall after an earthquake can lead to landslides).
Hydro-meteorological	Atmospheric, hydrological or oceanographic origin	Tropical cyclones (also known as typhoons and hurricanes); floods, including flash floods; droughts, heatwaves and cold spells, and coastal storm surges	Hydro-meteorological conditions may also be a factor in other hazards, such as landslides, wildland fires, locust plagues, epidemics and the transport and dispersal of toxic substances and volcanic eruption materials (e.g. a drought can increase the probability of forest fires occurring).
Biological	Organic origin or conveyed by biological vectors, including pathogenic micro-organisms, toxins and bioactive substances	Bacteria, viruses or parasites, as well as venomous wildlife and insects, poisonous plants and mosquitoes carrying disease-causing agents	These hazards can have specific impacts on human health and food provision systems (e.g. livelihoods and food security may be put at risk by agricultural epidemics).
Environmental	Chemical, natural and biological hazards. These can be created by environmental degradation or physical or chemical pollution in the air, water and soil	Soil degradation, deforestation, loss of biodiversity, salinization and sea-level rise	Many of these processes and phenomena can be termed drivers of hazard and risk rather than hazards per se. They can, however, have far-reaching consequences on the socioeconomy in the watershed.
Technological	Technological or industrial conditions, dangerous procedures, infrastructure failures or specific human activities	Industrial pollution, nuclear contamination, toxic wastes, dam failures, transport accidents, factory explosions, fires and chemical spills	As another example of multi-hazards, technological hazards may also arise directly as a result of the impacts of a natural hazard event, and/or trigger disaster events (e.g. dam failure may trigger floods lower in the watershed).

Sources: Carter, W.N. 1992. *Disaster management: A disaster manager's handbook*. Manila, Philippines, Asian Development Bank. 417 pp.; and United Nations Office for Disaster Risk Reduction. 2019a. *Terminology on disaster risk reduction*. Cited 20 June 2019. www.unisdr.org/we/inform/terminology

Steps in hazard assessment

Hazard assessments should include the following steps for each hazard:

- identification of all hazards prone to impact the specific landscape and consequently, a watershed(s);
- selection of the hazard model based on the most relevant hazards to be analysed, which can be a computer model or a simple calculation;
- collection of baseline data needed for the hazard model;
- modelling of the hazards and mapping the magnitude, frequency, return period, exceedance probability, spatial extent and possible compounding or cascading effects;
- mapping the areas likely to be affected;
- validation of results; and
- identification of community-level hazards through local hazard and risk mapping.

Identification of hazards

Local knowledge and experience can provide information on the most substantial hazards in the landscape, based on participatory risk assessment exercises (see Figure 4.2). Depending on the type of hazard, different models should then be used.

Figure 4.2 Resilient watershed management consultation exercise identifying climate related risks, Namche Bazaar, Khumbu, Nepal, 2014

©The Mountain Institute

Selection of hazard model(s)

For example, flood modelling can be based on a one-dimensional model that measures flood levels in the channel, or a two-dimensional model to measure flood depth and the extent of the floodplain. The selection of the hazard-modelling tool (e.g. Sobek, Mike21, LISFLOOD-2D, HEC-RAS, FLO-2D and FloodArea) must take into account the availability and credibility of data, as well as the expertise of the people responsible for running the model and interpreting the outcome. In addition to computer models and specialized programming, participatory methods that mobilize local knowledge can provide information that strengthens, clarifies or even challenges the modelling results.

Baseline data collection

Baseline data can come from different sources (including remote sensing, online databases, different stakeholders and local information centres) and in different formats, as seen below.

For desktop (quantitative) GIS mapping:

- the UNEP Global Risk Data Platform and information generated by local authorities;
- scientific data and measurements (e.g. meteorological, hydrological, seismological and vulcanological) by climate observatories and specialized agencies; and
- relevant maps (e.g. topographical, geological, land-use, land cover, infrastructure).

For desktop GIS mapping and community-based mapping:

- local traditional knowledge, oral histories and historical records;
- socioeconomic or agricultural surveys; and
- new data generated by a field team of physical and social scientists tasked with the collection of local hazard histories, frequency of occurrence, biophysical data, oral testimony of hazard events within living memory, gendered resource mapping and community risk mapping, etc.

Formats for expressing the magnitude (power or impact) of each hazard are well established. Monitoring and data collection should be embedded in national statistical offices and support a culture of evidence-based learning at national and subnational levels. Table 4.2 provides information on data sources by types of hazard. An open-source initiative for compiling disaster databases is provided by DesInventar Sendai – Disaster loss data for Sustainable Development Goals and Sendai Framework Monitoring System, led by UNDRR (UNDRR, 2019c).

Table 4.2: Modelling data sources for measuring magnitude by types of hazard

Type	Measuring magnitude	Examples of data source
Geophysical		
Earthquakes	For the purposes of a hazard assessment, an earthquake is frequently described in terms of peak ground acceleration (PGA).	The global earthquake model aims to provide a consistent, global suite of open source tools, data and models for estimating seismic risk.
Tsunamis	Tsunami hazard can be measured as the extent or the depth of water run-up (i.e. the extent of inundation of seawater on land). Flow direction and velocity are sometimes also modelled.	The 2015 GAR includes a data set describing the maximum probable run-up for a 500-year return period. It is available for download from the GAR data download page (UNISDR, 2015b). The United States of America's National Oceanic and Atmospheric Administration (NOAA) maintains a freely accessible historical catalogue of global tsunami data. The Indian Ocean Tsunami Information Center provides hazard information, resources and early warnings to countries in the Indian Ocean basin.
Volcanoes	Multiple hazards are associated with volcanic eruptions, including lava flow and ash fall. Due to the long return period and poor historical record of eruptions, the creation of a reliable hazard assessment for volcanoes is difficult.	The Global Volcano Model Network has developed a volcano hazard index based on historical eruption frequency and occurrence of pyroclastic, mud and lava flows.
Hydro-meteorological		
Tropical cyclones	Tropical cyclones typically present three kinds of hazards, each of which can be modelled separately: storm surge, wind and precipitation. Storm surge is usually measured as run-up distance; wind as wind speed; and precipitation as millimetres of rainfall or depth of inundation.	Cyclone tracks are found at the International Best Track Archive for Climate Stewardship, maintained by NOAA. National disaster response, coastal management or meteorological agencies maintain early warning systems and historical records related to tropical cyclone hazards.
Floods	Flood hazard is most often represented by the depth, extent and, in some cases, flow rate of a river for a given rainfall event or return period.	The Dartmouth Flood Observatory at the University of Colorado, United States of America, maintains the Global Active Archive of Large Flood Events.
Landslides	The major inputs to landslide hazard models, apart from source, are elevation (slope), soil type, land cover and land use. Many landslide hazard maps include an indication of earthquake hazard, as well as precipitation volume or frequency.	The United States of America National Aeronautics and Space Administration maintains the Global Landslide Catalog.
Droughts	Droughts are complex and poorly understood phenomena. They can be categorized as meteorological, hydrological, agricultural or socioeconomic, and can be measured accordingly.	The standardized precipitation-evapotranspiration index (SPEI) is used to compare drought severity through time and space. Data are available from the SPEI Global Drought Monitor.

Source: Asian Development Bank (ADB). 2017b. *Natural hazard data: A practical guide*. Manila, Philippines, Asian Development Bank. www.adb.org/documents/natural-hazard-data-practical-guide

Notes: 1. United Nations Office for Disaster Risk Reduction (UNISDR). (2015b). Global Assessment Report on Disaster Risk Reduction. www. preventionweb.net/english/hyogo/gar/2015/en/home/download.html

Hazard modelling

Once the choice of the model is defined and all the data required are collected and imported into the model, the model can be run to generate a series of outputs, such as magnitude, return period, exceedance probability and the extent of potential impact.

The magnitude of the hazard reflects the amount of energy or mass released by the hazard occurrence.

Earthquakes provide a good understanding of the conceptual difference between magnitude and intensity. The magnitude of the earthquake reflects the energy released by the event, as recorded at the epicentre and usually measured on the moment magnitude (M_W) scale or by peak ground accelerator (PGA). Two earthquakes of the same magnitude will always have different impacts, hence different intensities, depending on the exposure and sensitivity of the elements at risk to the shock. For this reason, the intensity of the earthquake is measured on the modified Mercalli intensity scale.

The magnitude is intrinsic to the hazard while the intensity depends on other factors beyond the hazard. In the case of floods, the magnitude is a function of the water height or volume of discharge.

The return period describes the probability that an event (i.e. a particular type of hazard of specified magnitude in a given location) will occur in the future.

The hazard probability is described for a specific time period (ADB, 2017a). For example, the Intergovernmental Panel on Climate Change (IPCC) has calculated that a 1-in-20-year annual maximum 24-hour precipitation rate is likely to become a 1-in-5- to a 1-in-15-year event by the end of the 21st century in many regions, thereby predicting an increase in frequency of heavy precipitation (IPCC, 2012). Return periods are expressed as averages; however, it may be meaningful to translate return periods into the annual probability of a hazard.

While the frequency and return period statistically measure the likelihood that a particular hazard will strike (e.g. a 500-year flood), the exceedance probability looks at the likelihood that a certain threshold will be reached or exceeded (e.g. a 10-m flood or an 8.2 M_W earthquake). The exceedance probability is commonly expressed in the form of annual exceedance probability (referring to the probability of a hazardous event occurring in any year) or probable maximum loss (referring to a worst-case scenario of maximum losses).

According to concept of frequency, high-frequency hazards such as droughts, floods and storms are distinguished from low-frequency hazards such as earthquakes and volcanic eruptions. For instance, a volcanic eruption may have a 500-year return period, compared with a 5-year return period for droughts.

Hazards also have different spatial extents, ranging from metres to kilometres. Slow onset hazards tend to cover a wide spatial extent compared with rapid onset hazards. For example, a landslide may have a small spatial extent while droughts and heatwaves may extend beyond national borders.

Hazard modelling is expected to generate maps containing magnitude, frequency and/or other statistics are mentioned above. Maps enable a rapid visualization of hazard-prone regions and can provide a practical tool for informing decision-making. In addition, maps can be produced for single or multiple natural hazards, depending on the hazard context and their intended use. They may also be used during the community consultation process to demonstrate to stakeholders the results of computer-generated hazard mapping for their region, which allows comparison with their own experience.

Validation

The aim of validation is to match the reality on the ground with the outcome of the model, to either confirm or reject the outcome. It determines the degree to which the outcomes of the hazards (magnitude, return period and spatial extent) represent the real world from the viewpoint of the intended users. For example, in flood hazard mapping, validation may consist of overlaying specific map features (such as flooded areas and urban areas) to establish the model's level of accuracy.

There are instances where hazard maps are available, either from previous studies or from global databases, remote sensing and/or earth observation satellite programmes. Validation may be carried out to establish the accuracy of these maps, prior to their integration into the risk assessment, as overlays with exposure maps to delineate risk reduction opportunity areas. The validation process should always include consultation with local people in the affected locations, as well as field visits that can help to ground truth the information produced by the hazard model.

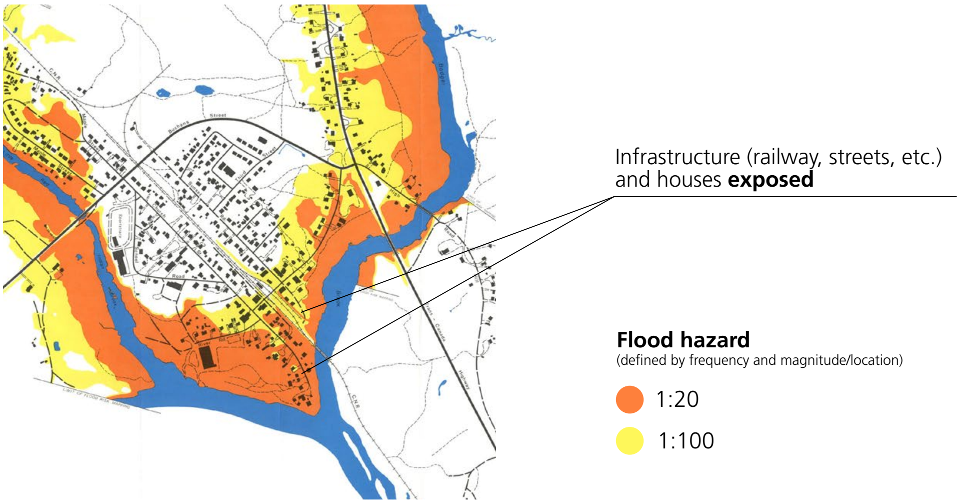
4.4 Exposure assessment

The exposure assessment indicates the areas that are impacted by the hazard, as well as the assets in the area. Identification of exposed assets is conducted by overlaying spatial data, such as population distribution and livelihood assets, with hazard maps (see example in Figure 4.3).

Assessing exposure requires georeferenced inventories of assets (ADB, 2017a). Assets may range from individual structures (e.g. power utilities or croplands) over limited areas to entire regions (represented, for example, by groups of buildings and lifeline infrastructure, such as hospitals, schools and road networks) that are within the geographical area of the watershed. In addition, assets should, where possible, be valued to facilitate quantification of risk in monetary terms to inform decisions concerning the economic impacts of risks (see Chapters 5 and 6). Lastly, assets should be valued at their replacement cost, not at their current market or depreciated book value.

At the community level, an exposure assessment may be carried out by asking stakeholders about their past experiences regarding specific hazards. Local inhabitants are aware of the hazards and are usually able to point out, for instance, the flooded area and the highest water level of a severe flood situation in the past or previous landslide locations. They can generally also indicate the degree of damage caused by specific hazards.

Figure 4.3 Example of flood information map



The colours show how far flood water will enter the built environment in a 1-in-20 year flood (orange) and a 1-in-100 year flood (yellow). The dots and lines indicate buildings and infrastructure. When in a coloured area, these buildings and infrastructure are exposed to flooding

Note: Not shown in map: different levels of e.g. physical vulnerability of houses or social vulnerability of the community

Source: Government of Newfoundland and Labrador. 1985. Flood information map, Badger, Newfoundland. Municipal Affairs and Environment, Water Resources Management Division. www.mae.gov.nl.ca/waterres/flooding/badger_flood_risk.pdf

While there is an increasing number of open access databases on natural hazards and exposure, programme-focused risk assessments at the subnational level may need to identify additional, reliable data from other sources, such as governments, national statistics offices and research institutes, as well as use local experience and knowledge to enhance the model's predictive accuracy. However, if such data are not already organized within a single database, finding and then preparing data to be integrated into possible models may prove time-consuming and costly. The Appendix in *Disaster risk assessment for project preparation: A practical guide* (ADB, 2017a) provides a list of open spatial data sources on populations and assets.

4.5 Risk hotspot identification and prioritization

Risk hotspots could potentially be found within one or more watersheds (or parts thereof), where people, infrastructure, housing, agricultural land, livelihood and production capacities and other sensitive assets are at risk. The reduced scale of analysis minimizes the uncertainty and increases the accuracy, in the prediction and monitoring of processes in watersheds.

Prioritization can be based on a single criterion or the combination of several. Possible sets of criteria include:

- human criteria, often expressed as mortality risk, but also as the number of people affected. Usually, highly populated areas are likely to be considered risk hotspots;

- economic criteria, generally expressed as potential economic loss. The GDP per unit area can be used as a proxy indicator to measure the economic risk of a specific watershed. In rural areas, livelihoods and assets of smallholders and other community members should be taken into consideration. This aspect is important because these livelihoods and assets may not necessarily represent a big economic impact, compared with other areas in the watershed; and/or

- environmental criteria, expressed as potential environmental disturbance. The threatened species per unit area can be used as a proxy indicator to assess the potential impact of natural hazards on biodiversity.

Once risk hotspots have been identified and prioritized, a more in-depth risk assessment can be conducted in the delineated areas. The number of risk hotspots will depend on local risk conditions, as well as the availability of data and resources, time, and the criteria established by local and government stakeholders involved in the risk assessment.

4.6 Risk reduction opportunity areas as priority areas for interventions

Once risk hotspots have been identified, the next step is to identify and prioritize the risk reduction opportunity areas. The importance of the landscape approach to risk reduction becomes evident through identification of these areas. As such, reduction opportunity areas may not immediately be in a highly hazardous zone or an evident risk hotspot. However, risk reduction interventions at the site identified will have strong potential for reducing the risks in other locations immediately surrounding the risk hotspot, or locations further downstream. These interventions may include increasing vegetation cover, drainage, erosion or avalanche control measures, which could prevent or reduce the possibility of larger landslides and flooding. In the process of prioritizing risk reduction opportunity areas, it is important to calculate the cost of various possible interventions, relative to the amount of risk that they will potentially reduce. In many instances, implementing risk mitigation measures in these areas can be more cost-effective than interventions made directly in the risk hotspot locations.

Risk reduction areas are identified through extensive computer simulations and scenario-building, combining historical data on precipitation, hydrology, geology, seismology, population, infrastructure and costs, among others. The simulations are used to determine how much risk each intervention could potentially reduce, and the costs involved. The decision on the type of intervention is made based on how much risk is acceptable and the budget available.

For example, in certain cases, it may be more cost-effective to remove debris from the road every year rather than set in place extensive landslide control measures. In other cases, if debris blocks transport on the road for more than a month and prevents critical supplies from being distributed, it may be considered more cost-effective to construct extensive landslide control infrastructure in that location. In other situations, increasing vegetative cover and drainage control on the slopes above the landslide location could be more effective for preventing the landslide expanding, thereby reducing the need to construct landslide control measures.

Figures 4.4 and 4.5 provide examples of risk reduction opportunity areas identified in the Mount Everest region of Nepal. Although other locations were identified as higher risk hotspots, such as landslide-prone hillslopes transected by trails, afforestation activities above the main village of Namche Bazaar provided a much stronger degree of protection for people and infrastructure by reducing overland flow rates and strengthening hillslope integrity (Figure 4.4). Likewise, draining a potentially dangerous glacial lake by 3 metres reduced the threat of a glacial lake outburst flood for some 150 000 people living downstream (Figure 4.5).

Figure 4.4

(Left) Hillslopes above Namche Bazaar, Khumbu, Nepal in 1990 were vulnerable to overland flow and erosion processes following decades of deforestation. (Right) Hillslopes above Namche Bazaar ten years after the national park's reforestation project in 2010. This intervention not only reduced the levels of overland flow during heavy rainstorms but also became a source of local pride.

Figure 4.5

(Top) Imja glacial lake, which is a potential hazard to downstream communities and infrastructure in the event of a glacial lake outburst flood. (Bottom) Draining Imja glacial lake in 2016 by constructing an outlet canal and control gate.

4.7 Vulnerability assessment

Understanding vulnerability

Once risk hotspots have been identified and prioritized, the next step in the risk assessment process is to conduct a vulnerability assessment. This stage determines the propensity or predisposition of an individual, a community, asset or system to be adversely affected by a hazard.

Sources of vulnerability can include poverty, inequality, gender, education and health status, disability and environmental risks. Table 4.3 provides examples of indicators for vulnerability assessments in several risk categories. Good indicators should be measurable, representative of local conditions, and capable of providing meaningful information that informs policy and action programmes (UNDRR, 2019b).

Table 4.3: Selected risk categories and indicators in vulnerability assessments

Risk category	Domains	Indicators
Life-cycle/ demographic risks	Birth, maternity, old age, family, break-up and death	Family size: household size, number of dependents, recent births, gender of head of household, old age, deaths in family, family dissolution, among others.
		Education levels: literacy rate, out-of-school population, pre-primary school gross enrolment ratio, primary school gross enrolment ratio, primary school net attendance ratio, secondary school net attendance ratio, secondary school net enrolment ratio
		Age structure: percentage of the elderly population, percentage of children under five, residents aged 65 and older
		Population characteristics: resident population density and population per settlement area
		Population growth: crude birth rate, positive birth rate and growth rate of resident population
Economic risks	Unemployment, harvest failure, business failure, resettlement, displacement and cross-border migration	Poverty: proportion of population below the international poverty line, by sex, age, employment status and geographical location (urban/rural); proportion of population living below the national poverty line, by sex and age; proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions; proportion of population covered by social protection floors/systems, by sex, identifying children, unemployed persons, older persons, persons with disabilities, pregnant women, newborns, work-injury victims, the poor and vulnerable
		Income: per capita income, ratio of high incomes (men/women), average number of wage-earners per household
		Employment: employment to population ratio, status in employment, employment by sector/occupation/education, informal employment, unemployment rate, labour productivity, social protection, percentage of high-skilled labourers unemployed, percentage of women with no economic activity, distribution of the working population in different sectors

Risk category	Domains	Indicators
Health and welfare risks	Illness, injury, accident, disability, epidemic (for example, malaria), famine, among others	Physical and mental health status: risk of suicide, elderly persons, substance addiction, under-five child mortality and neonatal mortality
		Safe water: population using safely managed drinking water services, population using safely managed sanitation services, population using modern fuels for cooking/heating/lighting, and air pollution level in cities
		Nutrition: prevalence of undernourishment (food deprivation), prevalence of critical food poverty (income deprivation), and prevalence of underweight children (child undernutrition)
Disability and special needs risks	Access to and benefit from public services	Percentage of persons with disabilities living off less than USD 1.25 per day; percentage of persons with disabilities covered by social protection, or percentage of persons with disabilities receiving benefits; percentage of deaths of persons with disabilities among all deaths due to disaster events; and proportion of households with persons with disabilities facing impoverishing health expenditure
Environmental risks	Pollution, climate change, deforestation, land degradation, landslides, volcanic eruptions, earthquakes, floods, hurricanes, droughts, strong winds, slash-and-burn agriculture, overharvesting of forest products, desertification, industrial logging/ illegal logging, overgrazing/cattle ranching and soil erosion	Infrastructure: quality of housing, age of construction, population density, dwelling in five- or more storey apartments, air quality, drinking water, ultraviolet exposure and climate change
		Agricultural systems: percentage of land-use changes, proportion of land area covered by forest and vegetation, percentage of land degradation, arable and permanent cropland area, reduced dependency on fertilizer and pesticide use, percentage of area under sustainable forest management
		Wetlands/rivers: percentage of area maintained as wetlands, riverbank vegetation maintenance, water quality and turbidity, and river fragmentation
		Coastal/marine: area of healthy seagrass beds and marine algae, proportion of marine area protected, health of marine ecosystems as measured by marine trophic index, coverage of live coral reef ecosystems, and area of healthy mangroves comprising buffer zones as measured by area, density and width

***Source*:** United Nations Office for Disaster Risk Reduction (UNDRR). 2019b. Global Assessment Report on Disaster Risk Reduction. Geneva. https://gar.unisdr.org/report-2019

Framing the vulnerability assessment

Vulnerability assessments can vary significantly based on the scope, existing coping capacity and resources available to a programme (i.e. expertise, data and budget). However, two major types of vulnerability assessment exist:

1. Explorative vulnerability assessments: These are broad assessments, covering a wide spatial area with low resolution, and based on expert opinion or desk review, making them less time-consuming and less expensive.

2. Focused vulnerability assessments: These are constrained to small geographical areas (e.g. a watershed) with a high resolution, and require the involvement of local stakeholders.

Participatory vulnerability assessments are carried out to identify the vulnerabilities that stakeholders have historically encountered. These vulnerabilities may relate to the indicators as listed in Table 4.4, such as poverty, old age or improper infrastructure, but they may also lie in insufficient coping capacities, including community organization and preparedness. In addition, the stakeholders will be asked to indicate which vulnerabilities they consider more or less significant to prioritize (see, for instance, de Brito, Evers and Almoradie, 2018). Together with the stakeholders, areas are highlighted to demonstrate where specific vulnerabilities play an important or less important role. In this way, a matrix and/or map can be produced, with the priority vulnerabilities identified. The capacity assessment of the stakeholders and institutions is conducted in parallel with the vulnerability assessment to determine how well the stakeholders, community networks and institutions are inherently prepared to address and reduce risk.

Depending on the scale and availability of the data, a focused vulnerability assessment may be conducted based on pre-existing or secondary data (for instance, census data, World Bank data portal, FAOSTAT or FAO's AQUASTAT database). When these data are not available or the scale of the analysis is small, data collection is needed and usually conducted through household surveys.

In data-scarce locations, simple community-level vulnerability assessments and handwritten maps may be sufficient.

Typical steps in an indicator-based vulnerability assessment include:

1. Preparation of the vulnerability assessment: This step consists of laying down certain prerequisites, such as the scope and time frame of the analysis, checking to see if there are previous vulnerability assessments that could serve as a benchmark, and taking stock of existing data and information.

2. Identification and selection of indicators: The selection of indicators must include all the elements to be measured.

3. Data management and multivariate analysis: A multivariate analysis explores the overall structure of the provisional list of indicators and assesses their suitability.

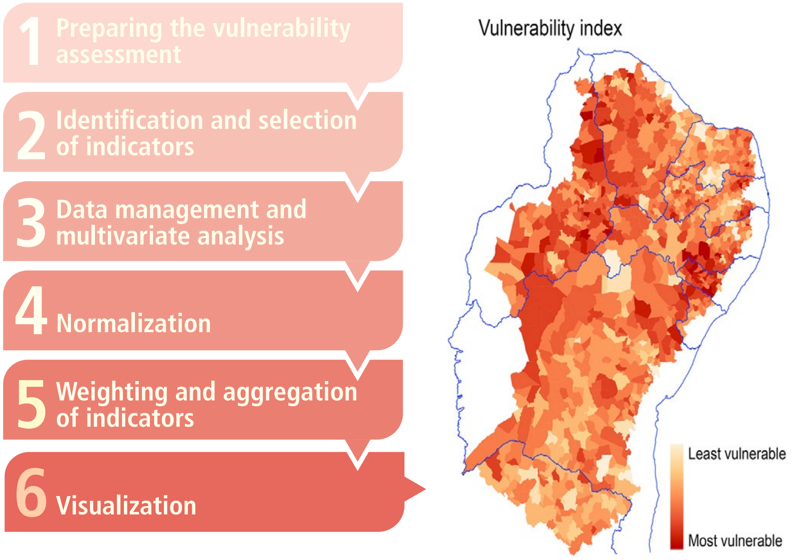
4. Normalization: This step consists of adjusting values measured on different indicators (multiscale) to a common scale of analysis.

5. Weighting and aggregation of indicators: Weighting of the normalized values of indicators is undertaken when some indicators have greater influence on vulnerability compared with others. The weighted values are subsequently aggregated into one index value.

6. Visualization: Presenting the outcome of the vulnerability assessments, generally through maps and matrices, and sometimes tables. Maps provide the opportunity to make overlays of different aspects when a GIS system is used. Matrices are necessary visualization products, as they provide information on different societal groups.

Figure 4.6 shows the six steps of an index-based vulnerability assessment.

Figure 4.6: Steps for the index-based vulnerability assessment



The map shows the index scores divided over different areas.

***Source*:** Adapted from Sena, A., Ebi, K.L., Freitas, C., Corvalan, C. & Barcellos, C. 2017. Indicators to measure risk of disaster associated with drought: Implications for the health sector. *PLOS ONE*, 12(7): e0181394. https://doi.org/10.1371/journal.pone.0181394

Inclusiveness in vulnerability assessments

Data collected on communities and livelihoods within the location should be sex-disaggregated whenever possible. A gender analysis is required as a way of understanding social differences, examining power dynamics and roles within societies, bringing to light assumptions about what people do and gathering information on needs and priorities, as well as people's access to resources and services (FAO, 2016). It is therefore important to identify how certain members of society are most vulnerable in the face of different hazards while also recognizing the particular capacities that they mobilize to adapt to change, so that differentiated strategies and measures can be designed.

Specific tools can be used to support a capacity and vulnerability assessment that distinguishes between men, women and children (FAO, 2016). The process also identifies how the specific capacities that vulnerable groups possess can contribute to increased resilience in the risk hotspot (see Table 4.4).

Table 4.4: Summary of gender entry points in the development of a resilient watershed management plan or policy in the agriculture sector

Section of plan	Summary and issues	Gender entry points
Vision, objectives and guiding principles (Chapter 1)	Most plans on disaster risk reduction make reference to vulnerable groups in the vision and objectives, and seek to promote equity, participation and fairness among their guiding principles. Nevertheless, often the plans do not specify how existing gender inequalities and discrimination among certain socioeconomic groups, and women in particular, will be addressed. It is therefore essential at this stage to explicitly express a commitment to gender equality to facilitate the adoption of a coherent and systematic gender approach throughout the document. In addition, this section should identify at least one area of gender-based inequality (e.g. differences in work burden, access to and control over productive resources and services, or need for empowerment) that the plan will address.	Express a commitment to promoting gender equality. Identify the gender-based inequalities that the plan will address. Identify the specific vulnerabilities, needs, roles and responsibilities for each gender and age group.
Situation analysis (Chapters 2 and 3)	The situation analysis section typically includes a summary of the policy context, as well as the hazards addressed in the plan. It provides an opportunity to lay the foundation for gender-responsive work and to include a justification for the relevance of gender issues in disaster risk reduction in the agriculture sector. It is also the first occasion for establishing the relevant gender and agriculture issues in the context of the disaster event.	Incorporate a justification for the relevance of promoting gender equality within the summary of policies or plans on disaster risk reduction. Document the gender dimensions of the disaster and climate risks addressed within the plan. Ensure that each of the aspects of risk (hazard, exposure, vulnerability and capacity) are considered.
Strategic areas of action (Chapters 4 and 5)	It is common to define the strategic areas of action and their related activities in line with the four pillars of the Sendai Framework for Disaster Risk Reduction. Addressing gender within the activities envisioned by the plan includes identifying the roles and capacities of different groups within the target populations. Emphasis is placed on the importance of drawing on the perspectives and experiences of communities, taking into account the perceptions of both women and men.	Understand disaster risk in all its dimensions. Avoid perpetuating social inequalities in the process of strengthening disaster risk reduction institutions. Promote resilient agricultural practices that are accessible and usable by both women and men. Consider the differential impacts on women and men and various age groups and vulnerabilities in preparedness planning and early warning systems.
Implementation/ operationalization (Chapters 6 and 7)	The last section of the plan usually addresses practical issues related to implementation. Even if gender issues are thoroughly addressed in the previous sections of the plan, special attention must be given to how practical gender issues will be addressed for the implemented disaster risk reduction activities to meet women's as well as men's needs.	Employ institutional mechanisms that ensure participation by women and the decision-making power of women's groups. Mobilize and allocate resources to implement gender-responsive activities. Monitor progress on gender equality using gender-sensitive indicators. Ensure the varying roles, responsibilities and capacities of each gender and age group.

Source: FAO. 2016. *Gender-responsive disaster risk reduction in the agriculture sector. Guidance for policy-makers and practitioners*. Rome. www.fao.org/3/b-i6096e.pdf

4.8 Risk analysis

Visualization of risks through GIS-generated maps

BOX 4.1 Mapping methods used in participatory geographical information systems

Ephemeral mapping is the most basic mapping method, which involves drawing maps on the ground. Participants use raw materials such as soil, pebbles, sticks and leaves to represent the physical and cultural landscape.

Sketch mapping is a slightly more elaborate method. A map is drawn from observation or memory. It does not rely on exact measurements, such as having a consistent scale, or geo-referencing. It usually involves drawing symbols on large pieces of paper to represent features in the landscape.

Scale mapping is a more sophisticated map-making method, aimed at generating geo-referenced data. This allows community members to develop relatively accurate scaled and geo-referenced maps, which can be directly compared with other maps.

3D modelling integrates spatial knowledge with elevation data to produce three-dimensional stand-alone, scaled and geo-referenced relief models, which may prove particularly relevant for representing watershed basins. Geographic features relating to land use and cover are depicted on the model by the use of pushpins (points), yarns (lines) and paints (polygons). When the model is finished, a scaled and geo-referenced grid is applied to facilitate data extraction or importation. Data depicted on the model can be extracted, digitalized and plotted.

Photomaps are printouts of geometrically corrected and geo-referenced aerial photographs (orthophotographs). Orthophoto-maps are a source of accurate, remotely sensed data that may be used for large-scale community mapping projects. Community members can delineate land use and other significant features on transparencies that have been overlaid on the photomap. Information on the transparencies can be scanned or digitized and geo-referenced later. Remote sensing images at a suitable scale are an increasingly appropriate alternative when they are easily and freely available online.

Global positioning systems (GPS) data can be used to add accuracy to information depicted on sketch maps, scale maps, three-dimensional models and other less technology-rich community mapping methods.

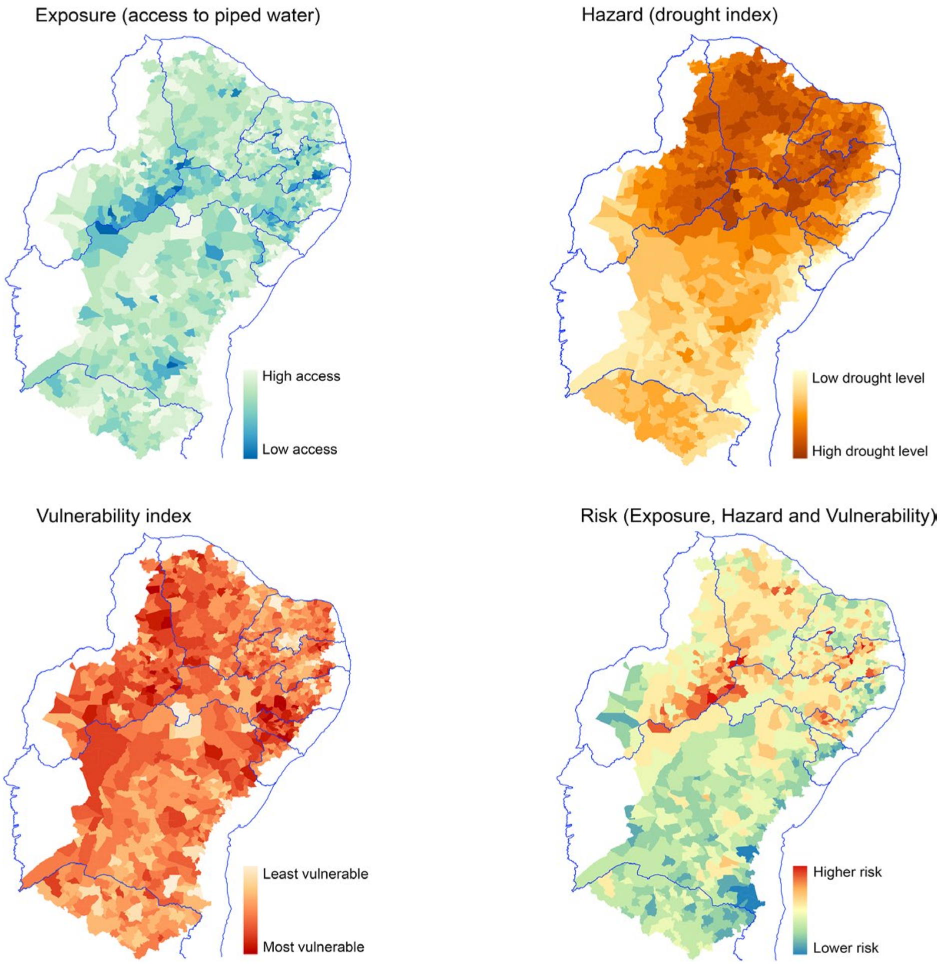
Map-linked multimedia information systems are similar to GIS technologies, but simpler to understand and manage. Local knowledge is documented by community members using digital video, digital photos and written text, and managed through the interface of an interactive, digital map. The other multimedia information can be accessed by selecting features of the interactive map.

A **geographic information system (GIS**) is a computer-based system designed to collect, store, manage and analyse spatially referenced information and associated attribute data. GIS technology is increasingly being used to explore community-driven questions. In the process, local spatially referenced, as well as non-spatial data are integrated and analysed to support discussion and decision-making processes. "Mobile GIS" has become much better adapted to participatory and local community use with the development of GIS software designed to work with smartphones and tablets in the field. Similarly, drones and other remote-controlled aerial vehicles may be used to generate aerial imagery and automate mapping.

Sources: Corbett, J., Rambaldi, G., Kyem, P., Weiner, D., Olson, R., Muchemi, J., McCall, M. & Chambers, R. 2006. *Overview: Mapping for change, the emergence of a new practice*. International Institute for Environment and Development. http://pubs.iied.org/pdfs/G02944.pdf and Rambaldi, G., Kyem, P.A.K., McCall, M. & Weiner, D. 2006. Participatory spatial information management and communication in developing countries. *The Electronic Journal of Information Systems in Developing Countries*, 25(1): 1–9. https://doi.org/10.1002/j.1681-4835.2006.tb00162.x

Once all the components of the risk assessments (hazard, exposure, vulnerability and capacity) have been mapped at varying spatial scales, the risk analysis can be conducted by overlaying the three datasets as illustrated below (see Figure 4.8). The figure shows how the overlays of all the maps generated are combined into one risk map, thus revealing the areas with the highest and lowest risks. Please see Box 4.1 for the various mapping types available.

Figure 4.7: Sample of a risk map as an overlay of the hazard, exposure and vulnerability maps



***Source*:** Sena, A., Ebi, K.L., Freitas, C., Corvalan, C. & Barcellos, C. 2017. Indicators to measure risk of disaster associated with drought: Implications for the health sector. *PLOS ONE*, 12(7): e0181394. https://doi.org/10.1371/journal.pone.0181394

Risk tolerance

The classification and prioritization of risk entails evaluating the risk acceptability/tolerance based upon the extent of hazard, exposure, vulnerability and capacity to address risk. Risk tolerance is primarily assessed in consultation with all relevant stakeholders, and then presented to decision-makers for a final decision.

Risks can be broadly classified into three levels of tolerance:

- Broadly acceptable: It is impossible to eliminate all risks, and therefore a calculated decision on which risks are broadly acceptable is needed. These are the general risks whose impact on lives, livelihoods and the economy can be adequately addressed by existing instititutional, financial and social capacity. The aim of risk management is to drive as many risks into this category as practicable through risk reduction measures.

- Tolerable: Risks and impacts can be managed by existing risk management systems or by increasing the institutional and financial capacity. Active steps and financial management to reduce these risks are likely to already be taking place because a positive cost-benefit analysis ratio for investment is expected, or because public expectation demands it. These risks should be reduced to "as low as reasonably practicable".

- Generally intolerable: Risks to and impacts on lives and livelihoods are very high and require extensive risk reduction actions to lower risk (highest priority).

4.9 Expected outputs

The output for this phase is an overview of the risk areas, either as risk maps or risk matrices, or both for each hazard, as well as prospective risk reduction opportunity areas and remedial activities. Table 4.5 provides an overview of possible outputs from the risk analysis process. For each relevant hazard, the exposure analysis leads to a risk hotspot prioritization. For the risk hotspots, a vulnerability assessment is carried out, leading to a risk analysis. Finally, examples are provided of risk reduction opportunity areas that should be focused on by the programme activities, since interventions here are most likely to provide the greatest number of benefits to the greatest number of people and infrastructure located elsewhere.

Table 4.5: Some examples of outputs from the risk analysis

Hazard	Exposure	Risk hotspot prioritization	Vulnerability	Risk analysis
Earthquake – frequency and magnitude	Distance to expected epicentre of buildings and other assets	Urban area; rural and mountain communities	Many inhabitants and old buildings	High priority
		Industrial area	High economic value and earthquake-resistant infrastructure	Secondary priority
Tsunami – frequency and magnitude	Height and energy of the tsunami with respect to urban, industrial and agricultural areas	Urban area; coastal communities	Stormbreakers and protective walls	Secondary priority
		Agricultural area	High economic value and high investment (greenhouses and irrigation)	High priority

Hazard	Exposure	Risk hotspot prioritization	Vulnerability	Risk analysis
Volcanic eruption – frequency and magnitude	Assets in pathways of lava streams, prone to falling debris and ash cover	Urban area; rural and mountain communities	Small communities	High priority
Tropical cyclone – frequency and magnitude	Assets in pathway of cyclone – windspeed and precipitation intensity	Urban area; coastal communities	Few brick and concrete houses	High priority
Flood – frequency and magnitude	Height and energy of flood water with respect to urban, industrial and agricultural areas	Urban area; rural and mountain communities	Houses on poles	Secondary priority
Landslide – frequency and magnitude	Assets affected by landslides	Urban area; rural and mountain communities	Communities likely to be destroyed	High priority
Drought – frequency and magnitude	Duration of lack of water	Urban area, rural and mountain communities	No piped drinking water	Secondary priority
		Agricultural area	No irrigation possibilities	High priority

Source: Author's elaboration

4.10 Further reading

- For an overview of how to perform a qualitative risk assessment, see; FAO. 2009. *Qualitative risk characterization in risk assessment*. www.fao.org/3/i1134e/i1134e03.pdf

- United Nations Environment Programme. 2013. *PROVIA Guidance on assessing vulnerability, impacts and adaptation to climate change*. Consultation document, 198 pp. www.adaptation-undp.org/sites/default/files/downloads/provia-guidance-nov2013.pdf

- For an overview of vulnerability assessment methodologies, see: Barsley, W., De Young, C. & Brugère. C, 2013. *Vulnerability assessment methodologies: An annotated bibliography for climate change and the fisheries and aquaculture sector*. www.fao.org/3/a-i3315e.pdf

- For a useful manual for trainers in participatory learning and community empowerment methods, see: Pretty, J.N., Guijt, I., Scoones, I. & Thompson, J., eds. 2002. *A trainer's guide for participatory learning and action*. International Institute for Environment and Development, London. http://pubs.iied.org/pdfs/6021IIED.pdf

- For more information on vulnerability assessments and indicators, see: Fritzsche, K., Schneiderbauer, S., Bubeck, P., Kienberger, S., Buth, M., Zebisch, M. & Kahlenborn, W. 2017. *The vulnerability sourcebook: Concept and guidelines for standardised vulnerability* *assessments*. www.adaptationcommunity.net/download/va/vulnerability-guides-manuals-reports/vuln_source_2017_EN.pdf

- For more information on the identification and application of robust hazard data for use in integrating risk considerations into projects, see: Asian Development Bank. 2017. *Natural hazard data. A practical guide*. www.adb.org/sites/default/files/institutional-document/387631/natural-hazard-data-practical-guide-main.pdf

- For an overview of environmental and social vulnerability assessment methods, see: FAO. 2018. *A review of existing approaches and methods to assess climate change vulnerability of forests and forest-dependent people*. Forestry Working Paper No. 5, 80 pp. www.fao.org/3/CA2635EN/ca2635en.pdf

- For a practical tool that employs the Local Adaptive Capacity Framework, see: Oxfam UK's Vulnerability and Risk Assessment toolkit. http://vra.oxfam.org.uk

- For more information on different aspects of index-based vulnerability assessments, see: Fritzsche, K., Schneiderbauer, S., Bubeck, P., Kienberger, S., Buth, M., Zebisch, M. & Kahlenborn, W. 2014. *The vulnerability sourcebook: Concept and guidelines for standardised vulnerability assessments*; Joint Research Centre–European Commission & Organisation for Economic Co–operation and Development. 2008. *Handbook on Constructing Composite Indicator: Methodology and user guide*.

- For more information on participatory risk assessment in relation to climate change, see: Toth, F. L. & Hizsnyik, E. 2008. Managing the inconceivable: participatory assessments of impacts and responses to extreme climate change. *Climatic Change*; Van Aalst, M.K., Cannon, T. & Burton, I. 2008. Community-level adaptation to climate change: the potential role of participatory community risk assessment. *Global Environmental Change;* GIZ. 2011. *Integrating climate change adaptation into development planning;* Chaudhury, M. *et al*., 2013. Participatory scenarios as a tool to link science and policy on food security under climate change in East Africa. *Regional Environmental Change*.

Rice field in India
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Mountain lake in Uttarakhand, India
©Amit Sah

5

Measures and strategies for resilient watershed management

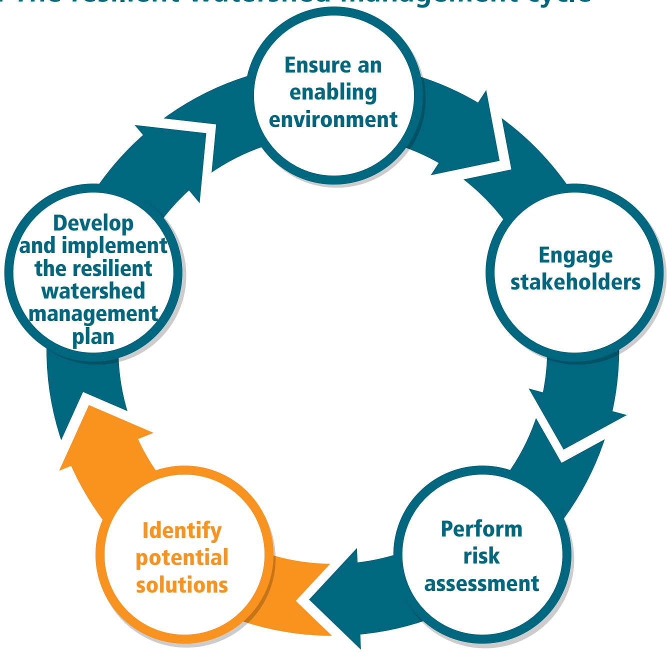
Mekong River in Viet Nam
©Anne Lin

5. Measures and strategies for resilient watershed management

5.1 Introduction

After the evaluation of risk has been carried out, risk reduction measures and strategies to strengthen climate and disaster risk management can be identified. They are essential components of the resilient watershed management approach (see Figure 5.1).

Figure 5.1: The resilient watershed management cycle



Source: Author's elaboration

Risk management measures specifically address the four aspects of risk: hazard, exposure, vulnerability and capacity. The measures can be categorized in the various stages of disaster risk management: prevention and mitigation; preparedness; and response, recovery and reconstruction.

The institution that coordinates watershed management is responsible for coordinating the identification and ensuring the implementation of the risk management measures required. This differs according to the scale of the interventions, scope of the risk reduction measures, budget available and extent of hazard. The responsible institution is often the ministry in charge of land management, water management, agriculture, forestry and/or spatial planning. Different technical institutions may be involved in assessing the suitability of the measures or in performing cost-benefit analyses. A participatory process will enable local stakeholders to take the lead in implementing pilot projects, provide feedback on initial measures, and design new measures and intervention improvements.

5.2 Identification of risk management measures for resilient watershed management

Risk prevention and mitigation

Prevention refers to activities and measures required to avoid existing and new disaster and climate risks while mitigation involves minimizing the adverse impacts of a hazardous event (UNISDR, 2017b). For example, building a dam or levee is a prevention measure to control flooding while arranging an overflow area in case of a flood is a mitigation measure to reduce negative impacts.

Prevention and mitigation policies, programmes and activities are direct responses to the exposure and vulnerabilities identified in the risk assessment (see Chapter 4). For example, if the exposure assessment revealed sites where communities are exposed to landslides and rockfalls, prevention measures should be considered, such as constructing retaining walls (known as gabions) and improving slope drainage. Examples of these practices, approaches and technologies can be seen in Table 5.1.

If the vulnerability assessment has identified high susceptibility to drought of local agricultural livelihoods, the resilient watershed management plan should consider mitigation measures that would reduce the impact, such as water-efficient agriculture, promotion of drought-resistant and saline-tolerant crops, and ecosystem restoration to improve the water catchment (Coburn, Spence and Pomonis, 1994). For longer-term climate change impacts, adaptation to the changing situation will need to be considered. Climate adaptation measures may include change of livelihood activities, behavioural change or change of crop types to adapt to the reduced availability of nutrients or water availability.

Table 5.1: Examples of technologies, practices and approaches promoted by FAO for building resilient livelihoods

Agriculture	Livestock	Fisheries
• Appropriate crop selection (drought-/saline-/flood-tolerant) • Intercropping • Crop breeding • Conservation agriculture and climate-smart agriculture • Adjustment of cropping calendars • Seed banks and exchanges • Terracing and soil conservation barriers • Post-harvest management (storage, food drying and food processing) • Livelihood diversification • Crop insurance • Integrated pest management • Urban gardening • Drainage control • Savings and credit system	• Proofing of storage facilities • Livestock shelters • Strategic animal fodder reserves • Fodder conservation • Resilient animal breeding • Vaccination to reduce or prevent the spread of animal diseases • Grazing and pasture resource management • Strengthening pest management systems to cope with threats • Biosecurity in animal production systems • Agro-silvopastoral systems • Savings and credit systems	• Implementation of the Code of Conduct for Responsible Fisheries • Fisheries, aquaculture, vessel and infrastructure insurance • Safety in the design, construction and equipment for fishing vessels • Aquaculture biosecurity measures to reduce or prevent the spread of fish diseases • Protection of water sources • Protection from bank erosion of ponds • Savings and credit systems
Water	**Land**	**Forests**
• Rainwater harvesting, conservation and storage to improve capture and use of rainfall • Water reserves to buffer droughts • Efficient irrigation, such as drip and furrow irrigation, which uses less water and reduces water loss • Management of fragile catchment areas (e.g. protected areas and restoration) • Capture of floods or recharge of groundwater for use in dry season • Environmental flows • Drainage control • Riverbank protection from erosion • Raising the plinth of water pumps	• Restoration of degraded lands • Land-use and territorial planning, including protected areas and infrastructure, such as roads, schools and hospitals • Sustainable wetland management • Soil conservation via erosion control • Field or network drainage to minimize flood impact • Appropriate energy sources and technologies to reduce pressure on land • Secure tenure rights of Indigenous Peoples and local communities	• Integrated fire management (e.g. prescribed fires and fire breaks) • Forest pest management • Agroforestry and sustainable management of non-timber forest products • Afforestation/reforestation • Community-based forestry • Improved cooking stoves and alternatives to wood energy in order to reduce deforestation and forest degradation

Source: FAO. 2013b. *Resilient livelihoods*. Disaster Risk Reduction for Food and Nutrition Security Framework Programme. Rome. www.fao.org/3/a-i3270e.pdf

Measures should address the specific issues, such as flooding or diminished freshwater supplies, as identified in the risk assessment. Furthermore, measures can be individual interventions or packages of related measures. Climate and disaster risk management is often associated with structural measures, such as dams, reservoirs and gabions. These measures generally require major investments, have a long life span and high maintenance costs, and may have social and environmental impacts.

However, care should be taken that both structural and non-structural options are included when selecting measures.

Hard and soft structural measures are often referred to as engineered physical construction measures, or enhancing nature-based solutions such as enhancing wetlands, expanding and revegetating riparian buffer zones, soil structural improvement, tree planting. They aim at avoiding possible impacts of hazards and achieving hazard resistance by building resilience into the watershed. Common engineered structural measures for disaster risk reduction include dams, flood levees, ocean wave barriers, earthquake-resistant constructions and evacuation shelters. Usually, a combination of both hard and soft measures is most effective and is referred to as a low impact design (LID) system. This is less environmentally intrusive, less costly and more effective than solutions relying only on hard-engineered structural measures that involve the use of concrete, metals and rocks (UNDRR, 2019a).

Non-structural measures do not involve physical construction and apply knowledge and practices or establish agreements to reduce disaster risks and impacts through policies and laws, the raising of public awareness, training and education. Common non-structural measures include building codes, land-use planning laws and their enforcement, insurance and risk transfer, research and assessment, information resources and public awareness programmes (UNDRR, 2019a).

Examples of non-structural measures are:

- adjusting agricultural tilling or terracing practices to reduce erosion;
- implementing income-generating activities;
- savings and credit schemes to increase the resilience of communities so they can bounce back quickly after a disaster event;
- nature-based solutions such as reforestation or restoration of degraded landscapes on slopes or riverbanks; and/or
- risk-transfer mechanisms, which may serve to compensate watershed stakeholders for losses caused by flooding or landslides.

While climate insurance may be seen as a form of risk acceptance, it can also play an important role in reducing disaster risk by encouraging disaster risk reduction behaviour (Le Quesne *et al.*, 2017). Insurance can support risk management if it is accompanied by requirements or incentives for people to take preventive measures, thereby constituting an important element of cost-effective adaptation to climate change risks. In the absence of insurance, these risks would be too large for private individuals and businesses to bear on their own (UN, 2018). *Risk reduction opportunity area*s should receive high priority as implementation sites.

Climate and disaster risk preparedness

Preparedness refers to the knowledge and capacities developed by governments, response and recovery organizations, communities and individuals to effectively anticipate, respond to and recover from the impacts of likely, imminent or current disasters (UNDRR, 2019b). In general, preparedness measures encompass the development of a contingency plan, which, for example, describes actions to be taken in the event of a disaster. Often included in the contingency plan are early warning systems, which monitor a potential disaster (e.g. a high-altitude lake) and sound an alarm if a certain threshold is reached (e.g. if a rapid increase in the lake's water level occurs).

Contingency planning is a management process that: analyses climate and disaster risks; and establishes arrangements in advance to enable timely, effective and appropriate responses (UNDRR, 2019b). It can be carried out at national, subnational or community levels for the needs of the affected population(s).

A watershed contingency plan considers information gathered from monitoring systems, such as water levels, precipitation and water quality, which is then communicated to the authorities responsible for establishing warning and response systems. The contingency plan establishes the procedural steps to follow, assigning clear roles and responsibilities for each task, communication mechanisms between different stakeholders, and the budgets required for implementation. For example, contingency planning to protect drinking water supplies should at least include an assessment of the ability of the water system to function in the absence of the largest source of supply, as well as a plan for alternative water supplies, and for responding to spills and contamination (Harter and Rollins, 2008).

The watershed contingency plan should specify the actions to be implemented, the implementation arrangements and lines of communication, and how these actions feed into the broader contingency plan. Moreover, contingency plans should be revised and updated prior to the season when the hazards addressed in the plan may occur (e.g. with with a plan focused on the mitigation of damage before the hurricane season).

Early warning systems

An early warning system includes technology and associated policies and procedures designed to predict and alert communities about the possible occurrence of natural and human-initiated disasters and other undesirable events. It is an integrated system of hazard monitoring, forecasting and prediction, disaster risk assessment, communication and preparedness activities, systems and processes, which enables individuals, communities, governments, businesses and others to take timely early action between the transmission of the warning and the impact of the hazard in order to reduce its impacts (UNDRR, 2019b). To be effective, early warning systems should actively involve the communities at risk, facilitate public education and awareness of disaster risks, disseminate messages and warnings, and ensure a constant state of preparedness.

An early warning system for resilient watershed management will build on the main hazards identified in the risk assessment to:

- define how the hazards will be monitored locally, such as through participatory monitoring of precipitation and soil moisture, thereby making use of already existing monitoring and early warning systems;
- define context-specific triggers to issue a warning, and describe how this will be communicated to the corresponding authorities;
- define context-specific early action measures;
- inform the population of the early action protocol, and raise awareness about the risks and how to react; and
- define responsibilities and communication mechanisms for each of these tasks.

Training and familiarizing local communities with the early warning system should be of the highest priority.

Disaster response and recovery

Resilient watershed management considers the occurrence and impacts of hazards in the landscape. As the impacts of climate change increase, there may be more frequent needs for disaster response. Disaster response refers to the actions taken directly before, during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety, and meet the basic subsistence needs of the people affected (UNDRR, 2019b). As such, resilient watershed management should also focus on reducing risks and avoiding the creation of new risks. Disaster recovery refers to the restoring or improving of livelihoods and health, as well as the economic, physical, social, cultural and environmental assets, systems and activities of a disaster-affected community or society. It therefore aligns with the principles of sustainable development and to "build back better" to avoid or reduce future disaster risks (UNISDR, 2017b).

Recovery measures in resilient watershed management can help to reduce future vulnerabilities by addressing the root causes of vulnerabilities. Where feasible, instead of introducing new measures, effort should be made to integrate the measures into existing practices such as ongoing agricultural and livelihood activities. As set out in the Sendai Framework for Disaster Risk Reduction Priority 4, "Disasters have demonstrated that the recovery, rehabilitation and reconstruction phase, which needs to be prepared ahead of a disaster, is a critical opportunity to 'build back better' " (see Box 5.1.).

When existing systems are highly exposed due to loss and damage incurred, this may be an opportunity to switch to less exposed systems. Rebuilding of houses or industries destroyed by floods, for instance, may be carried out in places that are less flood-prone or with new building codes. The destruction of crops by severe or prolonged droughts may also be an opportunity to shift to less drought-sensitive crops or to alternative economic activities and further diversification of income-generating activities (see Figure 5.2). During

BOX 5.1
"Build back better"

"Build back better" refers to the use of the recovery, rehabilitation and reconstruction phases after a disaster to increase the resilience of nations and communities by integrating disaster risk reduction measures into the restoration of physical infrastructure and societal systems, and into the revitalization of livelihoods, economies and the environment (UNDRR, 2019a).

"Build back better" is a priority of the Sendai Framework. It focuses on building capacity through the creation and strengthening of recovery-focused relationships, the establishment of planning and coordination mechanisms, and the introduction of methods and procedures to ensure that recovery activities are adequately informed and supported. Stakeholders, which include national and local governments, the private sector and civil society organizations, can undertake a number of tasks to implement this priority.

To facilitate building back better in watersheds, resilient watershed management should (UNISDR, 2017b):

1. develop an inclusive watershed recovery plan for rebuilding agricultural assets and activities, income generation, restoring water sources and reconstructing homes, among other measures;
2. formalize processes and systems to enable effective assessment of post-disaster damage and needs to more accurately quantify and characterize the recovery requirements, and to formulate broad recovery strategies; and
3. establish institutional arrangements so that the watershed recovery plan is recognized and integrated into policies, laws and programmes at the national level, which promote (incentivize), guide (ensure) and support building back better in recovery, rehabilitation and reconstruction, in both the public and private sectors, and by individuals and households.

Since recovery measures can guide other actions for years or decades, and potentially increase future vulnerabilities, recovery should be carefully planned, and decisions not made on an ad hoc or short-term basis (UN, 2018).

Notes:

1. United Nations Office for Disaster Risk Reduction (UNDRR). 2019a. *Terminology on disaster risk reduction*. Cited 25 October 2022. www.unisdr.org/we/inform/terminology

2. United Nations Office for Disaster Risk Reduction (UNISDR). 2017b. *Build back better in recovery, rehabilitation and reconstruction*. Consultative version. www.unisdr.org/we/inform/publications/53213

3. United Nations (UN). 2018. Words into Action Guidelines. *Implementation guide for addressing water-related disasters and transboundary cooperation: Integrating disaster risk management with water management and climate change adaptation*. New York and Geneva. www.unece.org/fileadmin/DAM/env/water/publications/WAT_56/ECE_MP.WAT_56.pdf

and after recovery, an evaluation should be made of the prevention, resilience improvement, preparation, response and recovery measures related to the extreme event (UNECE, 2009), and the resilient watershed management plan should be updated.

Figure 5.2: Examples of alternative income generating activities in a resilient watershed management project carried out in Morocco

(Left) Dairy production by local villagers. (Right) Honey production by local villagers (2019)

Tables 5.2 presents some specific measures for building resilience into watersheds and preventing or reducing the impacts of main hazards (floods, drought, wildfires, diseases, windstorms, and earthquakes, volcanic eruptions and landslides).

Table 5.2: Resilience measures to prevent and/or reduce the impacts of main hazards

5.2a

Floods	Protective measures	Recovery and rehabilitation
Watershed level		
Enhance riparian buffer zones (buffers zones will absorb and detain sediments, nutrients and contaminants)	Minimize channelization to provide space for river channel migration and for the creation of side channels, groundwater recharge; enhance wetlands in buffer zones; protect riparian vegetation (trees, shrubs, grasses); protect bank from erosion, restrict land use activities near banks; and encourage expansion of buffer width;	Revegetate buffer zone Restore wetlands Assure continuity of buffer zone within entire watershed
Select sites for temporary storage of flood water	Select topographic depressional areas in the watershed that have little infrastructure (e.g. agricultural fields, grasslands, parks) that can store peak runoff and can release water after peak discharge; develop compensation plans	Recover debris and sediment in temporary storage site Compensate owners Restore previous cover and land use Plan for more sites if capacity is exceeded
Structural measures	Improve and monitor dams, dykes, reservoirs and detention structures and use nature-based solutions where appropriate	Rebuild damaged structures, modifying design to increase resilience
Flood monitoring and response	Develop flood-monitoring systems and early warning systems; develop contingency plans	Improve predictive capacity, effectiveness of plans and early warning systems
Flood hazard mapping and land use regulations	Create floodplain hazard maps; avoid infrastructure development; regulate land use activities in flood zone; provide insurance coverage for damages	Revaluate and/or modify flood hazard maps Strengthen land use regulations in flood zone
Agriculture		
Conservation agriculture on sloping land	Protect land against erosion through conservation tillage, terracing, agro-forestry, hedgerow development and contour ploughing; improve soil carbon to enhance infiltration rates and soil-moisture holding capacity (e.g. carbon sequestration using grass, green manure, cover crops); control livestock density on grassland; minimize soil compaction; build sediment detention ponds	Rebuild terraces Provide financial incentives for conservation farming and soil carbon sequestration Improve soil erosion and sediment detention control systems
Intensive lowland agriculture	Maintain wetlands adjacent to fields; reduce excessive drainage; avoid large fields with single crop/plant diverse crops, including tree crops; select crops that can withstand temporary flood periods; minimize soil compaction from use of field equipment during wet periods; minimize period of bare soil exposure	Restore soil quality Change cropping pattern
Structural measures	Relocate and/or flood-proof livestock shelters, manure and crop storage facilities and farm buildings in flood zones, based on flood hazard maps.	Revaluate the safety of agricultural infrastructure Consider insurance issues

Floods	Protective measures	Recovery and rehabilitation
Livestock	Avoid livestock near river banks; develop evacuation plans for all animals, particularly dairy cows that need alternative milking facilities	Have plans in place for the disposal of flood-affected animals
Forestry		
Afforestation	Plant water-demanding species in flood-prone areas and in wet seepage terrain to help intercept rainfall, drain the soil and accelerate evapotranspiration; ensure good root development for stability; select diverse species as the best coping strategy; plant trees in risk-prone terrain; minimize monoculture	Assess which tree species were effective in withstanding floods and recovered well after floods
Established forests	Maintain forest cover to enhance rainfall interception, evapotranspiration and throughfall delay; create small openings to intercept and detain more snow in higher elevations; use a combination of broadleaf and conifer trees to assure good seasonal canopy cover; maintain surface roughness on the forest floor	Recover flood damages trees Replant with appropriate species
Urbanization (cities and communities)		
Low impact design (LID)	Create constructed wetlands in urban riparian zones; construct swales and infiltration systems on the side of roads and parking lots; enhance urban tree cover to reduce runoff; create rain gardens and reduce impervious surfaces; use pervious pavement systems; provide financial incentives to minimizing surface runoff on properties; replace combined sewers; monitor flows to demonstrate effectiveness of LID systems	Restore impacted wetlands and clean infiltration systems and sediment detention ponds
Structural measures	Build waterproof buildings and/or relocate infrastructure in flood prone areas and build protective structures where nature-based solutions are insufficient	Consider relocating buildings and improve affected infrastructure Provide financial incentives
Plan for evacuations	Develop rescue and evacuation plans and locations for temporary accommodation of impacted people	Evaluate emergency response
Recreation		
Resort development	Avoid recreation site development in floodplains, near avalanche tracks and flood prone areas	Reassess risk maps and relocate or develop flood-proof infrastructure
Outdoor activities and infrastructure	Avoid the creation of trails and campgrounds in hazardous zones in floodplains; have flood warning systems in place	Restore facilities

5.2b

Droughts	Protective measures	Recovery and rehabilitation
Watershed level		
Soil resources	Maintain soil health to increase water-holding capacity (including through drought tolerant grass cover); create surface roughness (e.g. micro-topography to enhance soil moisture retention); maintain native species that are drought-tolerant; prevent soil crusting and salinity	Aerate soils to restore infiltration after crust formation and salinity
Groundwater	Map groundwater and monitor levels; adopt groundwater protection measures, including licensing and metering of wells, land use regulation, and the establishment of management contracts; monitor water quality and regulate land use above sensitive aquifers to minimize contamination	Facilitate groundwater recharge during rain events/ periods through practices that reduce flow speed and foster infiltration (see flood control options), to allow for use of groundwater during drought (i.e. groundwater banking) Monitor water levels to determine sustainable use
Plans and monitoring	Develop drought monitoring and early warning systems and monitor soil moisture changes and temperature; develop plans for action during heatwaves; develop plans for compensation and insurance	Revaluate monitoring systems and predictive capacity and update as needed
Agriculture		
Alternative cropping patterns, irrigation and water management	Use drought-resistant crop varieties; select water-efficient crops (i.e. C4 crops); develop contingency plans for irrigation under water scarcity; avoid flood irrigation and promote the use of efficient irrigation systems; promote conjunctive use of surface water and groundwater in irrigation to ensure recharge during wet periods	Reassess drought resistance of different crop varieties
Livestock	Plan for distributed water supply points for animals to reduce pressure on available forage; plan for emergency feed distribution; destock herds to reduce livestock numbers when feed supplies are scarce; compensate farmers for losses	Provide feed storage and identify alternative water in anticipation of future droughts
Forestry		
Afforestation	Plant diverse and drought-resistant species; avoid monoculture; adapt planting density to drought hazard risk; focus on a mix of shallow and deep rooting species; consider competition for water with other users in afforestation plans	Revaluate tree selection and performance of different tree species
Established forest	Harvest the drought-affected trees and replace them with drought-resistant species; maintain ground cover to preserve soil moisture; maintain tall riparian trees to provide shade for small streams	
Urbanization (cities and communities)		
Low impact design (LID)	Promote rooftop water harvesting and storing for outdoor use and toilet flushing; develop contingency plans for drought periods	Evaluate LID uptake and modify incentives and regulations
Water conservation	Adopt water pricing and metering of water use; reduce leakages and losses in distribution systems; provide financial incentives for water-efficient appliances; promote labelling of water-efficient appliances; promote drought-resistant landscaping in cities; promote re-use of drainage water and treated wastewater for recreation areas; restrict outdoor water use	Improve water accounting (e.g. smart metres) Accelerate pipe replacement programmes

Heat waves	Identify cooling places (e.g. air conditioning and water stations) for vulnerable community members; maintain water-efficient trees to provide shade; assure alternative power sources for hospitals and water treatment facilities; make provisions for restricting outdoor work and activities during heat waves	Reassess building cone and power supply in cases of reoccurring heat waves

5.2c

Wildfires	Protective measures	Recovery and rehabilitation
Watershed level		
Planning, mapping and monitoring	Develop fire risk map; link with wind and weather forecasting for early warning; develop firefighting preparedness plans; establish fuel load inventories to enhance fire risk maps; establish evacuation plans	Carry out a retrospective analysis of effectiveness of efforts
Agriculture		
Grassland and livestock	Establish firebreaks for grass fire prevention; develop evacuation plans for livestock (i.e. shelters and alternative water supplies – a specific problem for dairy cows that need alternative milking options)	Assess impact of fire on soil surface depending on heat of fire and clay content of soil Restore soil structure Improve erosion control measures in case of rainstorms after fire
Crops	Establish firebreaks; reduce monocropping; ban burning of crop residues	Aerate and improve soil surface
Forestry		
Fuel load	Assess and reduce fuel load; remove dead trees, branches and litter cover; build firebreaks; initiate controlled burns; identify the most flammable vegetation; practise forest control near power lines	Conduct post-fire management of soil surfaces to prevent erosion and mudflows if rainfall occurs after fire
Urbanization (cities and communities)		
Building location and design	Ensure fireproofing of buildings; avoid urban expansion into forested areas; build firebreaks; reduce fuel loads around buildings; have sprinkler systems in place	Reassess the effectiveness of fire-proofing materials and protective measures
Smoke	Install air pollution monitoring networks; supply masks; install filter systems in care units; provide health advisories for outdoor activities; assure appropriate filter systems for drinking water treatment systems	Assess health exposure after fire from air pollution Modify advisory systems and protective measures used during smoke event
Firefighting response	Plan for fire-fighting response (e.g. location of equipment, water sources, rescue); establish evacuation plans; plan for temporary accommodations	Assess the effectiveness of fire-fighting response and evacuation efforts Modify the rebuilding process

5.2d

Windstorms	Protective measures	Recovery and rehabilitation
Watershed level		
Planning and monitoring systems	Identify prominent wind direction and climatic conditions that promote windstorms	Reassess wind exposed sites and intensities Improve protective measures

Power lines	Reduce tree damage risks along power line corridors (e.g. build wider corridors); establish contingency plans for power interruptions	Initiate new safety measures for power disruption and test effectiveness of alternative energy sources
Agriculture		
Cropping systems	Provide tree wind shelterbelts and agroforestry, reduce large fields under monoculture; develop insurance and compensation options	Retrospective analysis of what worked best and determine trade-offs
Forestry		
Afforestation	Use deep rooting species depending on soil conditions; maintain appropriate canopy cover	Clear damaged trees and replace with wind-resistant trees
Established forest	Minimize sharp forest edge formation (e.g. initiate contoured vegetation cover along forest edge)	
Urbanization (cities and communities)		
Power lines	Put power lines underground in communities exposed to windstorms	Examine differences in cost and benefits of under- and above-ground systems
Buildings	Check windproofing of roofs and establish structural codes in areas with frequent windstorms; develop insurance coverage options	Determine effectiveness of windproofing after different storm events

5.2e

Earthquakes	Protective measures	Recovery and rehabilitation
Watershed level		
Mapping, monitoring and planning	Develop earthquake risk maps; establish a seismic monitoring site; establish early warning systems and evacuation plans	Assess probability and risks of reoccurrence and avoid reconstruction efforts in critical areas
Agriculture and forestry	Establish management plans, including insurance schemes, to minimize destructive impacts and to compensate for losses	Rebuild access and infrastructure to higher standards Rehabilitate fields and forests
Urban	Implement earthquake proofing of buildings; avoid expansion in earthquake risk areas	Rebuild to higher standards and alternative sites where possible

5.2f

Volcanic eruptions	Protective measures	Recovery and rehabilitations
Watershed level		
Mapping, monitoring and planning	Examine volcanic history and identify type of eruption; practice active monitoring; develop early warning systems and evacuation plans	Improve monitoring Reassess the evacuation process
Land use	Restrict land use activities using the risk assessment method; limit urban development	Allow for natural recovery over many years Selectly rebuild of access infrastructure
Ash and air pollution	Provide filtration systems for water treatment plants; provide masks; develop air traffic alerts	Develop ash removal programmes Stabilize ash-covered slopes using erosion control measures

Landslides	Protective measures	Recovery and rehabilitations
Watershed level		
Mapping, monitoring and planning	Establish landslide hazard maps; make an inventory of unstable structures and material in sloping terrain; establish real-time monitoring for potential landslides in risk-prone areas; establish evacuation plans	
Management practices	Avoid construction of roads and structures on highly unstable slopes; use appropriate vegetation covers and erosion control practices to stabilize slopes.	Minimize amount of forest edge and reduce the amount of even aged trees with shallow rooting depth.

5.2g

Source: Author's elaboration

Table 5.3 presents resilience measures related to the impacts of pests and diseases. Although the watershed is not the planning and management unit level that is most relevant for addressing pests and diseases, the consideration of possible measures to mitigate their impacts is included here because of the importance of their interactions with other hazards and possible cumulative effects.

Table 5.3: Resilience measures to prevent or reduce impacts of plant pests and animal diseases

Disease	Protective measures	Recovery and rehabilitation
Agriculture		
Pest control for crops	Use integrated pest management practices; promote crop diversity; use disease-resistant varieties where possible; establish insect and pest insurance	Prepare for new types of infestation (e.g. modification of pesticide use and crop selection)
Disease control for livestock	Launch vaccination campaigns; promote a rational use of antibiotics to avoid antimicrobial resistance; develop health monitoring systems; for the removal and appropriate disposal of infected and sick animals; develop international collaboration for disease monitoring and communication	Assess effectiveness of monitoring system(s) and use of appropriate pest control
Forestry		
Forest insect and disease control measures	Minimize monoculture (e.g. pine beetle and spruce budworm infestation); rapidly remove infected trees; use aerial spray or pesticide in a limited manner; select insect-resistant tree species; promote biodiversity during afforestation efforts	Assess effectiveness of early response Remove infested trees and replant with greater diversity of species
Urbanization (cities and communities)		
Monitoring, planning, communication	Establish international collaboration for monitoring, responding and treating of flus, viruses and other infectious diseases (e.g. masks, vaccine supplies, distribution and administration of care).	Ensure early identification of protective measures and good communication of treatment options.

Source: Author's elaboration

Natural hazards such as earthquakes and slope instability can result in land degradation that does not necessarily involve climatic events. However, climatic events during and after these processes enhance their impacts, particularly in combination with poor land management. The main challenges for building resilient watershed assessment are the cumulative effects and interactions between climate-based hazards. For example, a heatwave during droughts can desiccate trees that are under moisture stress and infected by disease. Such conditions will increase fire risks and, when coinciding with wind events, will exacerbate the extent and severity of wildfires.

BOX 5.2 Challenges and complexities for building resilience into watersheds

Interactions between climatic events: (i) drought and heat wave, followed by wildfire and windstorms exacerbate impacts; (ii) forest fire risks are enhanced when trees are diseased and/or drought-stressed. If rain events occur right after fires, the risks of soil erosion, landslides, sediment transport and flooding is greatly increased; (iii) earthquakes followed by storm events lead to slope instability, soil erosion, landslides, flooding and sediment transport.

Alternation of wet and dry seasonal patterns: If storm intensity increases during the wet season, and temperatures and drought conditions increase during the dry season, some of the protective measures might not be sufficient and could constrain measures during the dry season. For example, fuelwood removal during the dry season and removal of infested trees will create more surface exposure that accelerates surface runoff during/following storm events during the wet season.

Cumulative effects: Non-point sources of pollution and widespread landslides after extreme storm events can produce cumulative effects that are difficult to predict.

Highland-lowland interactions: Cascading events such as flooding events in headwaters leading to excessive discharge and sediment transport can destroy dams and reservoirs, magnifying flood events and sediment deposition in lowlands.

Increasing magnitude of extreme events: If the intensity and magnitude of some climate events reach the threshold level, it is unlikely that any of the protective measures will be sufficient. .

Source: Author's elaboration

5.3 Prioritization of measures

Defining and prioritizing climate and disaster risk management measures is based on the risk assessment, as described in Chapter 4.

The proposed options, measures and risk reduction priorities should be assessed in relation to: (i) their anticipated level of effectiveness; (ii) whether there are potential synergies with other ongoing risk management activities; and (iii) integration into ongoing land use and livelihood activities. The strategies to reduce risks should consider the following principles (UN, 2018):

- Avoid creating new risks.
- Address pre-existing risks.
- Share and spread information on risks.
- Assess residual risks.

There are various approaches for prioritizing climate and disaster risk management measures. A general evaluation focuses on a range of elements that, for example, can include effectiveness and feasibility. Often, the appraisal of the measure also includes an economic assessment. The following section describes various approaches that can be applied to the prioritization of risk management measures, depending on the situation and needs of the decision-makers.

Identified measures can be assessed on the basis of economic evaluations, including cost-benefit analysis and multi-criteria analysis. In conjunction, general criteria to select relevant risk management options can be applied that include the following (WWF, 2015):

1. Will this option be effective? How effective would this measure be in achieving the overall aim of reducing vulnerability to disaster and climate risks?

2. Is the option technically feasible? Does the technology and/or expertise exist to carry out this measure?

3. Is the option financially/logistically feasible? Are there sufficient resources available to carry out this measure? How much would it cost to implement this measure, and who would pay?

4. Are there any risks/negative effects associated with this option? Could there be any detrimental impacts on the ecosystem, local communities or agricultural production systems? Could the results of implementing this measure be unacceptable?

Additional criteria may also be used that are not directly linked to the measures per se, but which are related to the conditions that are in favour of that option. Questions regarding these criteria include the following (GIZ 2011):

1. Are there strong co-benefits? For example, reforestation that prevents landslides also contributes to carbon sequestration and groundwater recharge.

2. Is there a high urgency? Is urgent action needed? What are the consequences if no action is taken?

3. Is there a window of opportunity? If a plan is submitted for revision, is there a need to reconstruct infrastructure? Is it aligned with funding requirements?

4. Is the option a “no-regret” option? Is the measure also beneficial in the event that the projected climatic changes do not occur?

5. When should the option be implemented? The timing of implementation is relevant to determine the urgency of the measure, with a suggested classification into short-term (less than 5 years), medium-term (5 to 15 years) and long-term (more than 15 years).

Based on the various analyses and criteria developed, options for disaster risk reduction measures are then identified. The "best" or "preferred" option may involve a combination of elements. Measures will also need to be developed on a case-by-case basis to reduce the highest risk to the landscape and local communities. Continuous monitoring will be needed to better understand ongoing changes, such as economic growth, urbanization and demography, as well as to develop appropriate measures for addressing the new and existing risks as they become better understood. This approach requires flexibility, and measures that are highly inflexible or where reversibility is difficult should be avoided (UN, 2018).

Figure 5.3: Community consultation in Makalu-Barun National Park and Buffer Zone, Nepal, 1995

The most common and relevant methods for evaluating risk reduction and management measures within the framework of resilient watershed management are outlined in Table 5.3. Further resources are highlighted for more information.

Table 5.4: Methods for evaluating risk reduction and management measures

Description	Strengths	Weaknesses	Further resources
Economic evaluations			
The economic appraisal of resilient watershed management needs to take into account the fact that benefits result from avoidance of disaster damage and loss. The expected reduction in losses and indirect benefits need to be measured and compared with the cost of proposed disaster risk reduction measures.	There are many methodologies available for economic assessments of disasters, particularly the emphasis on pre-event or post-disaster response. Defines the roles and profiles of stakeholders	Actual direct and indirect benefits will depend on the number and scale of hazard events occurring over the lifetime of the investment. Often, people need formal training to use these methodologies. Scale may be an issue. Sometimes methodologies are limited to certain disasters.	Damage and Loss Assessment (Jovel and Mudahar, 2010) Post-Disaster Needs Assessment (PDNA, 2019). Hazus (Federal Emergency Management Agency, 2019). Multi-criteria Integrated Resource Assessment (EPA, 2015). Initial Rapid Assessment, 2009 (developed by the IASC). Support Analysis Framework (Petrucci, Pasqua and Gullà, 2010). Emergency Management Australia (Australian Institute for Disaster Resilience, 2002).
Cost-benefit analysis of measures			
Cost-benefit analysis is to assess the economic efficiency of disaster risk reduction measures. It is a decision-making tool for comparing scenarios with or without disaster risk reduction in place. The aim is to find the optimum balance between the cost of an intervention and the cost of damages attributed to a disaster, and establish – if unnecessary measures are taken – whether there is over-investment.	A favourable cost-benefit analysis for a disaster risk reduction measure can be a strong argument for investment. Cost-benefit analysis can be used to select the most efficient measures from a portfolio of projects. Cost-benefit analysis is an established tool in decision-making, and in some countries it is a statutory requirement.	Cost-benefit analysis is methodologically complex and should be seen as a decision facilitator rather than the sole criterion for decision-making. It should include social, ecological and cultural concerns.	Cost-benefit analysis of disaster risk reduction. A synthesis for informed decision making (Hugenbusch and Neumann, 2016). Economic approaches for assessing climate change adaptation options under uncertainty: Excel tools for cost-benefit and multi-criteria analysis (Noleppa, 2013). Assessing the costs and benefits of adaptation options. An overview of approaches (UNFCCC, 2011).
Multi-criteria analysis			
Multi-criteria analysis is a collection of methodologies to compare, select or rank multiple alternatives that typically involve incommensurate attributes. Multi-criteria analysis includes decision models, which contain a set of decision options that need to be ranked or scored by the decision-maker; a set of criteria, typically measured in different units; and a set of performance measures, which are the raw scores for each decision option against each criterion (Huang, Keisler and Linkov, 2011)	Well-suited to obtaining and modelling the disaster management preferences of stakeholders Improves coordination among emergency response agencies, and affected citizens Combines technical knowledge on benefits and trade-offs of choices with locally-relevant criteria Suitable when benefits for saving lives and biodiversity cannot be quantified and valued purely in monetary terms	Difficult to assign weights if there is a large number of different criteria Standardizing scores may lead to loss of information Hard to agree on which criteria are relevant – may result in disagreement with stakeholders May need to conduct a sensitivity analysis to determine if ranking is robust	Multi-criteria decision analysis in environmental sciences: Ten years of applications and trends (Huang, Keisler and Linkov, 2011). Economic approaches for assessing climate change adaptation options under uncertainty: Excel tools for cost-benefit and multi-criteria analysis (Noleppa, 2013). Assessing the costs and benefits of adaptation options. An overview of approaches (UNFCCC, 2011)

Description	Strengths	Weaknesses	Further resources
Adaptation pathways			
Adaptation pathways describe a sequence of policy actions or investments in institutions and infrastructure over time to achieve a set of specified objectives under uncertain, changing conditions. An adaptation pathways map provides insight into policy options, the sequencing of actions over time, potential lock-ins, and path dependencies	Enables long-term plans to be developed in which specific decisions can be postponed, maintaining a clear focus on the disaster risks and vulnerabilities	Future scenarios are based on quality of data available. Relatively new approach, so there are only a few examples of its implementation	Dynamic adaptive policy pathways: Supporting decision- making under uncertainty using adaptation tipping points and adaptation pathways in policy analysis (Deltares, 2019)
Valuation of ecosystem services			
Valuation of ecosystem services involves attaching a value to the benefit that people obtain from ecosystems. This valuation has the potential to be an environmentally-effective, economically-efficient and socially-equitable tool in support of resilient watershed management.	Enables the value of ecosystems to be included in cost-benefit analysis, multi-criteria analysis and other evaluation schemes Enables benefit sharing between different areas in the watershed.	Very difficult to set a value on ecosystem services in monetary terms.	Recommendations on payments for ecosystem services in integrated water resources management (UNECE, 2007).

Source: Author's elaboration

Notes:

1. Jovel, R.J. & Mudahar, M. 2010. Damage, loss, and needs assessment guidance notes : Volume 1. Design and execution of a damage, loss, and needs assessment. World Bank, Washington, DC. openknowledge.worldbank.org/handle/10986/19047

2. PDNA. 2019. Post Disaster Needs Assessment – International Recovery Platform. Cited 25 October 2022. www.recoveryplatform.org/pdna

3. Federal Emergency Management Agency. 2019. Hazus | FEMA.gov. Cited 25 October 2022. www.fema.gov/hazus

4. Environmental Protection Agency (EPA). 2015. Multi-criteria Integrated Resource Assessment (MIRA). In: US EPA. Cited 25 October 2022. www.epa.gov/risk/multi-criteria-integrated-resource-assessment-mira

5. Petrucci, O., Pasqua, A.A. & Gullà, G. 2010. Landslide damage assessment using the Support Analysis Framework (SAF): The 2009 landsliding event in Calabria (Italy). Advances in Geosciences. pp. 13–17. Paper presented at 11th Plinius Conference on Mediterranean Storms, Barcelona, Spain, 7–11 September 2009. 30 June 2010. www.adv-geosci.net/26/13/2010

6. Australian Institute for Disaster Resilience. 2002. Disaster loss assessment guidelines. Australian Disaster Resilience Manual 27. https://knowledge.aidr.org.au/media/1967/manual-27-disaster-loss-assessment-guidelines.pdf

7. Hugenbusch, D. & Neumann, T. 2016. Cost-benefit analysis of disaster risk reduction: A synthesis for informed decision making. Aktion Deutschland Hilft e.V., Germany. www.aktion-deutschland-hilft.de/fileadmin/fm-dam/pdf/publikationen/aktion-deutschland-hilft-studie-zur-katastrophenvorsorgeenglische-version-english-version.pdf

8. Noleppa, S. 2013. Economic approaches for assessing climate change adaptation options under uncertainty: Excel tools for cost-benefit and multi-criteria analysis. Bonn and Eschborn, Germany, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). https://pdfs.semanticscholar.org/a1f1/afc7fd939c6af79da5a01862571941c95aa9.pdf?_ga=2.123203275.1164670997.1572095794-1753646993.1572095794

9. United Nations Framework Convention on Climate Change (UNFCCC). 2011. Assessing the costs and benefits of adaptation options. An overview of approaches. https://unfccc.int/resource/docs/publications/pub_nwp_costs_benefits_adaptation.pdf

10. Huang, I.B., Keisler, J. & Linkov, I. 2011. Multi-criteria decision analysis in environmental sciences: Ten years of applications and trends. The Science of the Total Environment, 409(19): 3578–3594. https://doi.org/10.1016/j.scitotenv.2011.06.022

11. Deltares. 2019. Dynamic adaptive policy pathways: supporting decision making under uncertainty using adaptation tipping points and adaptation pathways in policy analysis. In Deltares. Cited 25 October 2022. www.deltares.nl/en/adaptive-pathways

12. United Nations Economic Commission for Europe (UNECE). 2007. Recommendations on Payments for Ecosystem Services in Integrated Water Resources Management. No. ECE/MP.WAT/22. Geneva. https://unece.org/environment-policy/publications/recommendations-payments-ecosystem-services-integrated-water

5.4 Expected output

For each risk identified in Chapter 4, risk reduction measures are developed in a participatory process that addresses the different aspects of risk – hazard, vulnerability, exposure and capacity. The resilient watershed management implementation plan should be organized in the various phases of risk management – prevention, preparedness, adaptation, mitigation, and recovery.

Mountains in Kazakhstan
©Mark Nikulin

Lake Titicaca, Peru

6

Monitoring and evaluation

6. Monitoring and evaluation

Sacred Valley in Peru
©Deb Dowd/Unsplash

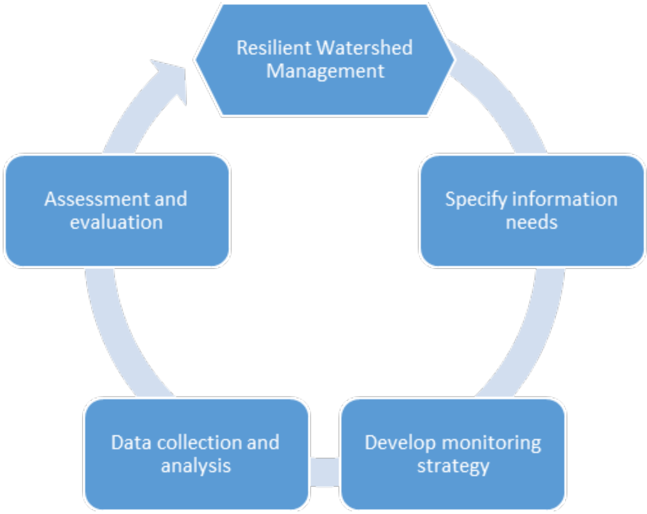
6.1 The monitoring and evaluation process

The purpose of a monitoring and evaluation system is to provide information on the implementation, results and outcomes of the resilient watershed management plan.

The process of monitoring and evaluation involves:

- defining which information is needed for evaluating the effectiveness of the resilient watershed management activities categorized in the four aspects of risk: hazard, exposure, vulnerability and capacity;
- defining the the scale and scope of, and how the information is collected;
- collecting and analysing the baseline data based on indicators categorized in the four aspects of risk: hazard, exposure, vulnerability and capacity;
- assessing the resulting information and evaluating what consequences the assessment has on the effectiveness of risk reduction through resilient watershed management; and
- resampling the baseline data at yearly intervals (depending on the variable, scope and scale) in order to determine what changes, if any, have occurred.

Figure 6.1: Steps in developing a monitoring and evaluation plan



Source: Timmerman, J.G., Ottens, J.J. & Ward, R.C. 2000. The information cycle as a framework for defining information goals for water-quality monitoring. *Environmental management*, 25(3): 229–239.

Table 6.1. Organizations typically involved in risk management and watershed management

Category	Risk management	Watershed management
Institutions with primary responsibility	Ministry of Interior, national disaster or emergency management authorities, national security and civil defence authorities (mainly central government)	The ministry or the departments in charge of rural development, local government, water management, environment, agriculture, forestry and/or natural resources (central and subnational governments)
Fully dedicated institutions with specific responsibilities	Meteorological services, civil defence authorities, research centres, search and rescue teams, fire departments, Red Cross/Crescent Societies, natural resources research and monitoring centres	Rural development agencies, agricultural organizations, forestry associations, watershed management committees, irrigation agencies, environmental protection agencies, meteorological services, hydrological research centres, water boards, natural resources research and monitoring centres

Category	Risk management	Watershed management
Sectoral ministries and subnational governments with a role in integrating disaster risk reduction and/or water management into development planning	Agriculture, environment, education, urban development, water, transport, women's affairs/social affairs; subnational jurisdictions, such as municipalities, provinces, districts and wards; in some countries, almost all government ministries may have an existing or potential role in disaster risk reduction	Agriculture, forestry, industry, environment, education, urban development, transport, rural development, local government, women's affairs/social affairs; subnational jurisdictions, such as municipalities, provinces, districts and wards; in some countries, several government ministries may have an existing or potential role in water management
Private sector and civil society organizations	International NGOs, non-profit sector, community-based organizations and women's organizations, insurance companies and business associations	Agricultural cooperatives, watershed management committees, insurance companies, business associations (for example, ecotourism service providers), including international NGOs, community-based organizations, youth organizations and women's organizations

Source: United Nations. 2018. Words into Action Guidelines. *Implementation guide for addressing water-related disasters and transboundary cooperation: Integrating disaster risk management with water management and climate change adaptation*. ISBN: 978-92-1-117177-8. New York and Geneva. www.unece.org/fileadmin/DAM/env/water/publications/WAT_56/ECE_MP.WAT_56.pdf

Information needs for monitoring for resilient watershed management

Depending on the availability of resources (e.g. computing power), the monitoring and evaluation system may be more elaborate. However, at the community level, a more basic data and information system can be set up. This section discusses the principles that are relevant for more elaborate systems, which can also be applied to simpler systems.

When determining the level of detail and the type of information necessary, it is important to ensure and agree with all the stakeholders on the level of acceptable risk. It will be impossible to completely reduce risk. In certain cases, the costs may sometimes outweigh the extent of risk reduced. For example, for a small landslide that occurs once a year on a small road, the most cost-effective risk reduction measure may be to clear the road on a periodic basis. However, a landslide that occurs on a major highway and that can block the transportation of goods for a month may have higher economic impact and would warrant a larger investment in landslide control measures. As such, the information needs should at least specify the following (UNECE, 2006):

- appropriate variables and other data that must be collected on a regular basis;
- the frequency with which data must be collected and made available;
- criteria or indicator for assessment for addressing hazard, vulnerability, exposure and capacity;
- specified requirements for reporting and presenting information (for instance, presentation in maps, GIS and degree of aggregation);
- relevant accuracy for each variable; and
- degree of data reliability.

BOX 6.1 Selecting indicators to track the progress and performance of the resilient watershed management plan against its objectives and targets

A set of indicators ideally comprises environmental, social, economic and institutional indicators, and should be categorized under one of the risk aspects – **hazard, exposure, vulnerability and capacity.**

- Environmental indicators are mainly biophysical measurements, for example, of water quantity and quality, soil erosion and forest cover, which can provide information about the state and trends of watershed resources or the extent of resource productivity and natural resource management intensity. Specifically, for risks, indicators include snowmelt, rainfall, floods, droughts, loss of certain habitats, vegetation cover, soil moisture, slopes and infrastructure development such as roads.
- Social indicators refer to social well-being and livelihoods, and document changes in people's attitudes, behaviour and progress towards social equity. Regarding watershed risks, indicators such as risk awareness, watershed collaboration and participation in land conservation may be used.
- Economic indicators refer to economic well-being in terms of employment and income. In relation to risks, estimated restoration costs and costs of damage can be useful indicators.
- Institutional indicators measure the performance of service providers, the influence and dynamics of existing local institutions, or the functioning of watershed management committees put in place. Risk-relevant indicators include the existence of early warning systems, specific risk management regulation, insurance and land ownership complexity.

Some of these indicators have already been collected for the risk assessment.

Social and economic indicators should be disaggregated for different groups (such as by gender, age, wealth and ethnicity) to make it possible to monitor access to resources for different population groups, for example, participation in watershed management planning and implementation, or perceptions of tenure security.

Sources: FAO. 2017. *Watershed management in action – Lessons learned from FAO field projects*. Rome. www.fao.org/3/a-i8087e.pdf; and FAO. 2019a. *Basic knowledge: SFM Toolbox. Watershed management*. Rome. Cited 20 June 2019. www.fao.org/sustainable-forest-management/toolbox/modules/watershed-management/basic-knowledge/en; FAO. 2019b. *Disaster risk reduction at farm level: Multiple benefits, no regrets.* Rome. www.fao.org/3/ca4429en/CA4429EN.pdf

Different types of information

- Baseline information: This is a relatively static set of information that was collected for the risk assessment (see Chapter 4) and should be available for the monitoring and evaluation system, and when relevant, updated.

- Interventions: This is information about implementation of the measures assigned in the resilient watershed management plan, their effects on reducing climate and disaster risks, and on increasing the resilience of the communities.

- Socioeconomic information: This is information about land-use planning agricultural production, number of farmers, industries that use water and number of inhabitants in the watershed, etc.; it may also include information on water demand for industrial, domestic and agricultural uses. This information has been collected for the risk assessment (see Chapter 4) and should be updated regularly.

- Hydro-meteorological information: This is information that needs regular updating, ranging from a real-time to a monthly, depending on the parameter (see Chapter 4). Trends derived from this information can, for example, indicate changes in intensity and frequency of hazards.

- Early warning systems: These systems collect information relevant for preparedness to extreme events (see Chapter 5); they can be developed in the context of implementing the resilient watershed monitoring plan.

In addition to monitoring information, decision support systems can be helpful in making projections about the effects of developments (hydro-meteorological and socioeconomic) in relation to the level of risk in the watershed, specifically, their impact on exposure, vulnerability and capacity.

Some data are available from international sources and are listed here for general reference (see Table 6.2). In most cases, however, global databases are not useful for watershed management decision making, where the focus should be on sub-national data for each watershed.

Table 6.2: Possible data sources (non-exhaustive)

Data source	Type of information	Reference
United Nations Global Environment Monitoring System (GEMS)	General information	GEMStat, 2019
System for earth observation, data access, processing, analysis for land monitoring (SEPAL)	Open source satellite data	SEPAL, 2021
Information System on Water and Agriculture of the Food and Agriculture Organization of the United Nations (FAO AQUASTAT)	General information	FAO, 2019b

Data source	Type of information	Reference
World Meteorological Organization's Hydrological Information Referral Service (WMO INFOHYDRO)	General information	WMO, 2019
International Groundwater Assessment Centre (IGRAC)	Groundwater	IGRAC, 2019
Global Runoff Data Centre (GRDC)	Surface water	BfG, 2019
FAO Global Forest Resources Assessment	Tabular data and metadata on forest resources and their trends (60+ variable categories and 236 countries and territories)	FAO, 2020b
World Data Centers, the Global Observation of Forest Cover and Land Dynamics (WUR)	Forest and land cover	WUR, 2015
Global Forest Watch	Forest and land cover	World Resources Institute, 2019
USGS/FEWS NET Data Portal	Geospatial data, satellite image products, derived data products for drought monitoring	FEWS, 2019
EM-DAT	International disasters	EM-DAT, 2019

Source: Author's elaboration

The monitoring and evaluation system design consists of the following elements:

Information needs. This step covers the purpose of the information collection and the intended users. Also, an overview of the information needs should be provided, detailing:

- the variables and other data to be collected, differentiated by the aspects of risk: hazard, exposure, vulnerability and capacity;
- the frequency of data collection; criteria for assessment;
- specified requirements for reporting and presenting; and
- relevant accuracy and data reliability.

Monitoring strategy. For all types of data, as identified in the information needs, this step outlines which institution will be responsible for collecting these data and how it will perform this task. This approach includes aspects such as:

- instruments used for data collection;
- locations where data are collected;
- analytical methods; and
- models used.

Assessment and evaluation. This step identifies which information products will be produced once the data are collected, including:

- assessment methods; type of reporting;
- frequency of reporting;
- media used for reporting; and
- intended audience for each type of reporting.

6.2 Further reading

- An overview of the process of monitoring and assessment is provided in *Strategies for monitoring and assessment* (UNECE, 2006) and *Guidelines on monitoring and assessment of transboundary rivers* (UNECE-TFMA, 2000).
- General development of monitoring systems can be found in:
  - Bartram, J. & Ballance, R. 1996. *Water quality monitoring – A practical guide to the design and implementation of freshwater quality studies and monitoring programmes*. London, Chapman & Hall.
  - Barcelo, D. 1993. *Environmental analysis: Techniques, applications and quality assurance*. Amsterdam, the Netherlands, Elsevier Science Publishers.
  - Chapman, D. 1996. *Water quality assessment – A guide to the use of biota, sediments and water in environmental monitoring*. London, Chapman & Hall.
- FAO, 2013. Module 18: Assessment, monitoring and evaluation. In *Climate-Smart Agriculture Sourcebook*. Rome. www.fao.org/3/i3325e/i3325e18.pdf

- Lai, K.C. Hancock, J. & Muller-Praefcke, D., 2012. *Stocktaking of M&E and management information systems*. FAO & World Bank. www.fao.org/3/a-i2883e.pdf

- Muller-Praefcke, D., Lai, K.C. & Sorrenson, W. 2010. *The use of monitoring and evaluation in agriculture and rural development projects. Findings from a review of implementation completion reports*. FAO & World Bank. www.fao.org/fileadmin/user_upload/tci/docs/bpid1-use%20of%20m&e%20in%20ag%20and%20rural%20development%20projects.pdf

- National Research Council, 2004. *Confronting the nation's water problems: The role of research*. Washington, DC, National Academies Press. https://doi.org/10.17226/11031

- Quevauviller, P. 1995. *Quality assurance in environmental monitoring: Sampling and sample pretreatment*. Weinheim, Germany, Wiley-VCH.

- An overview of spatial technologies can be found in Aguilar-Manjarrez, J., Wickliffe, L.C. & Dean, A., eds. 2018. *Guidance on spatial technologies for disaster risk management in aquaculture. A handbook*. Rome, FAO. 120 pp. www.fao.org/3/CA2368EN/ca2368en.pdf

High altitude wetland in Nepal
©Badri Baral

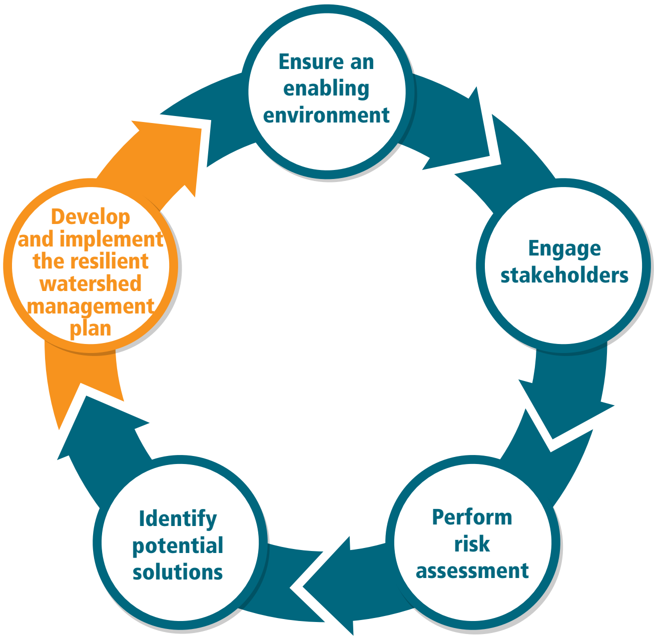
7 Conclusion

7. Conclusion

Yaks in northern Pakistan
©Shams Uddin

The last step in the watershed management planning process is the development and implementation of the resilient watershed management. The draft plan should be shared and agreed upon by the various stakeholders at the relevant national, regional and local levels. It is recommended that the facilitation of the planning be conducted by a risk management professional to ensure that all aspects are properly considered.

Figure 7.1: The resilient watershed management cycle



Source: Author's elaboration

The national government is normally responsible for overall plan approval; for ensuring that it adheres to current national natural resource policies; for ensuring that it is coordinated with other governmental agency activities; and for overall budgetary dispersal and oversight. Local governments are responsible for incorporating management plan activities into the overall annual workplan; distribution of funds to the implementing communities or community organizations; and broad budgetary oversight. At the local community or community organization level, responsibilities include: the implementation of approved activities; monitoring and evaluation of results; and provision of regular progress reports to the project manager.

It is also of the highest importance that field managers keep the local and national government authorities regularly informed of their progress. Even the most effective and productive field project in the country will suffer without strong and supportive constituency at the higher levels of government and management. The development of such support can be greatly facilitated by the regular provision to management authorities of summary field reports, videos and invitations for visits at the field sites.

The implementation plan must reflect the emphasis on the mainstreaming of a landscape, climate change and risk perspective and long-term sustainability into the process. The resilient watershed management plans should promote the integration of the physical and social sciences, and the experience and knowledge of local people. Risk reduction opportunity areas, as defined in this sourcebook, should be identified within the watershed and greater landscape area.

As presented in the previous chapters, before building a resilient watershed management plan in each watershed, the hazards posed by different climatic events, tectonic activities and land use activities need to be identified. This should be followed by a sensitivity and vulnerability assessment of the different hazards as well as an estimate of the probability and frequency of events such as flooding, drought, windstorms, fires, disease and tectonic activities. Based on this information, the various agencies and stakeholders need to decide and prioritize the risk posed to people and communities.

Once the assessment is in place, the most appropriate measures to reduce the risks can be identified. These measures range from structural and nature-based solutions, to regulatory measures, as outlined in this sourcebook. These measures are the key element to build resilience into watersheds, but require collaborations between all agencies and stakeholders involved. This is a complex process that requires new initiatives that are site-specific, address the specific hazards, and involve a wide range of methods and activities that are well documented and known to be effective. The main challenge for building resilience into watershed planning is primarily institutional and requires different governance, policies and legislation. It is hoped that this publication will provide a good framework and information resource on how to proceed in an innovative way to build resilience into watershed management and planning.

Sarez Lake, Tajikistan
©Nodir Tursun-Zade

8 References

References

ACAPS. 2016. *Building an effective assessment team*. Assessment Capacities Project. www.acaps.org/building-effective-assessment-team

Asian Development Bank (ADB), ed. 2017a. *Disaster risk assessment for project preparation: A practical guide*. Mandaluyong City, Metro Manila, Philippines. 66 pp.

Asian Development Bank (ADB). 2017b. *Natural hazard data: A practical guide*. Manila, Philippines, Asian Development Bank. www.adb.org/documents/natural-hazard-data-practical-guide

ASCE. 1996. *Hydrology Handbook. Second Edition.* New York.

Australian Institute for Disaster Resilience. 2002. *Disaster loss assessment guidelines*. Australian Disaster Resilience Manual 27. https://knowledge.aidr.org.au/media/1967/manual-27-disaster-loss-assessment-guidelines.pdf

BfG. 2019. *BfG - The GRDC*. Cited 25 October 2022. www.bafg.de/GRDC/EN/Home/homepage_node.html

Birkmann, J., Cardona, O., Carreño, M., Barbat, A., Pelling, M., Schneiderbauer, S., Kienberger, S. *et al*. 2013. Framing vulnerability, risk and societal responses: The MOVE framework. *Natural Hazards: Journal of the International Society for the Prevention and Mitigation of Natural Hazards*, 67(2): 193–211. https://econpapers.repec.org/article/sprnathaz/v_3a67_3ay_3a2013_3ai_3a2_3ap_3a193-211.htm

Bouma, J., Ittersum, M.K., Stoorvogel, J., Batjes, N., Droogers, P. & Pulleman, M. 2016. *Soil capability: Exploring the functional potentials of soils*. 10.1007/978-3-319-43394-3_3

Centre for Research on the Epidemiology of Disasters (CRED). 2018. *Natural disasters 2017*. Brussels. https://cred.be/sites/default/files/adsr_2017.pdf

Coburn, A., Spence, R. & Pomonis, A. 1994. Disaster mitigation. United Nations Development Programme. www.researchgate.net/publication/292655874_Disaster_Mitigation

de Brito, M., Evers, M. & Almoradie, A. 2018. Participatory flood vulnerability assessment: A multi-criteria approach. *Hydrology and Earth System Sciences*, 22: 373–390. https://doi.org/10.5194/hess-22-373-2018

Deltares. 2019. Dynamic adaptive policy pathways: supporting decision making under uncertainty using adaptation tipping points and adaptation pathways in policy analysis. In *Deltares*. Cited 25 October 2022. www.deltares.nl/en/adaptive-pathways

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). 2011. *Integrating climate change adaptation into development planning. A practice-oriented training based on an OECD policy guidance*. GmbH in coordination with Organisation for Economic Co-operation and Development. www.oecd.org/dac/environment-development/46905379.pdf

Eckstein, D., Kunzel, V., Schafer, L. & Winges. M. 2018. *Global Climate Risk Index 2020. Who suffers most from extreme weather events? Weather-related loss events in 2018 and 1999 to 2018*. Berlin. www.germanwatch.org/en/cri

EMDAT. 2019. *EM-DAT | The international disasters database*. Cited 25 October 2022. www.emdat.be

Environmental Protection Agency (EPA). 2015. Multi-criteria Integrated Resource Assessment (MIRA). Cited 25 October 2022. www.epa.gov/risk/multi-criteria-integrated-resource-assessment-mira

Environmental Protection Agency (EPA). 2020. *Heat island effect*. Cited 25 October 2022. www.epa.gov/heat-islands

European Commission. 2014. *Ecosystem services and green infrastructure. Environment*. Cited 25 October 2022. https://ec.europa.eu/environment/nature/ecosystems/index_en.htm

FAO. 1998. *Participatory processes for integrated watershed management*. Rome. http://www.fao.org/3/a-x0704e.pdf

FAO. 2005a. *Preparing for the next generation of watershed management programmes and projects - Water resources for the future*. Rome. http://www.fao.org/3/a-a0438e.pdf

FAO. 2005b. *Forests and floods. Drowning in fiction or thriving on facts?* Indonesia. http://www.fao.org/3/a-ae929e.pdf

FAO. 2006. *The new generation of watershed management programmes and projects*. Rome. http://www.fao.org/3/a-a0644e.pdf

FAO. 2008*. Disaster risk management systems analysis - A guide book*. Rome. http://www.fao.org/3/i0304e/i0304e.pdf

FAO. 2010. *Enhancing FAO's practices for supporting capacity development of member countries. Learning Module 1*. Rome. http://www.fao.org/3/a-i1998e.pdf

FAO. 2012. *FAO approaches to capacity development in programming: Processes and tools. Learning module 2 – capacity development*. Rome. http://www.fao.org/3/a-i2531e.pdf

FAO. 2013a. *The role of trees and forests in the prevention of landslides and rehabilitation of landslides-affected areas in Asia. Second edition.* Bangkok. http://www.fao.org/3/a-i3245e.pdf

FAO. 2013b. *Resilient livelihoods*. Disaster Risk Reduction for Food and Nutrition Security Framework Programme. Rome. www.fao.org/3/a-i3270e.pdf

FAO. 2014a. *Local Level Disaster Risk Reduction and Climate Change Adaptation in Agriculture.* Philippines. http://www.fao.org/3/a-br341e.pdf

FAO. 2015. *Planning Communication for Agricultural Disaster Risk Management: A Field Guide.* Rome. http://www.fao.org/3/a-i5277e.pdf

FAO. 2016. *Gender-responsive disaster risk reduction in the agriculture sector. Guidance for policy-makers and practitioners*. Rome. www.fao.org/3/b-i6096e.pdf

FAO. 2017. *Watershed management in action – Lessons learned from FAO field projects*. Rome. http://www.fao.org/3/a-i8087e.pdf

FAO. 2018a. *The impact of disasters and crises on agriculture and food security*. www.fao.org/3/I8656EN/i8656en.pdf

FAO. 2018b. *Nature-Based Solutions for Agricultural Water Management and Food Security.* Rome. http://www.fao.org/3/CA2525EN/ca2525en.pdf

FAO. 2018c. *Guidance note on gender-sensitive vulnerability assessments in agriculture*. Rome. www.fao.org/3/I7654EN/i7654en.pdf

FAO. 2018d. *Terms and definitions – Forest Resources Assessment 2020*. www.fao.org/3/I8661EN/i8661en.pdf

FAO. 2019a. *Basic knowledge: SFM Toolbox. Watershed management*. Rome. Cited 25 October 2022. www.fao.org/sustainable-forest-management/toolbox/modules/watershed-management/basic-knowledge/en

FAO. 2019b. *Disaster risk reduction at farm level: Multiple benefits, no regrets.* Rome. http://www.fao.org/3/ca4429en/CA4429EN.pdf

FAO. 2019c. *Integrated landscape management – Land & water.* Rome. www.fao.org/land-water/overview/integrated-landscape-management/en

FAO. 2019d. *Policy support and governance.* Cited 25 October 2022. www.fao.org/policy-support/governance/en

FAO. 2019e. *Soil erosion – the greatest challenge for sustainable soil management*. www.fao.org/3/ca4395en/ca4395en.pdf

FAO. 2020a. *A guide to developing a resilient watershed management plan.* Rome. Cited 25 October 2022. https://elearning.fao.org/course/view.php?id=649.

FAO. 2020b. *Global Forest Resources Assessment 2020: Main report.* Rome. https://doi.org/10.4060/ca9825en

FAO. 2020c. *Climate-smart agriculture*. Cited 25 October 2022. www.fao.org/climate-smart-agriculture/en

FAO. 2021. *The impact of disasters and crises on agriculture and food security: 2021.* Rome. https://doi.org/10.4060/cb3673en

Federal Emergency Management Agency. 2019. *Hazus | FEMA.gov*. Cited 25 October 2022. www.fema.gov/hazus

FEWS. 2019. *Early Warning and Environmental Monitoring Program*. Cited 25 October 2022. https://earlywarning.usgs.gov/fews

GEMStat. 2019. *GEMStat*. Cited 25 October 2022. https://gemstat.org

Harter, T. & Rollins, L. 2008. *Watersheds, groundwater and drinking water: A practical guide*. University of California, Division of Agriculture and Natural Resources, USA.

Huang, I.B., Keisler, J. & Linkov, I. 2011. Multi-criteria decision analysis in environmental sciences: Ten years of applications and trends. *The Science of the Total Environment*, 409(19): 3578–3594. https://doi.org/10.1016/j.scitotenv.2011.06.022

Hugenbusch, D. & Neumann, T. 2016. *Cost-benefit analysis of disaster risk reduction: A synthesis for informed decision making*. Aktion Deutschland Hilft e.V., Germany. www.aktion-deutschland-hilft.de/fileadmin/fm-dam/pdf/publikationen/aktion-deutschland-hilft-studie-zur-katastrophenvorsorge-englische-version-english-version.pdf

Jovel, R.J. & Mudahar, M. 2010. Damage, loss, and needs assessment guidance notes : Volume 1. *Design and execution of a damage, loss, and needs assessment*. World Bank, Washington, DC. openknowledge.worldbank.org/handle/10986/19047

International Fund for Agricultural Development (IFAD). 2009. *Good practices in participatory mapping: A review prepared for the International Fund for Agricultural Development (IFAD).* Rome. www.ifad.org/documents/38714170/39144386/PM_web.pdf/7c1eda69-8205-4c31-8912-3c25d6f90055

IGRAC. 2019. *International Groundwater Resources Assessment Centre*. Cited 25 October 2022. www.un-igrac.org

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). 2019. *Global Assessment Report on Biodiversity and Ecosystem Services*. Paris. https://ipbes.net/global-assessment

Intergovernmental Panel on Climate Change (IPCC). 2007. Assessment of adaptation practices, options, constraints and capacity. www.ipcc.ch/site/assets/uploads/2018/02/ar4-wg2-chapter17-1.pdf

Intergovernmental Panel on Climate Change (IPCC). 2012. *Managing the risks of extreme events and disasters to advance climate change adaptation*. 582 pp. www.ipcc.ch/site/assets/uploads/2018/03/SREX_Full_Report-1.pdf

Intergovernmental Panel on Climate Change (IPCC). 2013. Climate change 2013: The Physical Science Basis. www.ipcc.ch/site/assets/uploads/2018/03/WG1AR5_SummaryVolume_FINAL.pdf

Intergovernmental Panel on Climate Change. 2014. AR5 *Climate change 2014: Impacts, adaptation, and vulnerability*. www.ipcc.ch/report/ar5/wg2/

Intergovernmental Panel on Climate Change. 2018. Global warming of 1.5°C. www.ipcc.ch/sr15

Intergovernmental Panel on Climate Change (IPCC). 2019. *IPCC DDC glossary*. Cited 25 October 2022. www.ipcc-data.org/guidelines/pages/glossary/index.html

International Federation of Red Cross (IFRC). 2020. *Introduction to Disaster Preparedness. Disaster Preparedness training programme*. https://www.preventionweb.net/files/2743_Introdp.pdf

International Union for Conservation of Nature (IUCN). 2011. *Environmental flows*. https://portals.iucn.org/library/efiles/documents/2011-096.pdf

Le Quesne, F., Tollmann, J., Range, M., Balogun, K., Zissener, M., Bohl, D., Souvignet, M. *et al*. 2017. *The role of insurance in integrated disaster & climate risk management: Evidence and lessons learned*. United Nations EHS Publication series No. 22. Bonn, Germany, GIZ.

Libert Amico, A., Ituarte-Lima, C. & Elmqvist, T. 2019. Learning from social-ecological crisis for legal resilience building: Multi-scale dynamics in the coffee rust epidemic. *Sustainability Science*, 15(2): 485–501. https://doi.org/10.1007/s11625-019-00703-x

Marin–Ferrer, M., Vernaccini, L. & Poljansek, K. 2017. *INFORM Index for Risk Management Concept and Methodology*. Publications Office of the European Union. Luxembourg, Joint Research Centre. www.inform-index.org/Portals/0/InfoRM/2017/INFORM%20Concept%20and%20Methodology%20Version%202017%20Pdf%20FINAL.pdf?ver=2017-07-11-104935-783

Moravcová, J., Bystřický, V., Pečenka, J., Polenský, J., Pavlíček, T., Nováková, N. & Ondr, P. 2016. River basin management in the past and at present and its impact on extreme hydrological events. Chapter 2. In *River Basin Management*. pp. 35–60. https://doi.org/10.5772/63398

National Oceanic and Atmospheric Administration (NOAA). 2015. *Stakeholder engagement strategies for participatory mapping*. NOAA Office for Coastal Management. https://coast.noaa.gov/data/digitalcoast/pdf/participatory-mapping.pdf

Noleppa, S. 2013. *Economic approaches for assessing climate change adaptation options under uncertainty: Excel tools for cost-benefit and multi-criteria analysis*. Bonn and Eschborn, Germany, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). https://pdfs.semanticscholar.org/a1f1/afc7fd939c6af79da5a01862571941c95aa9.pdf?_ga=2.123203275.1164670997.1572095794-1753646993.1572095794

Organisation for Economic Co-operation and Development (OECD). 2006. *The challenge of capacity development*. *Working towards good practice*. www.fao.org/fileadmin/templates/capacitybuilding/pdf/DAC_paper_final.pdf

Pan American Health Organization/World Health Organization (PAHO/WHO). 2015. *Recommendations for engaging indigenous peoples in disaster risk reduction. Emergency preparedness and disaster relief.* Washington D.C. www.paho.org/disasters/index.php?option=com_docman&view=download&category_slug=books&alias=2401-recommendations-for-engaging-indigenous-peoples-in-disaster-risk-reduction&Itemid=1179&lang=en

Partnership for Environment and Disaster Risk Reduction (PEDRR). 2016. *Advancing implementation of the Sendai Framework for Disaster Risk Reduction (2015–2030) through ecosystem solutions.* Briefing Paper. www.wetlands.org/download/7592

PDNA. 2019. *Post Disaster Needs Assessment – International Recovery Platform*. Cited 25 October 2022. www.recoveryplatform.org/pdna

Petrucci, O., Pasqua, A.A. & Gullà, G. 2010. Landslide damage assessment using the Support Analysis Framework (SAF): The 2009 landsliding event in Calabria (Italy). *Advances in Geosciences*. pp. 13–17. Paper presented at 11th Plinius Conference on Mediterranean Storms, Barcelona, Spain, 7–11 September 2009. 30 June 2010. www.adv-geosci.net/26/13/2010

Schreier, H. and Kurian, M. 2014. *Integrated water resources management: a practical solution to address complexity by employing the nexus approach*. Working paper. United Nations University Institute for Integrated Management of Material Fluxes and of Resources (UNU-FLORES). http:/collections.unu.edu/view/UNU:2701

Sena, A., Ebi, K.L., Freitas, C., Corvalan, C. & Barcellos, C. 2017. Indicators to measure risk of disaster associated with drought: Implications for the health sector. *PLOS ONE*, 12(7): e0181394. https://doi.org/10.1371/journal.pone.0181394

SEPAL. (2021). Open Foris. *System for earth observation, data access, processing, analysis for land monitoring*. http://3.65.44.68/tools/sepal

Sonneveld, B.G.J.S., Merbis, M.D., Alfarra, A., Ünver, O. & Arnal, M.A. 2018. *Nature-based solutions for agricultural water management and food security.* FAO Land and Water Discussion Paper No. 12. Rome, FAO. www.fao.org/3/CA2525EN/ca2525en.pdf

Tanner, T.M., Surminski, S., Wilkinson, E., Reid, R., Rentschler, J.E. & Rajput, S. 2015. *The triple dividend of resilience: Realising development goals through the multiple benefits of disaster risk management.* Global Facility for Disaster Reduction and Recovery at the World Bank and Overseas Development Institute. www.gfdrr.org/sites/default/files/publication/The_Triple_Dividend_of_Resilience.pdf

Timmerman, J.G. & Bernardini, F. 2009. *Adapting to climate change in transboundary water management*. Perspective document for World Water Forum 5. Istanbul. www.preventionweb.net/publications/view/12911

Timmerman, J., Matthews, J., Koeppel, S., Valensuela, D. & Vlaanderen, N. 2017. Improving governance in transboundary cooperation in water and climate change adaptation. *Water Policy*, 19(6): 1014–1029. https://doi.org/10.2166/wp.2017.156

United Nations. 2018. Words into Action Guidelines. *Implementation guide for addressing water-related disasters and transboundary cooperation: Integrating disaster risk management with water management and climate change adaptation*. New York and Geneva. www.unece.org/fileadmin/DAM/env/water/publications/WAT_56/ECE_MP.WAT_56.pdf

United Nations Office for Disaster Risk Reduction (UNDRR). 2019a. *Terminology on disaster risk reduction*. Cited 25 October 2022. www.unisdr.org/we/inform/terminology

United Nations Office for Disaster Risk Reduction (UNDRR). 2019b. *Global Assessment Report on Disaster Risk Reduction. Geneva*. https://gar.unisdr.org/report-2019

United Nations Office for Disaster Risk Reduction (UNDRR). 2019c. *DesInventar Sendai*. www.desinventar.net

United Nations Economic Commission for Europe (UNECE). 2006. *Strategies for monitoring and assessment*. ISBN 92-1-116951-8. Geneva. www.unece.org/index.php?id=11683

United Nations Economic Commission for Europe (UNECE). 2007. *Recommendations on Payments for Ecosystem Services in Integrated Water Resources Management*. No. ECE/MP.WAT/22. Geneva. https://unece.org/environment-policy/publications/recommendations-payments-ecosystem-services-integrated-water

United Nations Economic Commission for Europe (UNECE). 2009. *Guidance on water and adaptation to climate change*. No. ISBN 9789211170108. Geneva. www.unece.org/fileadmin/DAM/env/water/publications/documents/Guidance_water_climate.pdf

United Nations Economic Commission for Europe (UNECE). 2015. *Water and climate change adaptation in transboundary basins: Lessons learned and* *good practices.* No. ECE/MP.WAT/45. Geneva. www.unece.org/fileadmin/DAM/env/water/publications/WAT_Good_practices/ece.mp.wat.45_low_res.pdf

United Nations Framework Convention on Climate Change (UNFCCC). 2011. *Assessing the costs and benefits of adaptation options. An overview of approaches*. https://unfccc.int/resource/docs/publications/pub_nwp_costs_benefits_adaptation.pdf

United Nations Framework Convention on Climate Change (UNFCCC). 2019. *Glossary of climate change acronyms and terms*. Cited 25 October 2022. https://unfccc.int/process-and-meetings/the-convention/glossary-of-climate-change-acronyms-and-terms

United Nations Office for Disaster Risk Reduction (UNISDR). 2015a. *Sendai Framework for Disaster Risk Reduction 2015–2030*. Geneva. www.unisdr.org/we/inform/publications/43291

United Nations Office for Disaster Risk Reduction (UNISDR). (2015b). *Global Assessment Report on Disaster Risk Reduction*. (also available www.preventionweb.net/english/hyogo/gar/2015/en/home/download.html

United Nations Office for Disaster Risk Reduction (UNISDR). 2017a. Words into Action Guidelines. *National Disaster Risk Assessment. Governance system, methodologies, and use of results*. www.unisdr.org/files/52828_nationaldisasterriskassessmentwiagu.pdf

United Nations Office for Disaster Risk Reduction (UNISDR). 2017b. *Build back better in recovery, rehabilitation and reconstruction*. Consultative version. www.unisdr.org/we/inform/publications/53213

United Nations Office for Disaster Risk Reduction (UNIDSR). 2018. *Get up to high ground*. Geneva. https://www.undrr.org/publication/get-high-ground

UNTerm. 2020. Cited 25 October 2022. https://unterm.un.org/unterm/display/record/unhq/na?OriginalId=f3e7e97ceede367185256fbd006abac2

United Nations World Water Assessment Programme (WWAP). 2018. *The United Nations World Water Development Report 2018: Nature-based Solutions*. Paris. https://www.unwater.org/publications/world-water-development-report-2018

Wageningen University & Research (WUR). 2015. GOFC-GOLD Reference Data Portal. In: *CARTO*. Cited 25 October 2022. https://bm-wageningen.carto.com/viz/efcf03a8-15de-11e5-86c4-0e4fddd5de28/embed_map

Watanabe, T., Byers, A.C., Somos-Valenzuela, M.A. & McKinney, D.C. 2016. The need for community involvement in glacial lake field research: The case of Imja glacial lake, Khumbu, Nepal Himalaya. Chapter 13. In R.B. Singh, U. Schickhoff & S. Mal, eds. *Climate change, glacier response, and vegetation dynamics in the Himalaya: Contributions toward future Earth initiatives*. Springer International Publishing, Switzerland. pp. 235–250. doi:10.1007/978-3-319-28977-9_13

Willemen, L., Kozar, R., Desalegn, A. & Buck, L.E. 2014. *Spatial planning and monitoring of landscape interventions. Maps to link people with their landscapes. A users' guide*. https://ecoagriculture.org/publication/a-landscape-perspective-on-monitoring-evaluation-for-sustainable-land-management/spatial-planning-and-monitoring-of-landscape-interventions-maps-to-link-people-with-their-landscapes/

World Meteorological Organization (WMO). 2019. Hydrological Information Referral Service. Cited 26 October 2022. https://library.wmo.int/index.php?lvl=notice_display&id=5003#.Y1jZ3S8Rq8o

World Resources Institute. 2019. *Forest monitoring designed for action*. Cited 20 June 2019. www.globalforestwatch.org

World Wildlife Fund (WWF). 2015. *Adaptation options: Prioritization and implementation*. https://wwf.panda.org/discover/our_focus/wildlife_practice/profiles/fish_marine/marine_turtles/lac_marine_turtle_programme/projects/climate_turtles/planning/prioritizing_adaptation_options/


Moraine Lake in the Canadian Rockies
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9 Glossary

Glossary

Adaptation refers to adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (UNFCCC, 2019).

Adaptive capacities refer to the ability or potential of a system to respond successfully to natural hazards and climate variability and change, and include adjustments in both behaviour and in resources and technologies (IPCC, 2007).

Afforestation refers to the establishment of forest through planting and/or deliberate seeding on land that, until then, was under a different land use, and implies a transformation of land use from non-forest to forest (FAO, 2018d).

Build back better" refers to the use of the recovery, rehabilitation and reconstruction phases after a disaster to increase resilience by integrating disaster risk reduction measures into the restoration of physical infrastructure and societal systems, and into the revitalization of livelihoods, economies and the environment (UNDRR, 2019a).

Capacity is the ability of people, organizations and society as a whole to manage their affairs successfully (OECD, 2006).

Capacity development is the process whereby individuals, organizations and society as a whole unleash, strengthen, create, adapt and maintain capacity over time (OECD, 2006).

Climate-smart refers to community approaches that help to guide actions needed to transform and reorient agricultural, economic, land management and other systems to effectively support sustainable development in a changing climate (FAO, 2020c).

Coping capacities refer to the ability of people, organizations and systems, using available skills and resources, to manage adverse conditions, risk or disasters. The capacity to cope requires continuing awareness, resources and good management, in normal times as well as during disasters or adverse conditions (UNDRR, 2019a).

Customary land refers to a territory used for agriculture or other purposes, which is owned by Indigenous communities and administered in accordance with their customs, as opposed to statutory tenure, usually introduced during the colonial periods. Common ownership is one form of customary land ownership (UNTerm, 2020).

Disaster refers to a severe rupture in the functioning of a society at any scale, due to hazardous events interacting with conditions of vulnerability, leading to human, material, economic and/or environmental impacts (UNDRR, 2019a).

Disaster mitigation aims at lessening or minimizing the adverse impacts of a hazardous event (UNDRR, 2019a).

Disaster prevention includes all activities and measures to avoid existing and new disaster risks. Prevention measures can also be taken during or after a hazardous event or disaster to prevent secondary hazards or their consequences, such as measures to prevent the contamination of water (UNDRR, 2019a).

Disaster risk is the potential loss of life, injury, or destroyed or damaged assets that could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure and vulnerability (UNDRR, 2019a).

Disaster risk assessment is the qualitative or quantitative approach to determine the nature and extent of disaster risk by analysing potential hazards and evaluating existing conditions of exposure and vulnerability that together could harm people, property, services, livelihoods and the environment on which they depend (UNDRR, 2019a).

Disaster risk preparedness is the knowledge and capacities developed by governments, response and recovery organizations, communities and individuals to effectively anticipate, respond to and recover from the impacts of likely, imminent or current disasters (UNDRR, 2019a).

Disaster risk prevention entails activities and measures to avoid existing and new disaster risks (UNDRR, 2019a).

Disaster risk reduction entails preventing new and reducing existing disaster risk and managing residual risk, all of which contribute to strengthening resilience and therefore to the achievement of sustainable development (UNDRR, 2019a).

Ecosystem services refer to the benefits people obtain from ecosystems. These include provisioning services such as food, water, timber and fibres; regulating services that affect climate, floods, disease, waste and water quality; cultural services that provide recreational, aesthetic and spiritual benefits; and supporting services such as soil formation, photosynthesis and nutrient cycling (MA, 2005).

Emergency response includes all actions taken directly before, during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected (UNDRR, 2019a).

Enabling environment includes the institutional set-up of a country, its implicit and explicit rules, its power structures and the policy and legal frameworks in which individuals and organizations function (FAO, 2010).

Environmental flow is the water provided within a river, wetland or coastal zone to maintain ecosystems and their benefits where there are competing water uses and where flows are regulated (IUCN, 2011).

Exposure is the presence of people, livelihoods, ecosystem services and resources, infrastructure, or economic, social or cultural assets in places that could be adversely affected by a natural hazard (UNDRR, 2019a).

Governance is the set of processes through which public and private actors articulate their interests, frame and prioritize issues, and make, implement, monitor and enforce decisions (FAO, 2019d).

Green infrastructure is a strategically planned network of high-quality natural and semi-natural areas with other environmental features, which is designed and managed to deliver a wide range of ecosystem services and protect biodiversity in both rural and urban settings (European Commission, 2014).

Hazard is used to describe the potential occurrence of natural, socio-natural or anthropogenic events that may have physical, social, economic and environmental impacts in a given area and over a specific period of time (Birkmann *et al.*, 2013). Hazards may be natural, anthropogenic or socio-natural in origin. Natural hazards are predominantly associated with natural processes and phenomena. Anthropogenic hazards, or human-induced hazards, are induced entirely or predominantly by human activities, choices, errors or negligence. This term does not include the occurrence of armed conflicts and other situations of social instability or tension that are subject to international humanitarian law and national legislation. Several hazards are socio-natural, in that they are associated with a combination of natural and anthropogenic factors, including environmental degradation and climate change.

Hazards may be single, sequential or combined in their origin and effects. Each hazard is characterized by its location, magnitude, frequency and probability. Biological hazards are also defined by their infectiousness or toxicity, or other characteristics of the pathogen such as dose-response, incubation period, case fatality rate and estimation of the pathogen for transmission. (UNDRR, 2019a).

Heat island effect describes built up areas that are hotter than nearby rural areas. Heat islands can affect communities by increasing summertime peak energy demand, air conditioning costs, air pollution and greenhouse gas emissions, heat-related illness and mortality, and water pollution (EPA, 2020).

Preparedness refers to measures taken to prepare for and reduce the effects of disasters. That is, to predict and, where possible, prevent disasters, mitigate their impact on vulnerable populations, and respond to and effectively cope with their consequences. (IFRC, 2020).

Recovery is a disaster phase aimed at restoring or improving livelihoods and health, as well as economic, physical, social, cultural and environmental assets, systems and activities, of a disaster-affected community or society, aligning with the principles of sustainable development and "build back better", to avoid or reduce future disaster risk (UNDRR, 2019a).

Reforestation refers to the re-establishment of forest through planting and/or deliberate seeding on land classified as forest (FAO, 2018d).

Resilience is defined as the ability of a (social or environmental) system to anticipate, absorb, accommodate or recover from the effects of a potentially hazardous event in a timely and efficient manner, including by ensuring the preservation, restoration or improvement of its essential basic structures and functions (IPCC, 2012).

Response is a disaster phase that entails the actions taken directly before, during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected (UNDRR, 2019a).

Return period is the average time interval between the occurrence of an event of a given quantity and the occurrence of an equal or larger event (ASCE, 1996)

Risk hotspot refers to areas where assets and people are highly exposed to risk.

Risk reduction opportunity area refers to a location that may not immediately be in a highly hazardous zone or an evident risk hotspot, but where interventions will have strong potential for reducing the risks in other locations, such as drainage, erosion or avalanche control measures upstream, or along the slopes in unpopulated areas. As such, these actions will reduce the risk for people downstream.

Sedimentation refers to the deposition of sediment from flowing water (in channels or floodplains) or standing water (in wetlands, lakes or oceans) (FAO, 2019e).

Soil capability is the intrinsic capacity of a soil to produce products and ecosystem services (Bouma *et al*., 2016).

Vulnerability refers to the conditions determined by physical, social, economic and environmental factors or processes that increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards (UNDRR, 2019a). It is also defined as the propensity or predisposition to be adversely affected. Vulnerability must be understood within a holistic approach that recognizes the sensitivity or fragility of the system, embedded within a social dimension (e.g. gender, health, education); economic dimension (e.g. income, wages); physical dimension (e.g. roads, houses, railways); cultural dimension (e.g. indigenous knowledge, artefacts, cultural practices and norms); environmental dimension (e.g. ecosystem function and services, watershed, pollution); and institutional dimension (e.g. governance, laws), as well as within the dimension of resilience (IPCC, 2019).

In this sourcebook the **concept of vulnerability** to encompass the **notion of susceptibility** and **lack of resilience**. Susceptibility refers to the multifaceted nature of vulnerability. It is underpinned by societal conditions and processes viewed from a multidimensional approach (considering physical, social, cultural, environmental, economic and institutional dimensions), which increase the sensitivity of the community/system or watershed to negative impacts. The lack of resilience refers to the lack of capacity of a community/system or watershed to anticipate, resist, cope, adapt and transform from the occurrence of a hazard in a timely and efficient manner. For this reason, the coping and adaptive capacities are important elements of the vulnerability assessment, as they are linked to the notion of resilience.

Watershed management is defined as any human action aimed at ensuring the sustainable use of natural resources in a watershed, and attempts to provide solutions to threats. Watershed management considers the management and conservation of all available natural resources in a comprehensive way. This requires a multidisciplinary approach that integrates forestry, water supply and sewerage systems, agriculture, industry, residential development, transport, recreation, fishing and other activities. Watershed management also aims to preserve the range of ecosystem services – especially hydrological services – provided by a watershed and to reduce or avoid negative downstream impacts while, at the same time, enhancing resource productivity and improving local livelihoods (FAO, 2019a; Moravcová *et al.*, 2016).

People's ability to cope with and recover from the impacts of hazards is closely related to the ability of ecosystems to withstand natural and anthropogenic pressures. Building the resilience of people and ecosystems in the face of climate-related hazards is a therefore priority for the management of natural resources.

As an increasingly heavier toll is exerted on agriculture and food systems by drought, floods, wildfires, and other extreme events; adopting risk reduction and management practices must therefore become an integral part of watershed management.

This Sourcebook by the Mountain Partnership Secretariat and the Food and Agriculture Organization of the United Nations (FAO) aims to tackle multiple risks and cascading effects in watershed management and build the resilience of agrifood systems by systematically including a risk perspective in watershed management planning and implementation. It underlines the importance of understanding disaster and climate risks, adopting a landscape approach, and targeting vulnerable groups (e.g. women, youth, Indigenous Peoples, mountain peoples) at all stages of planning and implementing watershed management.

This publication contributes to FAO's work in developing guidelines, policy briefs and handbooks that provide decision-makers, field technicians and development practitioners with data-driven, up-to-date recommendations on key issues related to watershed management and sustainable development in the highlands and the lowlands.

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Ministry of Foreign Affairs and International Cooperation

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Swiss Confederation

Federal Department of Economic Affairs, Education and Research EAER
Federal Office for Agriculture FOAG

2022 International Year of SUSTAINABLE MOUNTAIN DEVELOPMENT

ISBN 978-92-5-137347-7

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CC3258EN/1/02.23