Climate Risk Assessment for Ecosystem-based Adaptation

A guidebook for planners and practitioners

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Abbreviations

AR4	IPCC Fourth Assessment Report
AR5	IPCC Fifth Assessment Report
BMU	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BMZ	Federal Ministry for Economic Cooperation and Development
CBA	Cost-benefit analysis
CBD	Convention on Biological Diversity
CCA	Climate Change Adaptation
CEA	Cost-effectiveness analysis
DRR	Disaster Risk Reduction
EbA	Ecosystem-based Adaptation
Eco-DRR	Ecosystem-based disaster risk reduction
ESS	Ecosystem Services
FEBA	Friends of Ecosystem-based Adaptation
GEF	Global Environment Facility
GI	Green Infrastructure
GIS	Geographical Information Systems
GCF	Green Climate Fund
IKI	International Climate Initiative
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
M&E	Monitoring & Evaluation
MCA	Multi-criteria analysis
NAP	National Adaptation Plan
NBS	Nature-based solution
PEDRR	Partnership for Environment and Disaster Risk Reduction
RBC	River basin Committee
SES	Social-ecological system
SUL_NBS	Sustainable Use of Land and Nature-based Solutions
UNCCD	UN Convention to Combat Desertification
UNISDR	UN International Strategy for Disaster Risk Reduction
UNFCCC	UN Framework Convention on Climate Change
WGII	Working Group II

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Quick tour guide

- *Building on and extending the Vulnerability Sourcebook (GIZ 2014) and its Risk Supplement (GIZ and EURAC 2017), this Guidebook provides guidance on how to systematically consider ecosystem-based solutions in the context of climate risk assessments.*

- *It demonstrates how to identify potential adaptation measures, perform related (spatial) planning, and utilise the risk assessment for monitoring and evaluation (M&E) after actions have been implemented.*

- *It presents one consistent and coherent approach to address Ecosystem-based Adaptation (EbA) – other approaches also exist with different underlying concepts, which are feasible and used in practice.*

- *It introduces key concepts and methodological steps relevant for climate risk assessments in the context of EbA and related concepts, illustrating its methodology with a concrete application example.*

- *It is designed to provide answers to the following key questions:*

  How can climate risk assessments in the context of EbA and related concepts be conducted? What are key steps and requirements (e.g. in terms of resources, data, and software)?

  How can climate risk assessments support the identification of EbA measures as part of an overall adaptation strategy, their (spatial) planning, and their monitoring and evaluation (M&E)?

- *It can be read and used as a stand-alone document. For additional details on key steps in the risk assessment procedure, references are made to the Vulnerability Sourcebook and its Risk Supplement.*

- *It is particularly helpful in cases that require a consistent, standardised approach to gather information on climate related risk and to use this information for adaptation planning.*

- *It can be applied at different spatial scales, ranging from local to landscape or even national levels, covering different social, economic, political and ecological settings and their connections within social-ecological systems (SES).*

- *It can be applied at different stages of adaptation planning, from initial baseline assessments to repeated assessments in the implementation or the M&E phases.*

- *It is complemented by an Annex, which provides:*

  1. information on qualification criteria and quality standards for EbA,

  2. additional sources and references where possible EbA measures are presented, and

  3. a second application example where key steps of the risk assessment and the identification of EbA measures are illustrated for a coastal area.

The following icons will help you navigate through the Guidebook:

? GUIDING QUESTIONS:

→ *Refers to more detailed information in the Vulnerability Sourcebook or its Risk Supplement.*

APPLICATION EXAMPLE:
Preparing the risk assessment

Introduction

Context of this Guidebook

Introduction into

- *the thematic scope*
- *target group*
- *structure of the Guidebook*
- *a concrete application example*

Ecosystem-based Adaptation (EbA) is 'the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change' (CBD 2009). The approach was recognised as being cost-effective and generating social, economic, health and cultural co-benefits, (such as impacts on health and well-being, additional sources of income, water purification, carbon storage, pollination, and recreation services) while contributing to the conservation of biodiversity (CBD 2009). In recent years, EbA measures have increasingly been promoted and piloted to help people adapt to climate change and reduce climate-related disaster risk. The current investments in EbA – e.g. by the International Climate Initiative (IKI) of the German Federal Government, the Global Environment Facility (GEF) or the Green Climate Fund (GCF) – and the increasing recognition of the approach as a cost-effective 'low-regret' solution in the context of National Adaptation Plan (NAP) processes represents a significant opportunity to promote the uptake of EbA and to mainstream it into general adaptation, disaster risk reduction, and development planning globally.

Climate vulnerability and risk assessments are now widely used as a structured way to identify potential measures as well as most appropriate locations for the implementation of adaptation and disaster risk reduction (DRR) planning at local, national and regional levels.

To provide guidelines for standardised assessments, the *Vulnerability Sourcebook* (GIZ 2014) was commissioned by GIZ and developed jointly by adelphi and EURAC Research. Its guidance is based on the concept of climate change vulnerability as described in the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC 2007). The recently developed *Risk Supplement to the Vulnerability Sourcebook* (GIZ and EURAC 2017) adapted the climate risk concept as introduced in the Fifth Assessment Report (AR5) by the IPCC Working Group II (IPCC 2014a). This risk concept, which is also applied here and adjusted to the EbA context, allows for the joint consideration of adaptation and DRR measures, making this Guidebook suitable for many more potential users.

Climate risk assessments in general, and in particular the modular 'Sourcebook approach' (GIZ 2014; GIZ and EURAC 2017) to standardised vulnerability and risk assessments, are powerful tools for identifying effective DRR and climate change adaptation (CCA) strategies. Ideally, they provide relevant information on the climate-related risks of societies, economies and ecosystems, along the dimensions of hazard, exposure and vulnerability. In the context of EbA planning, however, the connections and interdependencies between humans, livelihoods, ecosystems and their services need to be taken into consideration, focusing on social-ecological systems (SES) as the main unit of analysis, i.e. complex, integrated systems in which humans are part of nature (Berkes and Folke 1998; Ostrom 2009). Thus, adaptation planning in the context of EbA represents a departure from the 'conventional' adaptation planning (e.g. in the form of hard engineered solutions, such as dykes, sea walls, etc.) by means of 1) a more targeted and systematic incorporation of biodiversity and ecosystem services (ESS) into risk assessments, 2) a thorough identification of both ecosystem-based and conventional adaptation options in a spatially explicit manner, 3) unveiling both potential co-benefits and unintended negative outcomes of ecosystem-based options, and 4) identifying feedback loops. During the scoping process for this Guidebook, it has become apparent that there is a strong demand for guidance on how to assess climate risk(s) of SES, so as to enable and monitor adaptation planning, considering both ecosystem-based and conventional adaptation options and providing entry points for DRR considerations.

In response to this demand, this *Climate Risk Assessment for Ecosystem-based Adaptation* Guidebook provides a standardised approach to climate risk assessments in the context of EbA-planning by following the well-established, modular *Sourcebook* (GIZ 2014) methodology and using an illustrative application example.

Target group

This Guidebook targets both governmental and non-governmental organisations mandated with or engaged in the planning of adaptation, DRR and development measures. It aims to support these processes by providing a standardised methodology for assessing climate risks in the context of EbA and to showcase potential co-benefits of EbA based on direct and indirect linkages to other sectors.

The Guidebook is of particular interest to technical experts and planners working at local, sub-national or national levels. It offers an effective tool that can:

- *provide a sound assessment of climate risk(s) in the context of social-ecological systems (SES);*
- *improve adaptation and development planning by explicitly considering ecosystem-based and conventional options in the form of integrated 'adaptation packages';*
- *inform the selection and spatial planning of adaptation measures;*
- *support the monitoring and evaluation (M&E) of adaptation.*

BOX 1

Concepts and definitions related to Ecosystem-based Adaptation

This box provides an overview of the most relevant concepts which could benefit from this Guidebook and introduces the most relevant frameworks, policies and networks associated with these concepts.

Ecosystem-based Adaptation (EbA)

EbA is the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change. It aims to maintain and increase the resilience and reduce the vulnerability of ecosystems and people in the face of the adverse effects of climate change (CBD 2009).

Ecosystem-based disaster risk reduction (Eco-DRR)

Eco-DRR is the sustainable management, conservation, and restoration of ecosystems to reduce disaster risk, with the aim of achieving sustainable and resilient development (Estrella and Saalismaa 2013).

Green infrastructure (GI)

GI 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. It aims to enhance nature's ability to deliver multiple valuable ecosystem goods and services, such as clean air or water (EC 2013).

Nature-based solutions (NBS)

NBS is an umbrella concept for various ecosystem-related approaches. It covers actions to protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits. NBS aim to achieve society's development goals and safeguard human well-being in ways that reflect cultural and societal values and enhance the resilience of ecosystems, their capacity for renewal and the provision of services (Cohen-Shacham et al. 2016).

Relevant frameworks, policies, and networks

Concept	Frameworks & policies	Networks
EbA	UN Framework Convention on Climate Change (UNFCCC), Convention on Biological Diversity (CBD), UN Convention to Combat Desertification (UNCCD)	Friends of EbA (FEBA), EbA Community of Practice
Eco-DRR	Sendai Framework for Disaster Risk Reduction 2015-2030, UN International Strategy for Disaster Risk Reduction (UNISDR)	Partnership for Environment and Disaster Risk Reduction (PEDRR)
GI	Sendai Framework for Disaster Risk Reduction 2015-2030, European Commission Green Infrastructure Strategy	Natura 2000 network
NBS	International Union for Conservation of Nature (IUCN), EU Research and Innovation policy agenda on Nature-Based Solutions and Re-Naturing Cities – Horizon 2020	NbS-4-Resilience, Partnership on Sustainable Use of Land and Nature-based Solutions (SUL-NBS)

The Guidebook is written for users with a basic understanding of the concepts 'vulnerability' and 'risk'. It not only targets planners and coordinators of risk assessments, but also conservation experts who are concerned with risk reduction and adaptation. Conservation experts – including focal points of the Convention on Biological Diversity (CBD) – will find guidance on how to engage with the wider adaptation and DRR community in order to better achieve joint objectives of sustainable long-term adaptation and conservation. The Guidebook acknowledges the specific conditions prevailing in many developing countries and emerging economies, such as limited data availability.

Although this Guidebook focuses on EbA planning, it acknowledges related concepts such as Ecosystem-based disaster risk reduction (Eco-DRR), Nature-based Solutions (NBS) and Green Infrastructure (GI). They could clearly profit from the methodology outlined here for the identification and (spatial) planning of appropriate interventions. Box 1 provides definitions of related concepts. This may help users find opportunities to use the Guidebook for the planning and implementation of Eco-DRR, NBS or GI measures.

Instructions for using the Guidebook

This Guidebook is designed as a stand-alone document. However, the *Vulnerability Sourcebook (GIZ 2014)* and its recent *Risk Supplement (GIZ and EURAC 2017)* provide additional in-depth directions related to some assessment steps described in Chapter III. Further reference to these documents is provided where particularly useful.

The EbA Guidebook comprises four chapters:

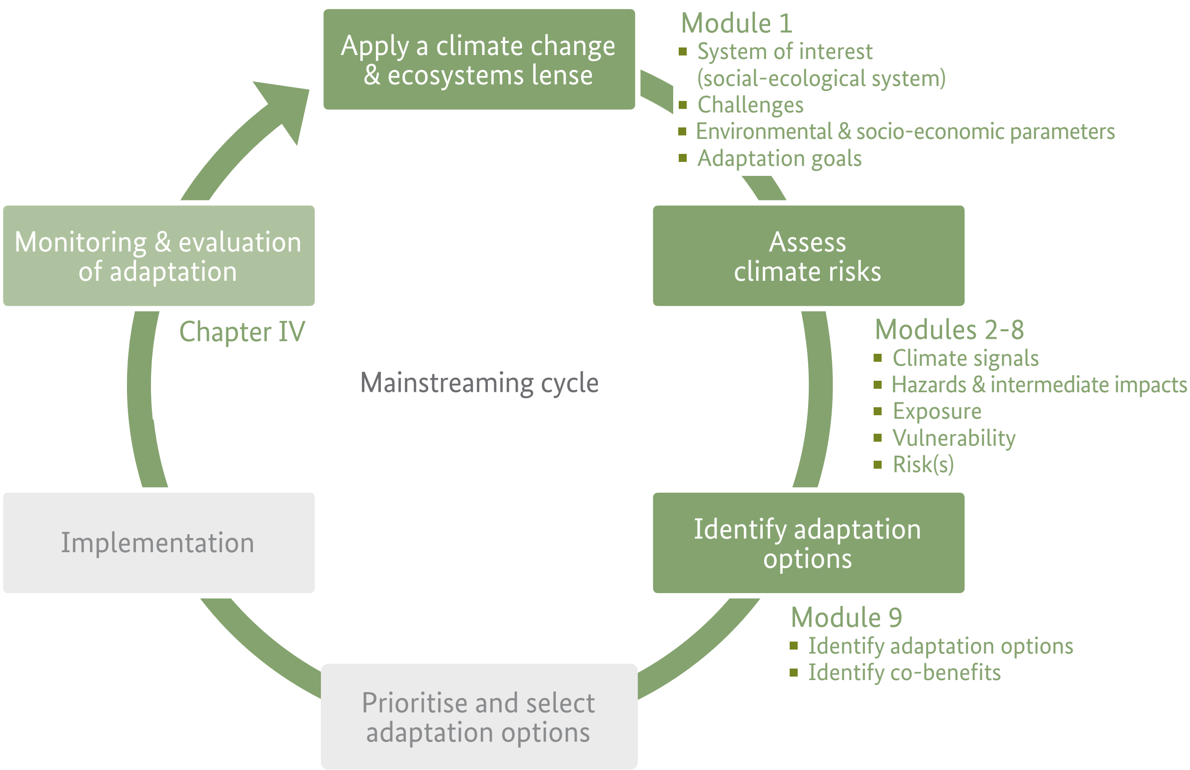
After the Introduction (Chapter I), Chapter II introduces the conceptual risk framework used in this Guidebook. It clarifies how (and in which sense) the terms 'risk', 'hazard', 'exposure', 'vulnerability', 'impact' and 'adaptation' are used. The framework is based on a state-of-the-art understanding of social-ecological risk assessments and suggests innovative, transparent and reproducible ways to identify, monitor and evaluate EbA measures. The conceptual framework and the definitions provided are particularly targeted at readers seeking a more profound understanding of the concepts behind vulnerability and risk assessments or adaptation planning.

Building on the conceptual framework, Chapter III provides detailed practical instructions for the implementation of risk assessments, following the well-established, modular Sourcebook methodology (GIZ 2014) and using an application example to illustrate its implementation. The nine modules provide simple and clear step-by-step instructions on the major stages to conducting a risk assessment (Module 1-7), visualising and communicating outcomes (Module 8), and identifying EbA measures (Module 9).

Some of the more technical modules (mainly Modules 4-7) are very similar to those outlined in the *Vulnerability Sourcebook* (and are presented in a more condensed form), while the others have been substantially adjusted to accommodate for the special aspects of risk assessments and the identification and spatial prioritisation of measures within the EbA context.

Each module in Chapter III starts with a brief overview of key steps and guiding questions. These general explanations are followed by the

Figure 1: EbA Mainstreaming cycle (Source: Adapted from GIZ 2016)



description of the individual steps, based on a concrete application example, focusing on flood risk in a river basin. The same application example is used throughout the nine modules, allowing for an integrated understanding of all stages.

Finally, Chapter IV provides a short overview on how to use climate-risk assessments to support the monitoring and evaluation (M&E) of EbA measures.

Introducing the application example

The application example complements the generic step-by-step instructions of the Guidebook by illustrating these steps and associated guiding questions using a semi-fictitious case.

APPLICATION EXAMPLE: Climate change adaptation within river basin management

The application example presents a case study which is typical for many EbA practitioners. It involves a river basin with a high risk of loss of lives and of damages to property due to river flooding.

Description of the river basin including social-ecological features:

The basin is characterised by a tropical rainforest climate with temperatures ranging from an average low of 22 °C to an average high of 34 °C. Between May and September, the rainfall amounts to 100 to 150 mm/month, from October to January the precipitation varies between 250 and 750 mm/month. The basin comprises an area of approximately 550 km² (55,000 ha) with a population of approximately 100,000 people, concentrated in an urban centre that relies economically on the agricultural outputs from the basin. The river basin is situated in six administrative districts (see Figure 2).

The upper catchment of the river basin (District 1) is located in a forested mountainous area with an elevation of about 1,750 m above sea level at the highest point and a steep slope gradient of 1,700 m elevation change within 15 km. In the past, landslides have frequently occurred in the upper river basin, so any change in land use poses a potential threat. District 2 is mainly characterised by scattered, informal settlements, natural vegetation cover and agricultural land. It also features two small wetlands. The main urban centre in the basin is located along the administrative boundary between Districts 3 and 4, where the elevation is only 8 m above sea level. With a population of 46,000, both districts combined host around 70 percent of the population in the river basin. Districts 5 and 6 border the coastline and are used primarily for agricultural production and aquaculture. Except for District 1, most of the river basin has been highly modified through the construction of canals, dykes and control measures such as dams.

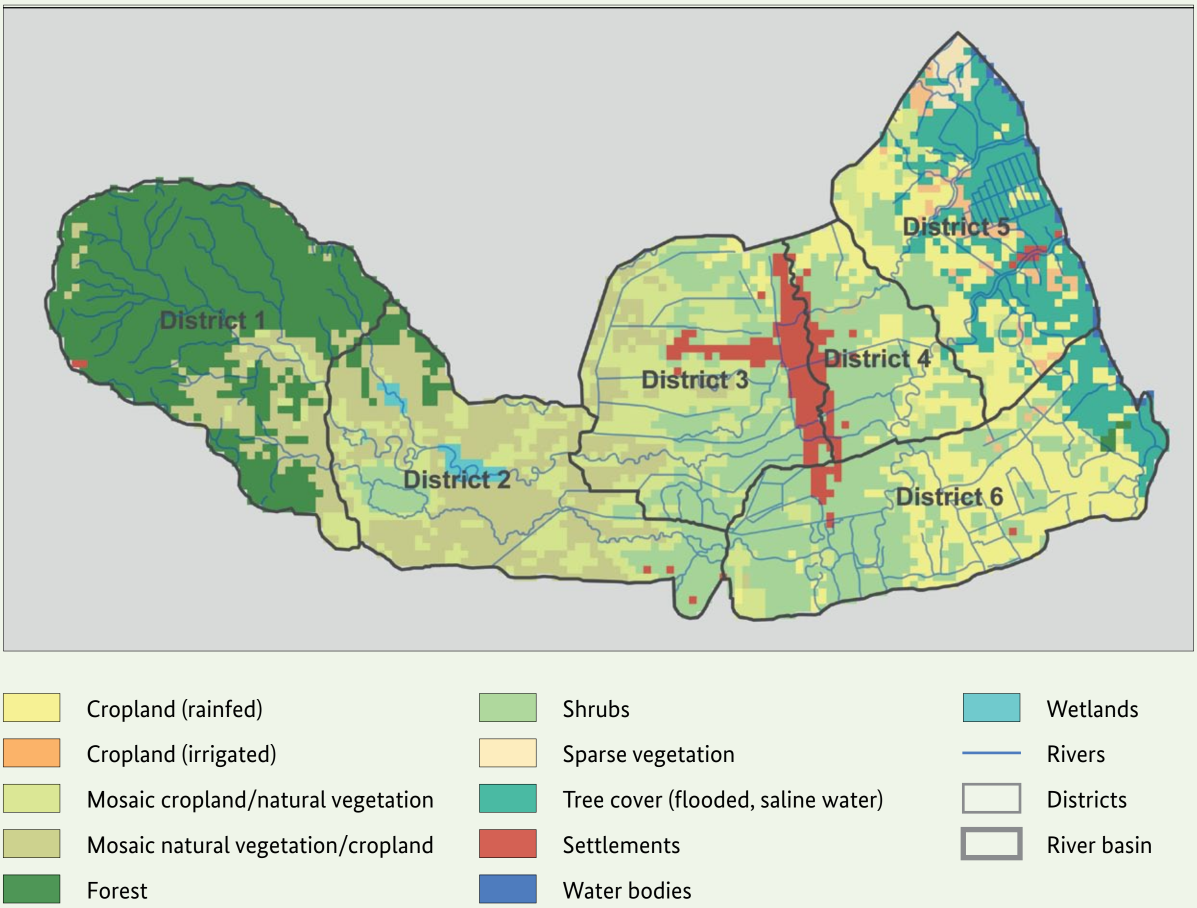
Adaptation challenges:

In the river basin, inadequate coordination between different sectors and a lack of formal rules for urban planning have increased inundation and damage levels during flooding events. Because there is little to no control over the location of new settlements, recent developments resulted in the loss of retention areas, as stream flows were modified, while no compensatory measures were taken to offset losses in ecosystem functions, such as water storage and regulation. Wetlands and floodplains have been converted into agricultural land without leaving buffer strips, and river modifications have further increased flow velocity and peak flows during flooding events, often relocating problems downstream. In addition to land use changes, flooding in the basin is likely to be exac-

erbated because of climate change, with projected flooding events increasing in both frequency and intensity. Thus, the local population could face large economic losses; crop failure and decline in production not only affects the agricultural sector, but also business sectors within the urban centre.

Local water management authorities have determined that it is necessary to perform a risk assessment in order to identify adaptation measures (incl. EbA solutions), which could be put in place to effectively counter present and future flood risks in the basin.

Figure 2: Land use types in the river basin (Source: authors)



II

Conceptual framework

The IPCC AR5 risk concept in the context of social-ecological systems (SES)

This chapter defines relevant key terms covering:

- Social-ecological systems (SES)
- Risk
- Hazard
- Exposure
- Vulnerability
- Impacts
- Adaptation

The latest IPCC assessment report (AR5), published in 2014, has introduced the concept of climate risk which replaced the AR4 concept of climate (change) vulnerability. It was adopted from the concepts and practices of carrying out risk assessments in the DRR community. The climate risk concept allows to include all aspects of an SES – from climate-related hazards to social- and ecosystem-related vulnerability and exposure factors – which contribute to risks.

Social-ecological systems (SES)

Definition SES: *complex 'systems of people and nature, emphasising that humans must be seen as a part of, not apart from, nature'. (Berkes and Folke 1998)*

By considering a complex systems of people and nature, it pays particular attention to the dependency of people (socio-economic-cultural context) on ESS[1] such as food and water supply (provisioning services), extreme event buffering and climate regulation (regulating services) which are of central importance in the context of risk reduction and adaptation. It considers both human-induced and biophysical drivers of risk and helps to pursue adaptation strategies that make use of the multiple benefits provided by ecosystems.

The risk of climate-related impacts within a social-ecological system results from the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability and exposure of human and natural systems. (Source: IPCC 2014a, p. 1046)

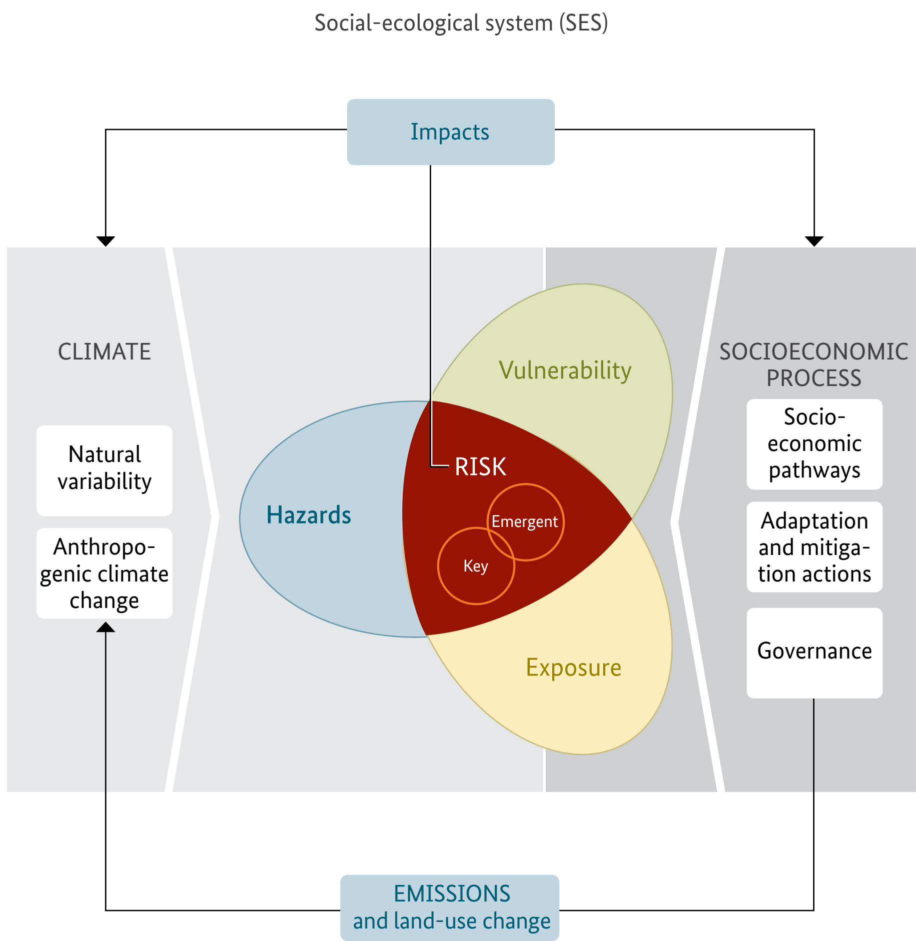
Risk

Definition Risk: *'The potential for consequences where something of value is at stake and where the outcome is uncertain (...). Risk results from the interaction of vulnerability, exposure, and hazard (...).' (IPCC 2014a, p. 40)*

A climate risk is the potential for specific, climate-related consequences (climate impacts) that

[1] http://www.aboutvalues.net/ecosystem_services/

Figure 3: Illustration of the core concepts of the IPCC WGII AR5.
The risk of climate-related impacts within a social-ecological system results from the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability and exposure of human and natural systems (Source: IPCC 2014a, p. 1046)



may affect assets, people, ecosystems, culture, etc. Typically, an SES will be exposed to more than one climate risk. When starting a climate risk assessment, it is thus necessary to specify the risk(s) the study focuses on, to identify the types of hazards and climate impacts that create the risk(s) and to clarify who or what may be affected. Examples for risks include: risk of water scarcity for smallholder farmers (water scarcity as a potential consequence of climate impacts, smallholder farmers are at risk); risk of food insecurity for rural population; risk of species extinction for biodiversity;

risk of damage to transport infrastructure due to erosion and landslides, etc.

Risk is something where the 'outcome is uncertain'. In a risk assessment, this uncertainty can be addressed in different ways. In disaster risk assessments, one common approach is a probabilistic assessment, where risk is represented as the probability of hazardous events or trends to occur, multiplied by the impacts of these events or trends (IPCC 2014a). In the context of climate change risk, such a probabilistic approach is often not feasible. Most hazards and consequences cannot be described as standard events, which is one requirement for a probabilistic approach. Furthermore, the consequences of climate change can per-se not be assessed with a probabilistic approach, since the future of socio-economic pathways, greenhouse gas emission pathways and thus climate impacts is uncertain. Instead, scenario approaches are applied (e.g. different climate consequences for different greenhouse gas emission scenarios; different vulnerability scenarios based on socio-economic pathways). Therefore, we propose to understand climate risk as a function of hazard, exposure and vulnerability, as proposed by the IPCC in its AR5 report (IPCC 2014a), but to make the likelihood and uncertainty explicit wherever possible, particularly in the selection of hazard indicators.

→ *For a more in-depth discussion see Chapter II of the Risk Supplement, p. 11-21.*

Hazard

Definition Hazard: *'The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. In the [IPCC] report, the term hazard usually refers to climate-related physical events or trends or their physical impacts.' (IPCC 2014a, p. 39)*

A hazard may be an *event* (e.g. a heavy rain event), but it can also be a *direct physical impact*. A hazard is not necessarily an extreme weather event (e.g. tropical storm, flooding), but can also be a slow onset trend (e.g. less water from snow melt, increase in average temperature, sea-level rise, salinity intrusion, etc.). If possible, the probability of a specific hazardous event or trend should be estimated. This can be done by defining hazards as critical events or critical physical impacts (e.g. 'heavy rain events' instead of 'rain' or 'heat days' instead of 'temperature'). Later in the assessment, this will be further specified by setting thresholds and identifying frequencies (e.g. 'number of days with more than 50 mm rainfall').

Exposure

Definition Exposure: *'The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.' (IPCC 2014a, p. 39)*

'Exposure' refers to relevant elements of the SES system (e.g. people, livelihoods, assets, but also species, ecosystems, etc.) that could be adversely affected by hazards. The degree of exposure can be expressed by absolute numbers, densities, proportions, etc. (e.g. 'population density in an area affected by drought'; 'percentage of wetlands in a district affected by pollution', etc.). A change in exposure over time (e.g. 'change of number of people living in drought-prone areas') can significantly increase or decrease risk.

Vulnerability

Definition Vulnerability: *'The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.' (IPCC 2014a, p. 39)*

Vulnerability addresses those attributes of the exposed SES-elements that may increase (or decrease) the potential consequences of a specific climate hazard. It comprises two relevant elements: sensitivity and capacity.

Sensitivity is determined by those factors that directly affect the consequences of a hazard. Sensitivity may include ecological or physical attributes of a system (e.g. type of soil on agriculture fields, water retention capacity for flood control, building material of houses) as well as social, economic and cultural attributes (e.g. age structure, income structure). In the context of EbA, it is recommended to consider how (intact or deteriorated) ESS affect sensitivity.

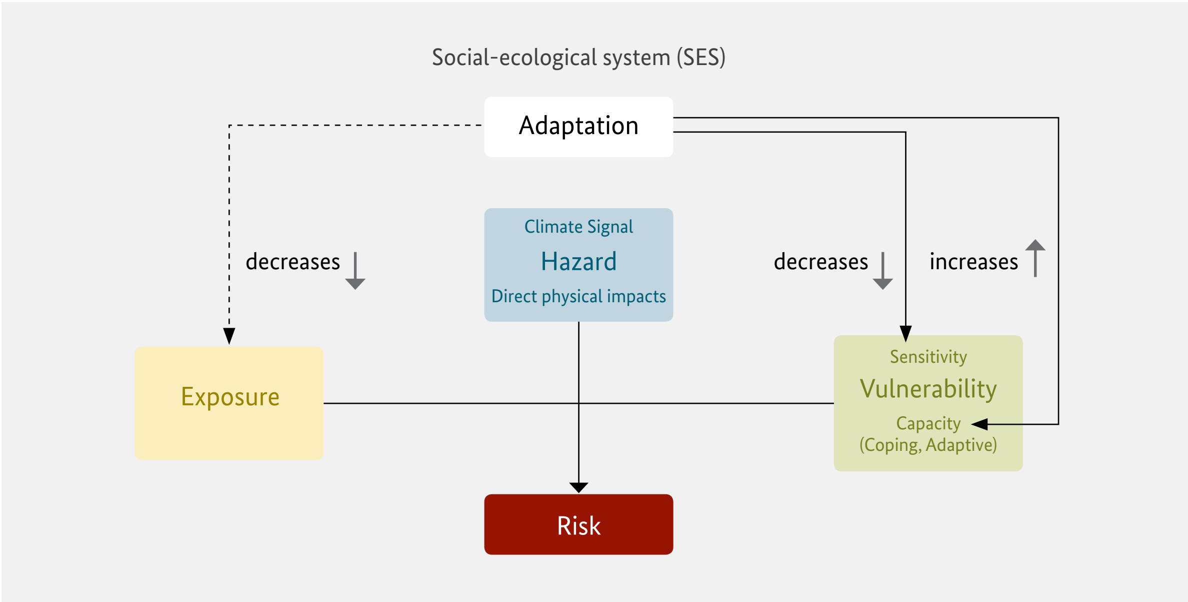
Capacity in the context of climate risk assessments refers to the ability of societies and communities to prepare for and respond to current and future climate impacts. It does not cover the capacity of ecosystems to respond to impacts but rather the social capacity to manage ecosystems. Capacity comprises two major components: the *coping capacity* ('The ability of people, institutions, organizations, and systems, using available skills, values, beliefs, resources, and opportunities, to address, manage, and overcome adverse conditions in the short to medium term', IPCC 2014b, p. 1762; e.g. early warning systems in place), and the *adaptive capacity* ('The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences'; IPCC 2014b, p. 1758; e.g. knowledge to introduce new farming methods). A lack of capacity can significantly increase the vulnerability of a system at stake and therefore its level of risk.

Impacts

Definition Impacts: *'Effects on natural and human systems. In [the IPCC] report, the term impacts is used primarily to refer to the effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. The impacts of climate change on geophysical systems, including floods, droughts, and sea level rise, are a subset of impacts called physical impacts.' (IPCC 2014a, p. 39)*

'Impact' is the most general term to describe consequences, ranging from direct physical impacts of a hazard to indirect consequences for the society (so-called social impacts). Impacts are basic building blocks of the cause-effect chains (impact chains).

Figure 4: Adaptation can reduce the risk by reducing the vulnerability and sometimes the exposure (Source: GIZ and EURAC 2017)



Reducing risk through adaptation

Definition Adaptation: '*The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities.' (IPCC 2014a, p.40)*

Generally, adaptation measures can reduce the risk by reducing vulnerability and, in certain cases, also exposure (see Figure 4). Vulnerability can be reduced either by decreasing sensitivity or by increasing capacity. For instance, if a flood risk needs to be tackled, the restoration of wetlands may be able to reduce sensitivity, while more knowledge on flood resistant buildings may increase capacity. In principal, adaptation measures may also focus on reducing exposure, e.g. by relocating farmers to an area that is not drought-prone. However, these measures are oftentimes politically sensitive and not always viable. It is therefore recommended to focus on adaptation measures targeting the sensitivity and/or capacity analysed within the impact chain. In the context of EbA, measures that could decrease sensitivity – for instance by restoring ecosystem services– are of particular interest.

→ *For more information on identifying and planning EbA options see Module 9.*

→ *For more detailed information on the differences in the concepts, see Chapter II of the Risk Supplement (p. 11-21).*

III

Guidelines

This chapter provides detailed instructions on how to conduct a risk assessment within the context of EbA. The chapter is structured along nine sequential modules describing key steps and guiding questions to be considered for risk assessments and how such assessments can support the identification and spatial prioritisation of adaptation measures including both ecosystem-based and conventional options.

EbA is a landscape approach – i.e. a framework to integrate policy and practice for multiple land uses within a given area –, where decisions (policies, planning, and implementation) need to be based on spatial information. The generic instructions and the illustrative application example imply a strong spatial perspective and suggest the use of Geographical Information Systems (GIS) to support the risk assessments.

Table 1 provides an overview of the content of the nine modules and their key means of implementation.

Table 1: Overview of the nine modules of this Guidebook

Module	What you will learn in this module	Key means of implementation
1 Preparing the risk assessment	You will assess the initial situation of the analysis, define objectives and decide on the topic and scope of the climate risk assessment, especially with regard to EbA. You will also plan the implementation of the risk assessment.	Desktop-based; correspondence and interviews with experts and relevant actors
2 Developing impact chains	You will get acquainted to and develop impact chains. You will learn how these chains form a central element of the overall risk assessment approach and how they provide entry points for the identification of EbA options. You will define the underlying factors for the three risk components hazard, exposure and vulnerability.	Desktop-based and workshops with experts for the thematic area(s) at stake; other relevant actors
3 Identifying and selecting indicators for risk components	You will identify and select indicators in order to quantify the factors that determine the risk. You will learn what makes a good indicator and how to phrase it with reference to a critical state.	Desktop-based and workshops with experts for the thematic area(s) at stake
4 Data acquisition and management	You will learn how to acquire, review and prepare the data you need.	Desktop-based; data acquisition through data transfer, data analysis, expert interviews, questionnaires, etc.
5 Normalisation of indicator data	You will normalise the different indicator datasets into unit-less values with a common scale from 0 (optimal) to 1 (critical). You will learn about setting thresholds of a normalisation range for quantitative indicators and how to apply a five-class evaluation scheme for categorical values.	Desktop-based; experts for the thematic area(s) at stake (particularly for the threshold definition)
6 Weighting and aggregating indicators	You will learn how to weigh indicators if some of them are considered to have a greater or smaller influence on a vulnerability component than others. You will also aggregate individual indicators to the three risk components.	Desktop-based
7 Aggregating risk components to risk	You will aggregate the risk components 'hazard', 'vulnerability' and 'exposure' to a single composite 'risk indicator'.	Desktop-based
8 Presenting and interpreting the outcomes of the risk assessment	You will learn how you can present and interpret the results of the risk assessment.	Desktop-based for the preparation, dissemination events for the presentation
9 Identifying EbA options	You will firstly see how impact chains and risk assessments can support the identification and spatial planning of EbA options. The module subsequently explains the concept of 'EbA co-benefits' and describes how you can specify them.	Desktop-based; workshop with key actors for strategy development and planning

Module 1
Preparing the risk assessment

This module outlines four essential steps and useful guiding questions for preparing a climate risk assessment in the context of EbA. It shows you how to assess the initial situation of your analysis, how to define objectives, decide on the topic and scope of the assessment (especially with regard to EbA), and make key decisions that will influence the entire risk assessment. It is important to include relevant actors already at this stage of the process. This ensures transparency and provides substantiation for any decisions and open questions.

Step 1
Understand the context of a climate risk assessment for adaptation

Each risk assessment takes place in a unique setting. Taking time to explore this context helps you define the objectives and scope of the assessment and to plan resources accordingly.

? GUIDING QUESTIONS:

- *At what stage of adaptation planning is your assessment taking place? And what are the development and adaptation priorities (if already defined)?*

The risk assessment usually occurs in the context of broader processes such as the preparation for a National Adaptation Plan (NAP) with clear development and adaptation goals and priorities. Identifying and understanding such processes helps to articulate the objective and to highlight potential synergies between the assessment and other processes.

- *Which institutions and resources can and should be involved in your risk assessment?*

Choosing the relevant partner institutions and stakeholders is decisive for the participative process, as it creates co-ownership and has an impact on the success of the assessment. Local institutions from different levels (community, regional, national), experts and stakeholders from different sectors add valuable knowledge to the assessment process, and their participation will enhance acceptance of the result.

Step 2
Identify objectives and expected outcomes

The decision to conduct a climate risk assessment is usually driven by a particular need or information gap. This step helps you define the objectives of the assessment and the intended outcomes and outputs. Knowing what to expect also makes it easier to manage the expectations of participating institutions and stakeholders.

? GUIDING QUESTIONS:

- *Which processes will the climate risk assessment support or feed into?*

In order to define the objective of the risk assessment, ongoing adaptation processes and the information requirements of relevant stakeholders need to be taken into account.

- *What do you and key stakeholders wish to learn from the assessment?*

Typical examples for objectives include the identification of risk hotspots in a certain area, or the identification of relevant measures that help to reduce the climate risk.

- *Who is the target audience for the risk assessment results?*

It is crucial to clearly define the target audience such as: local communities, ministries and national agencies tasked with adaptation planning, decision makers at different administrative levels.

- *What outputs do you expect?*

Possible desired outputs may be a map of risk hotspots, a set of (ecosystem-based) adaptation measures, their co-benefits and drawbacks, or a narrative analysis of a climate risk and its determining factors.

Step 3
Determine the scope of the assessment

Once you have identified the objectives and the context, you need to define the scope of the risk assessment. Knowing the scope is the basis for developing impact chains, the key component of this risk assessment, described in the next module.

? GUIDING QUESTIONS:

- *What exactly is your risk assessment about?*

You should determine the thematic focus of the assessment (e.g. a certain sector or application field, such as river basin management, agricultural production, water provision, etc.) and the overall relation between climate, ESS and risk in the area under consideration. Are you considering particular social groups? Does your assessment focus on just one subject or on combined subjects (e.g. risk to agricultural production affecting crops *and* livestock)? And which elements at risk (e.g. farmers, agricultural land, infrastructure, etc.) should you consider?

- *What climate related risks do you intend to assess?*

Are you, for instance, addressing the risk related to hazardous events such as flooding, or the risk related to trends such as increasing precipitation? Which events and impacts were observed in the past? Which known risks and impacts may be relevant for the future?

- *What major non-climatic drivers influence these risks?*

For a full assessment, you also need to consider how non-climatic drivers (such as unsustainable land use or changes in income situation of local communities) influence the risks.

- *What ecosystems and relevant ecosystem services affect these risks?*

Try to find out which ecosystems play a key role in reducing the risks and how they are managed. What key ecosystem services (e.g. water regulation, flood prevention, erosion control) do they provide that could reduce risks?

- *What is the geographical scope of your assessment and what spatial detail are you aiming for?*

Decide whether the assessment will focus on a specific community, a district/province, or on a clearly definable ecosystem (e.g. a river delta or protected natural area), on a single spatial unit (e.g. one district) or several areas that need to be compared (e.g. two or more districts). Is there a specific spatial scale that needs to be considered?

- *What is the time period of the assessment?*

A climate risk assessment can refer to different time (reference) periods. It is advisable to start with the current climate risks related to impacts from current climate variability, climate extremes and recent changes of climate conditions. Additional future climate risks (related to impacts due to future climate variability and future climate extremes, e.g. for the year 2050) can subsequently be elaborated.[2]

- *What are the right methods for your climate risk assessment?*
  Risk assessments can incorporate various different methods, using quantitative models (e.g. climate or hydrological models), participatory approaches or a combination of the two.

Step 4
Prepare an implementation plan

Based on the understanding gained through Steps 1 to 3 of this module, you can develop a concrete work plan for implementing the risk assessment. In doing so, you need to involve the participating institutions and stakeholders and carefully consider the resources available.

? GUIDING QUESTIONS:

- *Which people and institutions are involved?*
  Take sufficient time to identify key actors and institutions relevant for conducting the risk assessment. This will avoid implementation delays at a later stage of planning.

- *Tasks and responsibilities: Who has what?*
  It is crucial that all key stakeholders involved have a clear and thorough understanding of the objectives and their roles. This will encourage cooperation and reduce overlaps in responsibilities.

- *What is the time plan of the risk assessment?*
  Realistic time planning is key, especially when dealing with unexpected challenges. It can be helpful to include milestones in the implementation plan and to ensure proper monitoring.

- *What resources are required?*
  As these assessments usually call for large amounts of data, it is imperative to plan sufficient time for data acquisition, preparation and processing. The more data-driven the assessment, the more technical capacities and skills are required.

→ *For practical guidelines how to develop a concrete work plan for implementing the risk assessment see Vulnerability Sourcebook, p. 40–53. A template assessment implementation plan is included in Annex 1 of the Vulnerability Sourcebook.*

2 Ideally next to future climate-related hazards also future vulnerability and exposure pathways should be considered. However, due to data constraints, this is in most cases not feasible.

APPLICATION EXAMPLE: River basin management – preparing the risk assessment

Step 1
Understanding the context of a climate risk assessment for adaptation

■ *At what stage of adaptation planning is the assessment taking place? Are there already risk or impact assessments?*

In the river basin, there is a growing awareness of the necessity to implement adaptation measures. An adaptation strategy at national level was in preparation, future concrete actions needed to be based on a more sophisticated risk assessment. This was the first climate risk assessment in the river basin.

■ *What are the development and adaptation priorities (if already defined)?*

It was determined, that as a result of climate change, floodings will increase in frequency and in intensity in the river basin. Therefore, the local population is expected to face large economic losses due to crop failure and a decline in production. Ecosystem services such as water provision and regulation present unused potential for sustainable adaptation measures. A key priority is flood risk reduction through the implementation of EbA measures in the river basin.

■ *Which institutions and resources can and should be involved in the risk assessment?*

Key actors to be included in this risk assessment were the Regional Department of Water Management, the national Ministry of Environment, and – on the local level – river basin working groups and committees, communities and private sector representatives. Their involvement from the start and throughout the assessment was not only important to gather all available local knowledge, but also essential for the ownership of the process and the acceptance of the measures. During the implementation process, expert knowledge on potential measures, their feasibility and risk factors were gathered.

Step 2
Identifying objectives and expected outcomes

■ *What do you and key stakeholders wish to learn from the assessment?*

The team agreed that it was most important to determine the risk of river flooding for people's lives, damage to property and critical infrastructures, and (how) it can be reduced through adaptation, including EbA measures. And that the assessment should also specify which potential co-benefits and trade-offs EbA options might have.

■ *Which processes will the risk assessment support or feed into?*

It was evident that the outcome of the risk assessment (with its focus on EbA) would inform the Regional and National Adaptation Plan.

■ *Who is the target audience for the risk assessment results?*

The results of the risk assessment would primarily be presented to the local community, i.e.

all residents and especially landowners, leaders and farmers, regional governments and the relevant administrations and departments.

- *What outputs are expected?*

It was expected that by the end of the assessment process, there would be a map of flood risk hotspots and related ecosystem services, a list of indicators and datasets, a narrative analysis of the risk and its determining factors. Also, the assessment should help identify adaptation measures (incl. EbA) and locations where they can be implemented most efficiently.

Step 3
Determining the scope of the assessment

- *What exactly is the risk assessment about?*

The assessment aimed to determine the risk of damage to property and loss of lives due to flooding, considering the effect(s) of EbA measures, their co-benefits and drawbacks for the six districts in the river basin, considering all social groups.

- *What climate related risks should be assessed?*

The assessment focused on the risk of flooding caused by too much precipitation.

- *What events and impacts occurred in the past?*

River flooding due to too much precipitation had occurred both in the wet and in the dry season.

- *Which known risks may be relevant for the future?*

Precipitation increase during October and November (rainy season becomes wetter).

- *What major non-climatic drivers influence these risks?*

During the assessment process, the team found that the number of people living in the river basin is increasing. The major sectors agriculture, industry and mining, but also others, depend on water from the river and have modified the natural river flow by converting the natural vegetation, which had an important risk buffering function, into cropland and other land use types. The river runs through settlement areas, and houses are built in close proximity to the shore. Deforestation and wetland degradation are becoming more widespread. In parts of the basin, more than half of the population depends on income from agriculture. The area is economically deprived. There is a lack of spatial planning and only some flood resistant housing.

- *What ecosystems and relevant ecosystem services affect these risks?*

The western mountainous area up-stream is dominated by a large forest that plays an important role for water regulation and erosion prevention. The eastern lowlands are characterised by natural coastal forest and cropland. Several wetlands are located in the central part of the river basin. Their water retention capacity significantly reduces flood risks. In several places buffer zones are found along the river that prevent soil erosion and siltation of rivers.

- *What is the geographical scope of your assessment and what spatial detail are you aiming for?*

The assessment covered one river basin consisting of six administrative districts.

■ *What is the time period of the assessment?*

The assessment referred to current climate risks related to impacts from current climate variability.

Step 4
Preparing an implementation plan

■ *Which people and institutions are involved?*

It was decided that institutions such as the local office of an international development agency, the local university, the local government, and local non-governmental organisations dealing with ESS would be involved throughout the assessment process. In the preparation phase, meetings with all partner institutions and stakeholders were scheduled to introduce them to the climate risk assessment, the objectives, methodology and envisaged outcomes. Together with relevant partners, local water management authorities determined which institution needed to be involved in which step in the process and would be responsible for what task.

■ *Tasks and responsibilities: Who does what?*

Discussions with all partners involved in the assessment led to the following allocation of tasks: The international development agency was responsible for the methodological approach, guidance to the team, planning, organising and coordination. The local university would gather data (qualitative and quantitative) and take on data management and mapping. The local non-governmental organisation would provide local knowledge, take part in action groups and passes the information on to other people in the community. The local government would participate in all meetings, provide technical expertise and information about ongoing adaptation planning processes.

■ *What is the time plan of the risk assessment?*

The risk assessment was to be completed in 18 months.

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Module 2
Developing impact chains

This module gives an introduction into the development of impact chains. They form a central element in the overall risk assessment approach and provide entry points for the identification of EbA options. First, the concept and the key elements of impact chains are described, then the key steps in the development of such chains will be introduced, and finally you will see how impact chains can inform the identification of EbA measures.

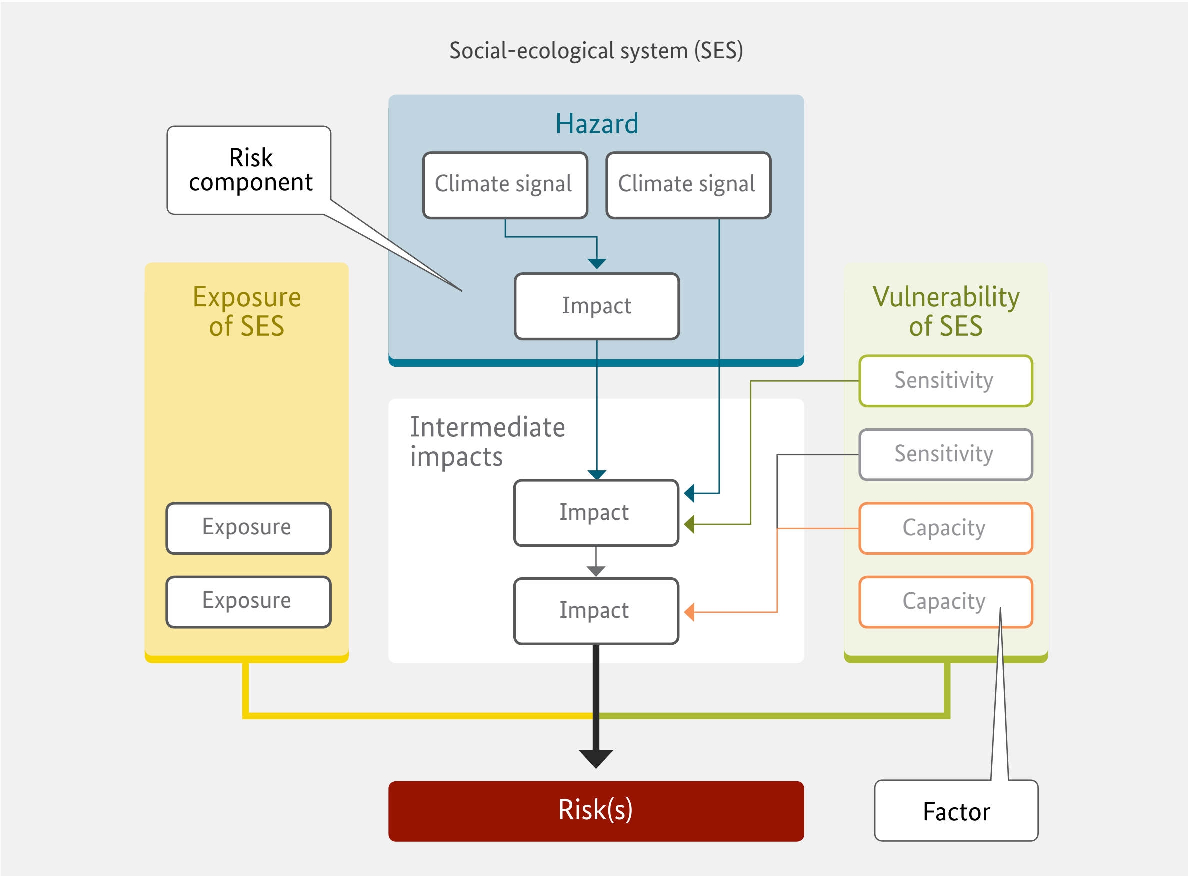
A climate risk project that aims to identify adaptation measures on a more qualitative level may already conclude with the development of impact chains. However, an assessment with the objective of comparing climate risk in different regions or of enabling future monitoring and evaluation (M&E) needs to quantify risks and their components and thus to continue with Module 3.

Impact chains: definition and key elements

An impact chain, or cause-effect chain, is an analytical tool that helps you better understand, systemise and prioritise the factors that drive risk in the system of concern. The structure of the impact chain concurs with the key components of the conceptual framework presented in chapter II. Impact chains – as proposed in the *Vulnerability Sourcebook,* its *Risk Supplement* and in this Guidebook – always have a similar structure (see Figure 5): a climate signal (e.g. a heavy rain event) may lead to a direct physical impact, causing a sequence of intermediate impacts (e.g. erosion upstream, contributing to flooding downstream), which – due to the vulnerability of exposed elements of the social-ecological system (SES) – finally lead to a risk (or multiple risks).

Impact chains are composed of risk components (hazard, exposure, vulnerability; see coloured containers in Figure 5) and underlying factors for each of them (white boxes). The hazard component includes factors related to the climate signal. The vulnerability component comprises factors related to the sensitivity of the SES and the social capacity. The exposure component is comprised by one or more exposure factors. In contrast to these three components, intermediate impacts are not a risk component by themselves, but merely an auxiliary tool to fully grasp the cause-effect chain leading to the risk. By definition, they are a function of both hazard and vulnerability factors. This means that all impacts identified which do not only depend on the climate signal, but also on one or several vulner-

Figure 5: Structure and key elements of an impact chain (Source: GIZ and EURAC 2017)



ability factors need to be placed here. As opposed to a climate signal, an intermediate impact can be influenced by measures.

Impact chain development: key steps and basic principles

The development of impact chains comprises four sequential steps that are briefly described in this section: (1) identify potential climate impacts and risks, (2) determine hazard(s) and intermediate impacts, (3) determine the vulnerability of the social-ecological system, and (4) determine exposed elements of the social-ecological system. A sound understanding of the system of concern and the incorporation of expert/local knowledge through a participatory process (e.g. workshops, focus group discussions, etc.) form the basis for the development of impact chains. Building such impact chains is an iterative process. New relevant aspects can emerge during the development process.

There are a number of basic principles to consider when you brainstorm on the various factors to generate an impact chain:

- *To avoid double counting, a factor should be allocated to one risk component only.*

- *Factors allocated to one component should (as much as possible) be independent of factors of other components.*

- *Factors representing potentially hazardous events can either be allocated to the hazard component (preferably when these events are external triggers, which can hardly be influenced by adaptation within the system) or classified as intermediate impacts (preferably when they are influenced by the vulnerability and can be reduced by adaptation)*

→ *For further details on basic principles see Vulnerability Sourcebook, p. 58–59.*

Step 1
Identify potential climate impacts and risks

? GUIDING QUESTIONS:

- *Which major climate impacts and risks affect your system of concern?*

The development of an impact chain always starts with the identification of potential climate impacts and risks (e.g. risk of loss of life due to a specific hazard). If the risk assessment covers more than one risk (e.g. risk of loss of life and risk of damage to critical infrastructure due to tropical storms), you might want to develop different impact chains for each risk. These could be combined in a later stage of the risk assessment (see Module 7).

Step 2
Determine hazard(s) and intermediate impacts

? GUIDING QUESTIONS:

- *Which climate-related hazards pose a risk to your system of concern?*
- *Which intermediate impacts link the hazard(s) and the risk(s)?*

First, identify the relevant climate signal(s) (e.g. too much precipitation) which lead(s) to the potential impacts and risks identified in Step 1. The climate signal leads to a sequence of intermediate impacts (which can be partly influenced by the vulnerability of the social-ecological system), such as too high water levels or increased flow velocity and flooding.

For all hazards and intermediate impact factors, we recommend a wording that implies a critical state, e.g. ‘too much precipitation’ rather than ‘precipitation’. With hazard factors and intermediate impacts identified, you now have a good basis for determining relevant vulnerability factors.

Step 3
Determine the vulnerability of the social-ecological system

? GUIDING QUESTIONS:

- *What are the main societal and ecological drivers of vulnerability of the social-ecological system?*
- *Which aspects contribute to ecological and societal susceptibility, and which factors determine the social capacities to cope with hazards or to adapt to changing conditions in the system?*

Factors allocated to the vulnerability component should represent two aspects, sensitivity and capacity, where capacity includes factors associated with the (lack of) *short-term coping* as well as *long-term adaptive capacity* (see definitions of coping and adaptive capacity in chapter II).

An unambiguous allocation of the individual factors to either of the two sub-components is often not possible. This, however, is unproblematic since, at a later stage, the factors of both sub-components will be aggregated into the component vulnerability of the social-ecological system.

Please consider the state of relevant ecosystems, their services (particularly regulating services) and how they might contribute to increased climate risk(s) and/or help to mitigate risk(s).

Step 4
Determine exposed elements of the social-ecological system

? GUIDING QUESTIONS:

- *Which elements of the social-ecological system are present in places that could be adversely affected by hazards?*

'Exposure' refers to the presence of relevant elements of the social-ecological system (e.g. people, livelihoods, assets, but also species, ecosystems, etc.) in places that could be adversely affected by hazards. The scoping process in Module 1 already provided initial ideas about the ex-

BOX 2

Additional interlinkages between factors of the impact chains

Please note that these four steps lead to the creation of separate boxes showing a limited number of relationships that are not further specified. In reality, any system comprises many more connections and cross-linkages of different forms, intensities and significance. You can draw these interlinkages in the impact chains and thus create a paper model that helps to understand the complexity of reality. However, these additional connections, which do not directly lead from a factor to another, cannot be operationalised within the scope of this risk assessment.

posed elements, which now need to be further specified. For instance, the more people live in flood-prone areas, the higher the related risk. In most cases, the exposure component will consist of considerably less factors than hazard or vulnerability.

→ *For further details on the four key steps see Risk Supplement, p. 27–37, and Vulnerability Sourcebook, p. 56-66.*

How can impact chains inform the identification of EbA measures?

Impact chains not only provide an understanding of the key components and underlying factors contributing to potential climate impacts and risks, but also support the brainstorming on potential adaptation options or 'packages' – including EbA. The vulnerability factors can serve as starting points for such a brainstorming exercise, and are of particular interest with regard to EbA factors related to the ecological dimension of the social-ecological system (i.e. the ecosystems and their services). If the impact chain, for example, shows a sequence of causes and effects, leading from deforestation to reduced erosion prevention (loss of a regulating service) and increased flooding in downstream areas, then it is evident that afforestation or reforestation programmes can be suitable EbA measures for tackling the flooding problem.

APPLICATION EXAMPLE: Developing impact chains

Step 1
Identification of potential climate impacts and risks

The scoping phase (Module 1, Step 3) revealed that the main risk in the basin is the 'risk of damage of property and loss of live due to flooding'.

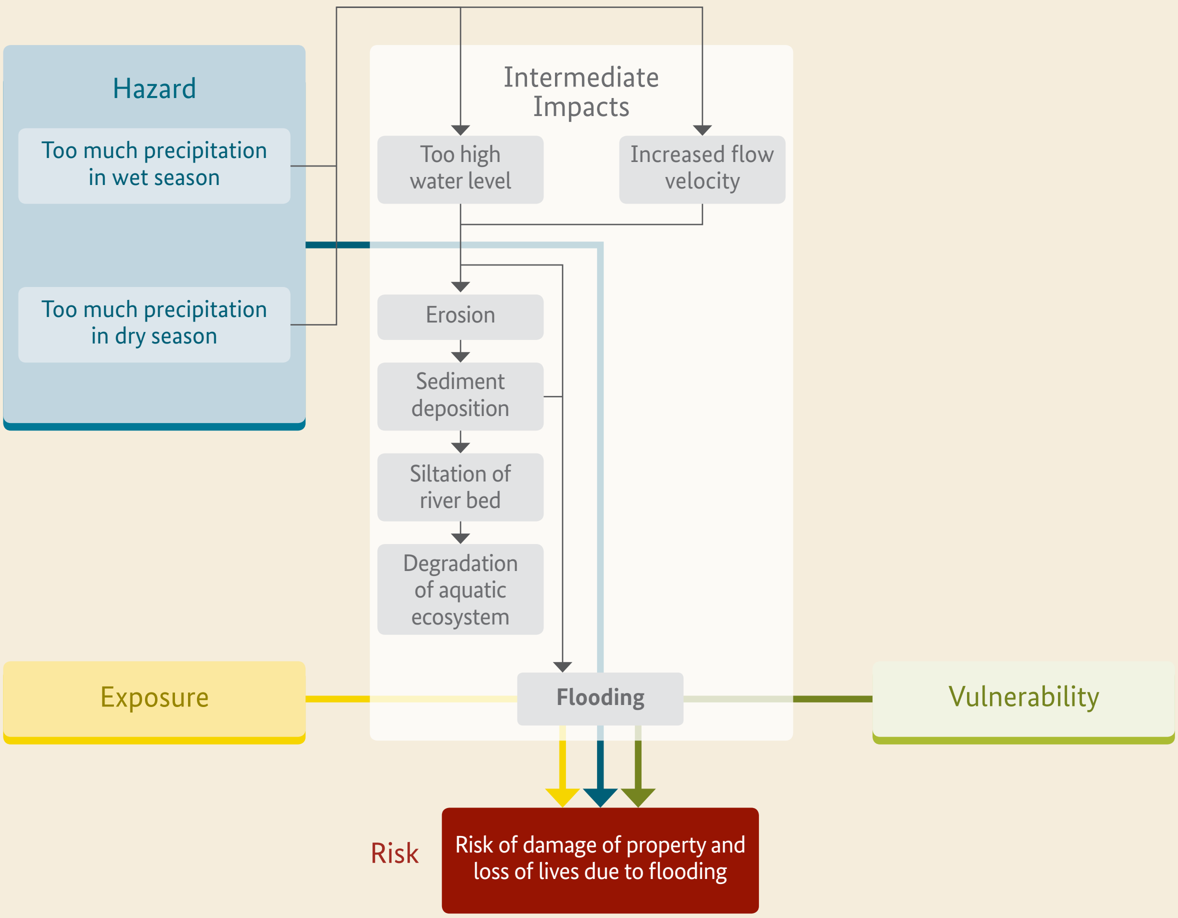
Step 2
Determining hazards and intermediate impacts

Figure 6 shows the draft impact chain with intermediate impacts and hazard factors for the river basin. Here 'too much precipitation' has been identified as the key hazard (note: the definition of thresholds determining 'too much precipitation' will be introduced in Module 3). These readily measurable factors led to more complex factors such as too high water level and increased flow velocity and in turn to increased erosion, causing sediment deposition in downstream areas and increased flooding.

Step 3
Determining the vulnerability of the social-ecological system

Figure 7 shows the impact chain complemented by relevant vulnerability factors. Linking

Figure 6: Impact chain with intermediate impacts and hazard factors identified



vulnerability factors with the related intermediate impacts helped to understand cause-effect relationships, e.g. the intermediate impact 'erosion' in the catchment is not only a result of too high water levels and increased flow velocity, but also directly related to 'deforestation' and the deterioration of the ESS 'erosion protection'.

Note that vulnerability factors in the impact chain were phrased expressing a critical state, e.g. 'wetland degradation' instead of 'wetland', or 'lack of water and wetland management capacity' rather than 'water and wetland management capacity'.

The impact chain indicates the distinction between *social* and *ecological sensitivity factors* as well as *capacity factors* and highlights the role of ecosystem services. For example, the high dependency on agricultural income in the river basin leads to deforestation which in turn leads to reduced erosion protection and consequently to erosion.

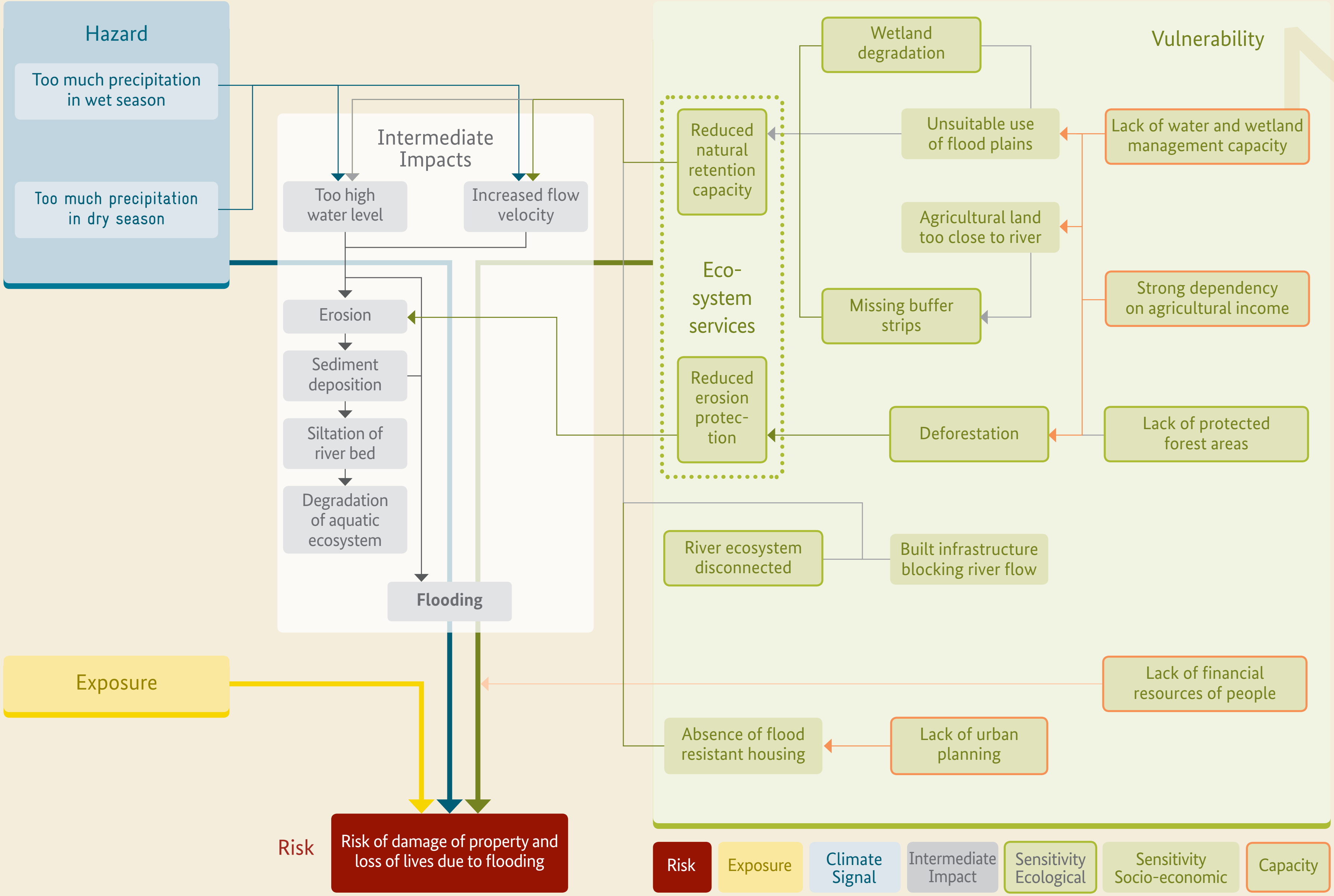


Figure 7: Impact chain with vulnerability factors added, including ecological and social sensitivity and capacity

Step 4

Determining exposed elements of the social-ecological system

The brainstorming exercise with relevant stakeholders revealed that, in the past, the elements frequently affected by floodings in the river basin were

- *people,*
- *property and buildings, and*
- *critical infrastructure, more specifically power plants.*

Figure 8 shows the impact chain, which now includes exposed elements.

As indicated in the general introduction of Module 2, the impact chain can also serve as a basis for the identification of adaptation measures. Figure 9 shows the impact chain with those factors highlighted that can serve as *potential entry points* for adaptation practitioners working on natural resource conservation and management. For example, the impact chain shows that, according to the consulted experts, the unsustainable use of floodplains in the river basin has led to wetland degradation (ecosystem) and in consequence to reduced natural retention capacity (regulating service). Additional factors contributing to the ecological dimension of vulnerability in the river basin are: degradation of forest ecosystems resulting in reduced erosion control (regulating service); lack of protected areas; disconnected river ecosystems.

Based on such a visualisation, the following EbA options were identified (see Table 2 and Figure 10): (1) wetland restoration, (2) retention ponds, (3) riparian zone restoration, (4) afforestation / reforestation, and (5) buffer strips along rivers.

Table 2: Ecosystem-based (green dots) and conventional (blue dots) adaptation options; cf. Figures 8-10

	Ecosystem-based Adaptation options	Conventional adaptation options
1	Wetland restoration	Capacity building
2	Retention ponds	Livelihood diversification
3	Riparian zone restoration	Communication & awareness campaigns
4	Afforestation/reforestation	
5	Buffer strips	

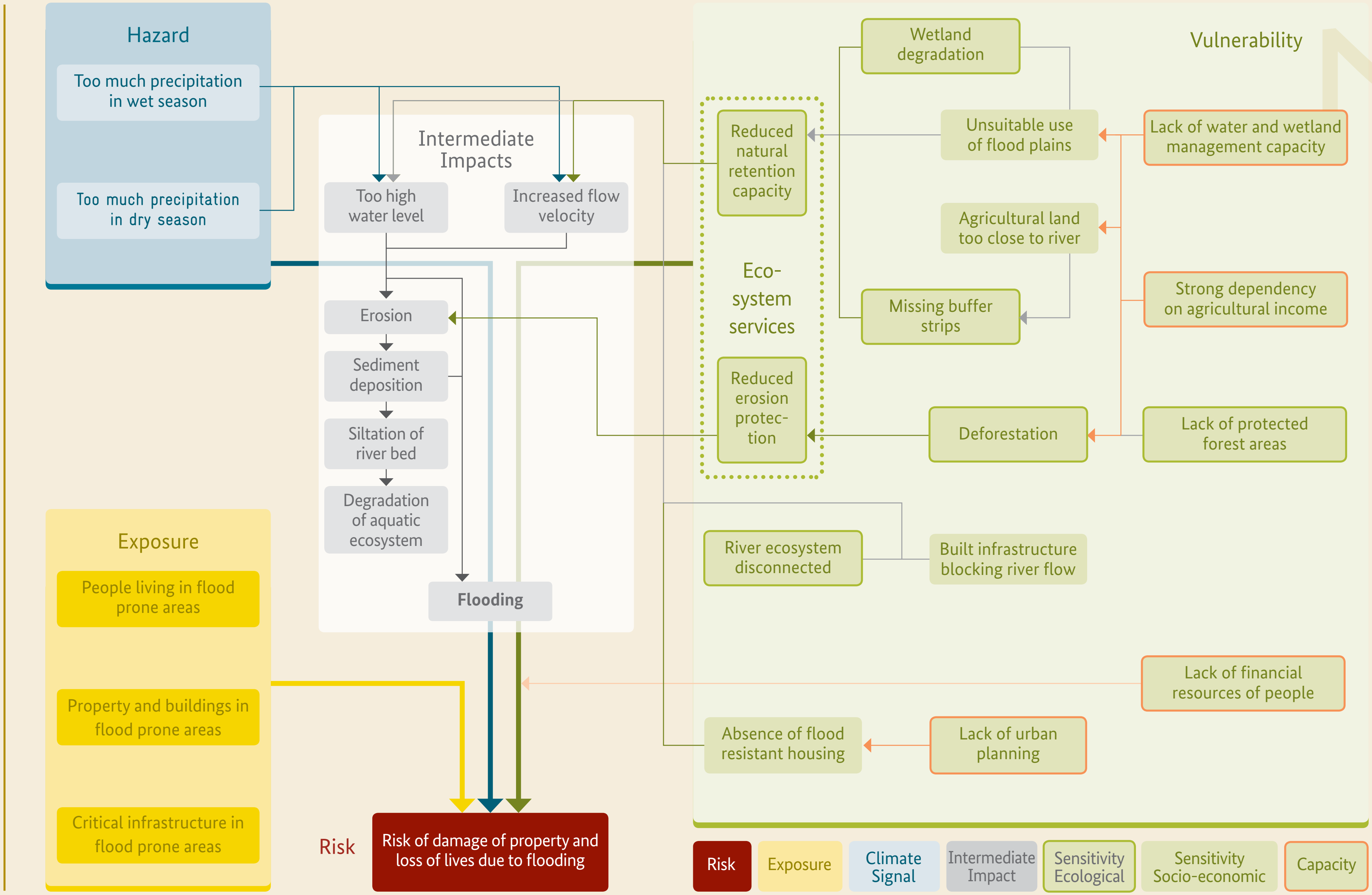


Figure 8: Impact chain with exposure added

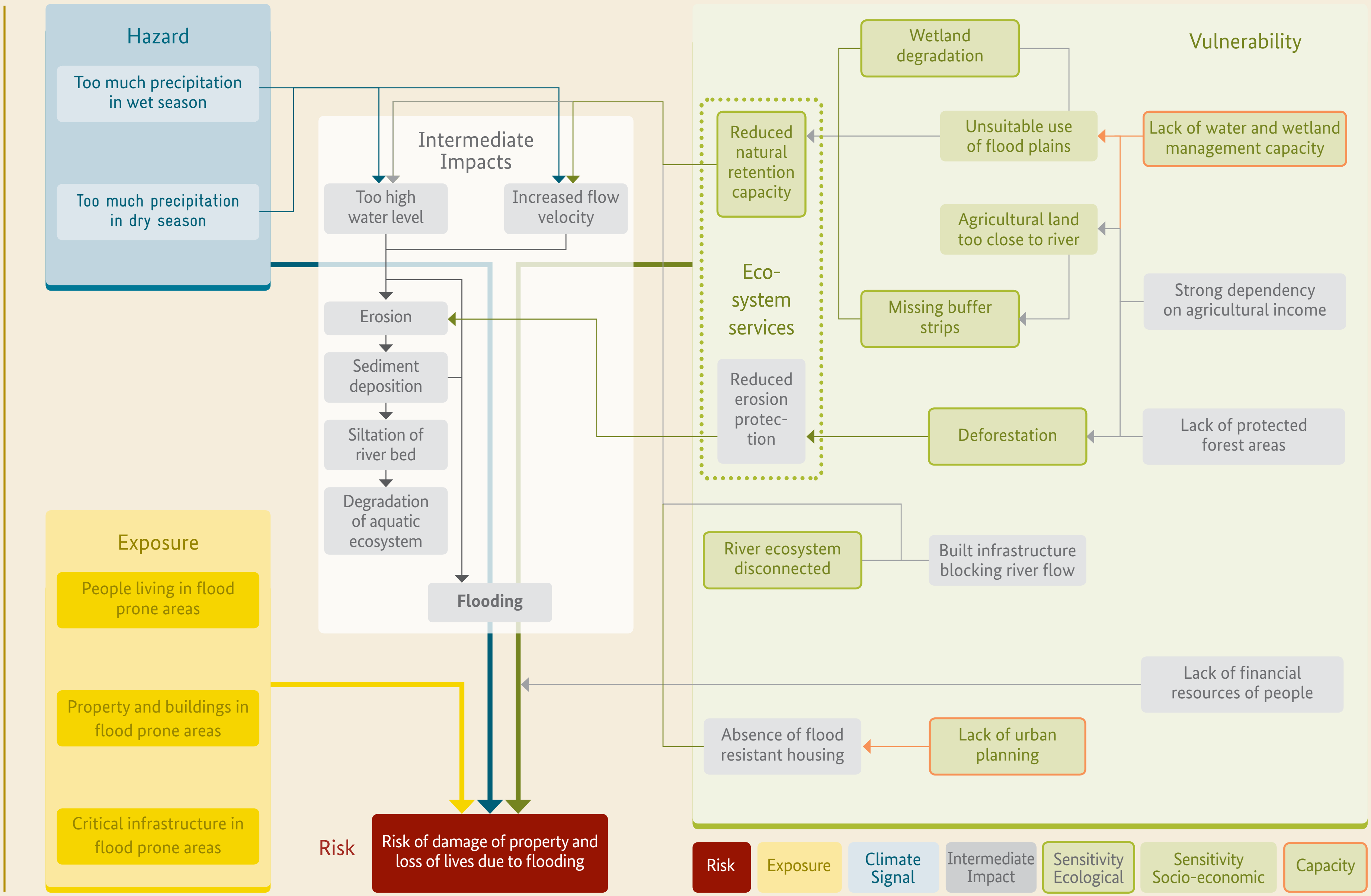


Figure 9: Entry points for adaptation practitioners working on natural resource conservation and management (green and orange boxes)

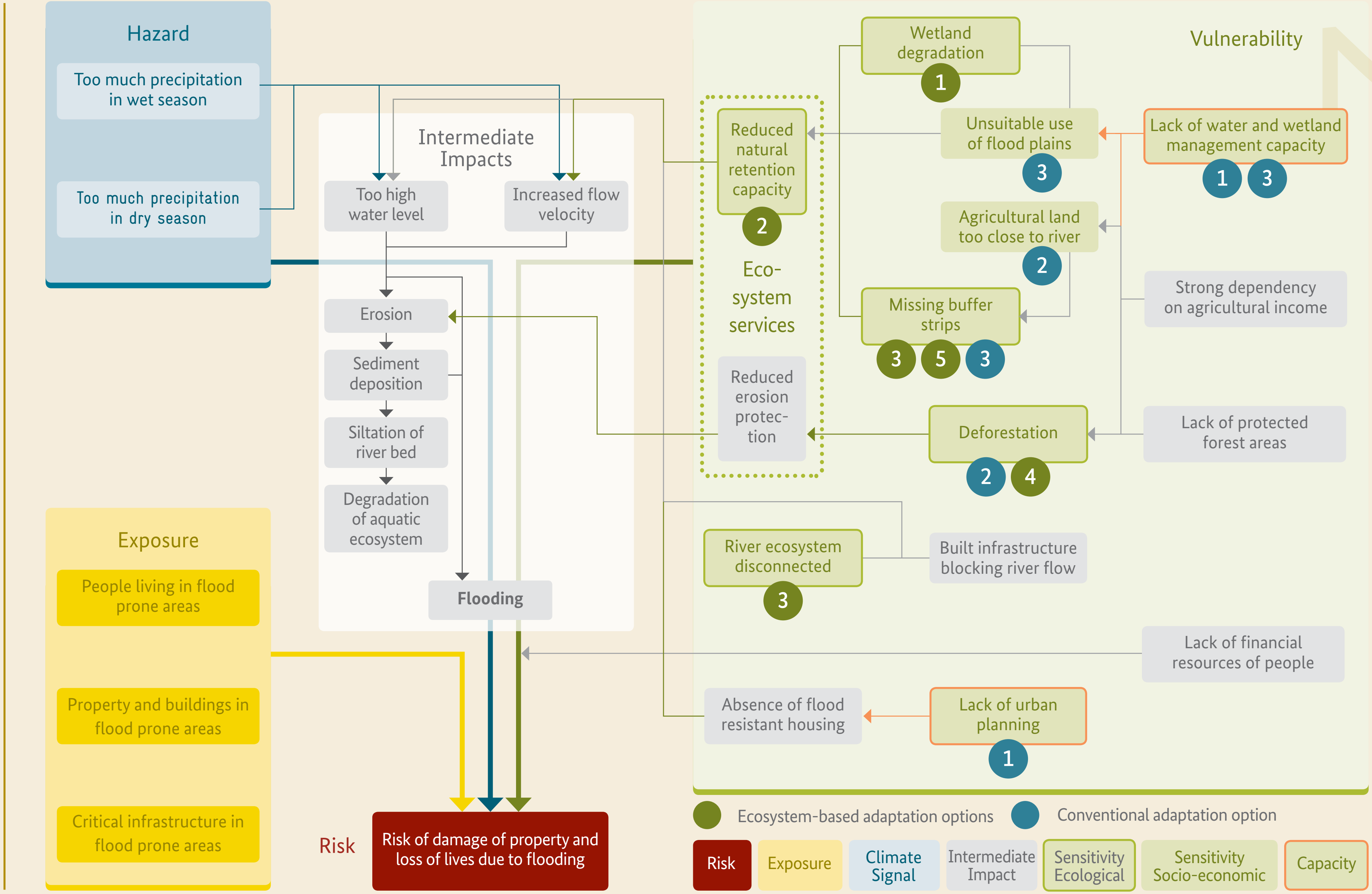
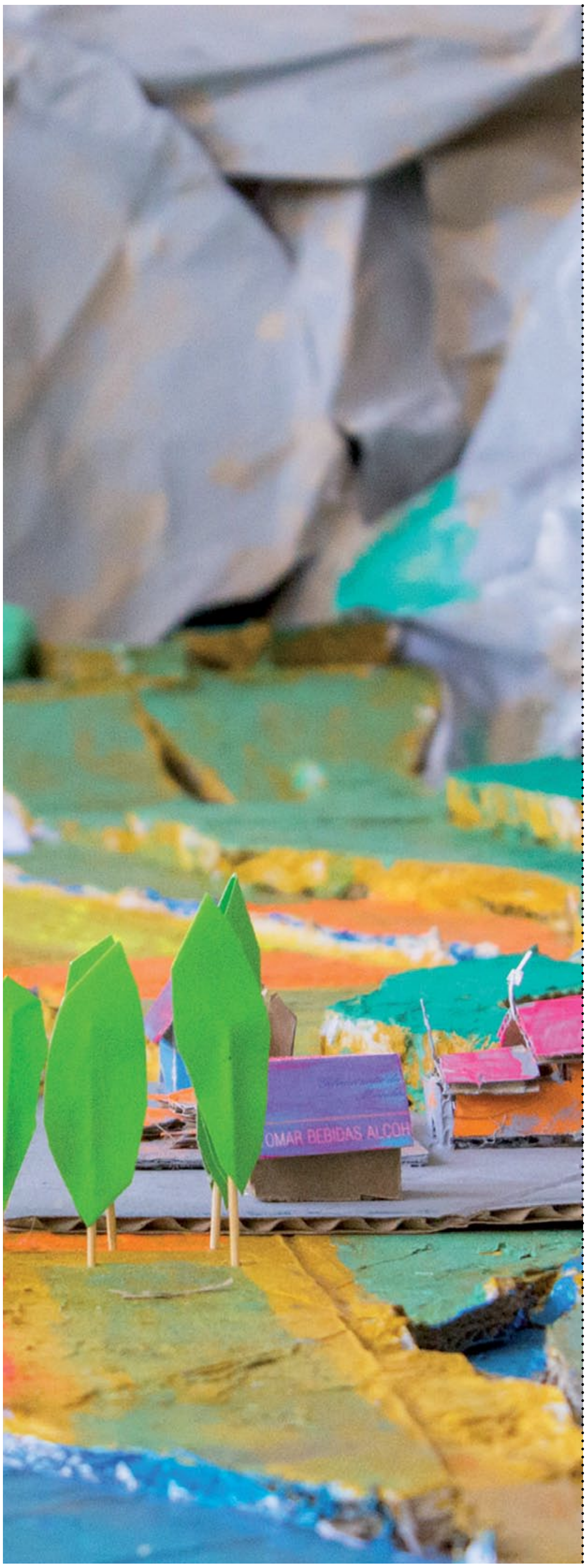


Figure 10: Ecosystem-based (green dots) and conventional (blue dots) adaptation options – see also Table 2



m3

Module 3

Identifying and selecting indicators for risk components

This module explains how to select indicators to quantify the factors determining the risk. The guiding question here is: How to assess the various factors that lead to the risk?

Good indicators for risk components are

- *valid and relevant (they represent well the issue you would like to address),*
- *practical and affordable (they are accessible with reasonable efforts and resources),*
- *clear in their direction (an increase in value is unambiguously positive or negative with relation to the factor and risk component),*
- *phrased with reference to a critical state (relevant according to the AR5 risk approach).*

To quantify *hazard factors*, it is particularly advised to to use numbers representing intensities (for example 'water level > 1 m of average') or frequencies (for example 'heat days per year') to describe the potential occurrence of a hazardous event. The hazard factor 'too much precipitation', for instance, could be phrased as 'number of days with more than 100 mm of precipitation', thus referring to a critical state.

Keep in mind that *intermediate impacts* are not risk components by themselves, but only represent an auxiliary tool to understand the cause-and-effect relationship leading to the risk. For this reason, they will not be included in the aggregation to the overall risk (see Module 7) and thus do not have to be represented by indicators.

Step 1
Selecting indicators for hazards

In this step, you select indicators describing *climate drivers* or *hazards* such as temperature extremes or severe precipitation events leading to intermediate impacts.

Step 2
Selecting indicators for vulnerability and exposure

In order to determine indicators describing vulnerability you need to select indicators for the level of sensitivity and of capacity. For each indicator you specify the direction: does a high value represent a high risk or a low risk? When selecting indicators for the capacity component, you need to consider both coping and adaptive capacities. For exposure, useful indicators are typically numbers, densities or proportions (e.g. 'percentage of population living in a floodplain').

Step 3
Check if your indicators are specific enough

In this step, you should check again that each indicator is a suitable description of the factor, that it is explicitly phrased, and that it has a clear direction with regard to the risk considered.

Step 4
Create a list of provisional indicators for each risk factor

At this point, you will have identified at least one indicator per factor in the impact chain. Now compile all indicators in a table. It should contain the relevant information about each indicator: the reasons for selecting it, the spatial as well as temporal coverage, unit of measurement, intervals for updates, and potential data sources required.

→ *For details see Vulnerability Sourcebook, p. 74–84, and Risk Supplement, p. 42–46.*

APPLICATION EXAMPLE: Identifying and selecting indicators for risk

Step 1
Selecting indicators for hazards

Two factors describing the hazard were selected. Both are climate drivers, both have to do with precipitation and both can be represented by indicators available from observations: From consultations with local experts, it was known that precipitation of more than 100 mm in the wet season and more than 120 mm in the dry season over a certain number of days increases the risk of river flooding (critical state). Figure 11 illustrates indicators for two hazard factors.

Step 2
Selecting indicators for vulnerability and exposure

During workshops and consultations with local experts from the Regional Water Department, the Ministry of Environment and local leaders, a set of indicators was identified, describing the vulnerability factors defined in Module 2.

For the vulnerability factor 'absence of flood resistant housing', for example, it was decided to use 'percentage of elevated buildings' as an indicator. This indicator is valid as it represents the factor that ought to be assessed, it is reliable also for monitoring in the future, it has a precise meaning, it is clear in its direction (a higher percentage of elevated buildings decreases the vulnerability), the data needed came from an accessible source and was available at an appropriate temporal and spatial resolution. Figure 12 illustrates indicators selected for six *sensitivity*, four *capacity* and three *exposure factors*.

Step 3
Checking if the indicators are specific enough

For each selected indicator one needs to check again if it is sufficiently explicit, if it was phrased towards the risk approach by making sure it had a clear 'direction' and if spatial and temporal coverage and resolution were appropriate for the risk assessment. The team was confident that 'percentage of elevated buildings' represents a suitable sensitivity indicator for the factor 'absence of flood resistant housing' for the following reasons: it is directly related to the risk (a lower percentage of elevated buildings increases the risk) and the data available for this indicator was at household level and from the last census conducted two years ago, thus spatial resolution was high and the data represented the current situation well.

Step 4
Creating a list of provisional indicators for each factor

For each component, the indicators identified were listed in a table which displays the unit of measurement as well as their direction in relation to the risk (Table 3).

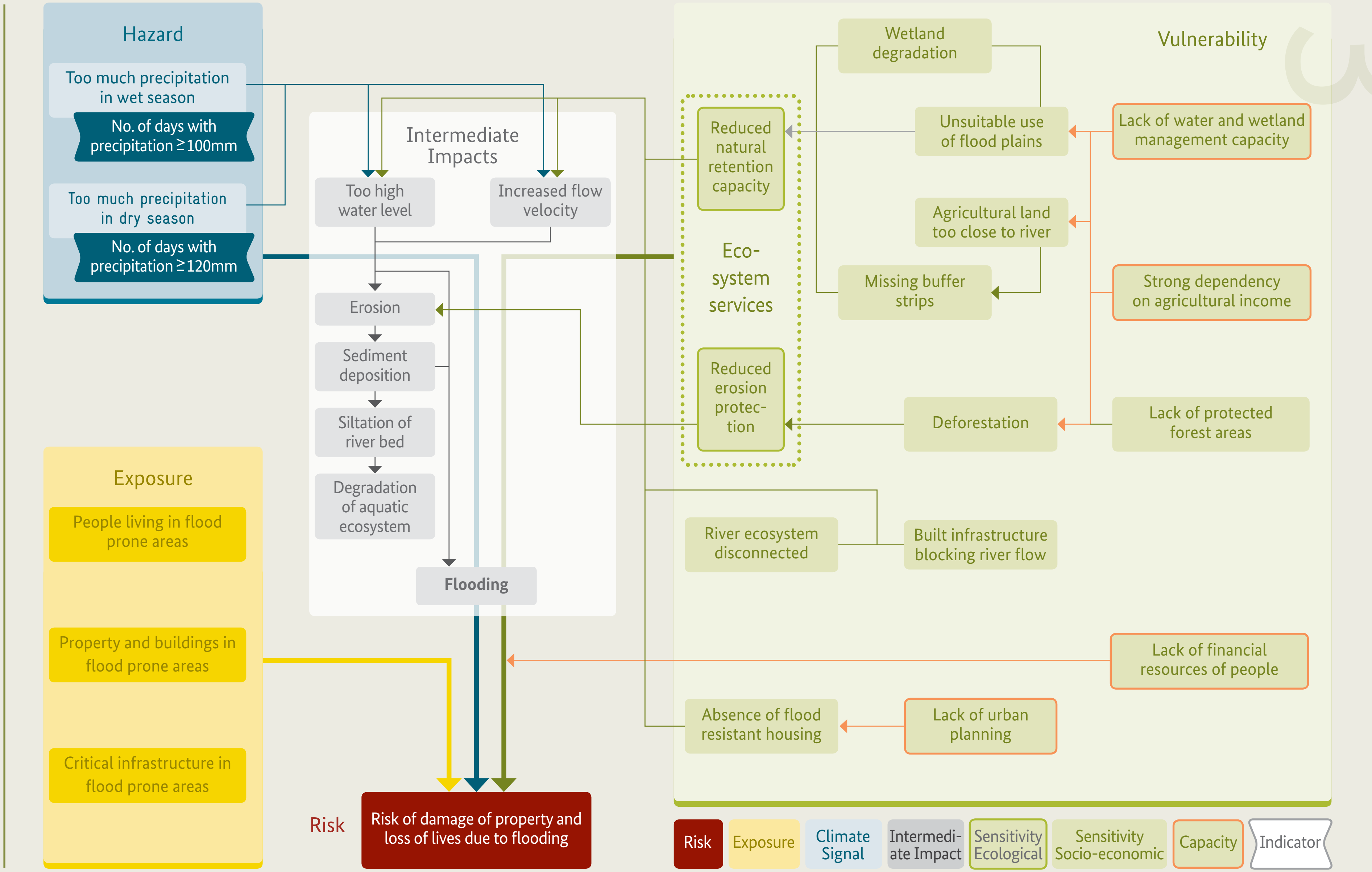


Figure 11: Impact chain with hazard indicators added

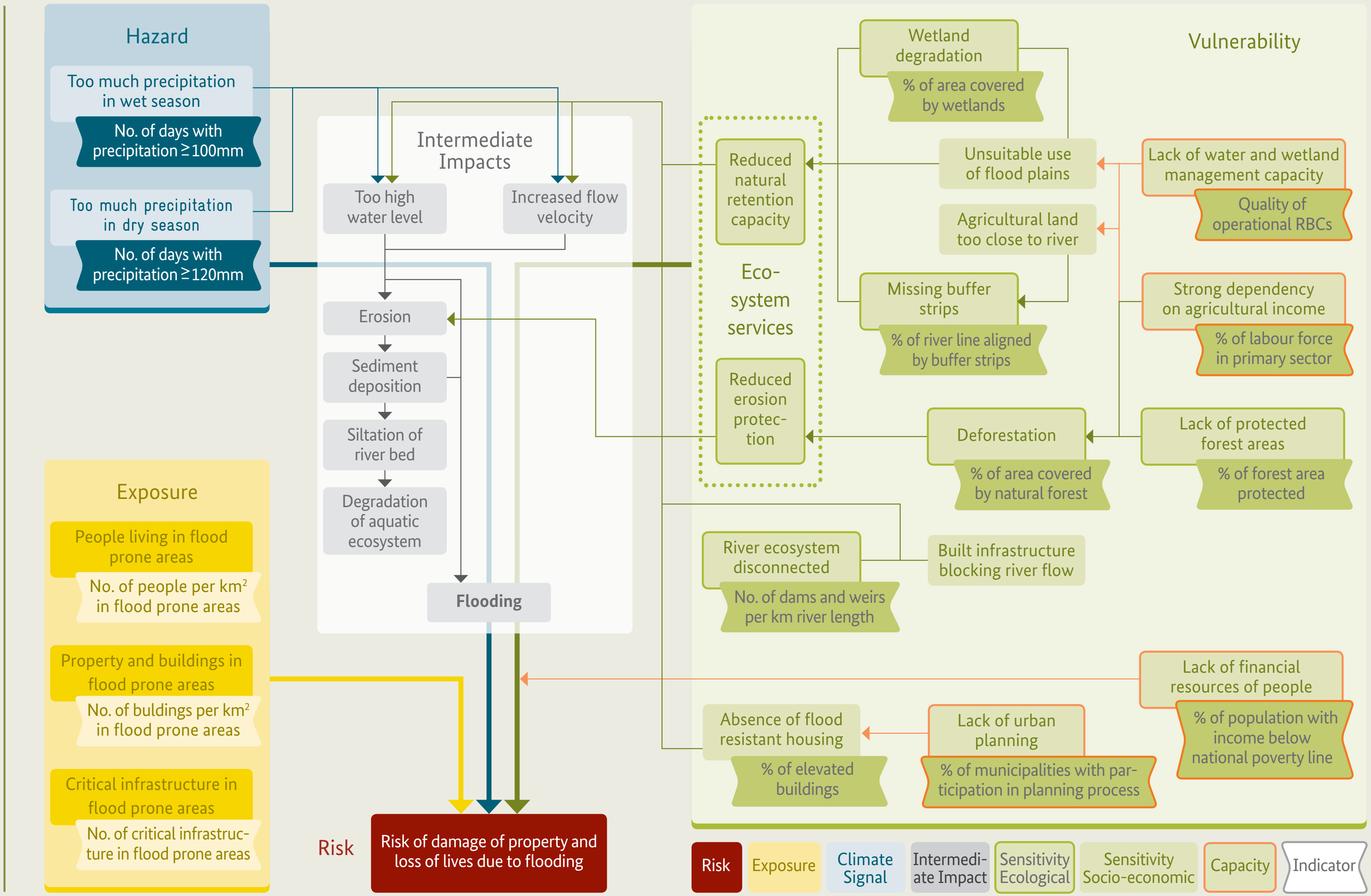


Figure 12: Impact chain with indicators

Table 3: Factors and indicators for each risk component (hazard, exposure and vulnerability) with the indication of the direction that contributes to an increase of risk (+ = greater indicator values; - = smaller indicators values)

Component	Factor	Indicator	Direction
Hazard	Too much precipitation in wet season	Number of days with precipitation ≥ 100mm	+
	Too much precipitation in dry season	Number of days with precipitation ≥ 120mm	+
Exposure	People living in flood-prone areas	Number of people per km² in flood-prone area	+
	Property & buildings in flood-prone areas	Number of buildings per km² in flood-prone areas	+
	Critical infrastructure in flood-prone areas	Number of critical infrastructure in flood-prone areas	+
Vulnerability	Wetland degradation	Percentage of area covered by wetlands	–
	Missing buffer strips	Percentage of river line aligned by buffer strips	–
	Deforestation	Percentage of area covered by natural forest	–
	Lack of protected forest areas	Percentage of forest area protected	-
	River ecosystems disconnected	Number of dams and weirs per km river length	+
	Absence of flood resistant housing	Percentage of elevated buildings	–
	Lack of water and wetland management capacity	Quality of operational River basin committees (RBCs)	–
	Strong dependency on agricultural income	Percentage of labour force in primary sector	+
	Lack of urban planning	Percentage of municipalities with participation in planning process	–
	Lack of financial resources of people	Percentage of population with income below national poverty line	+

m4

Module 4
Data acquisition and management

This Module shows how to acquire, review and prepare the data you need. It includes guidance on data collection, database construction and linking relevant data to the chosen indicators to allow risk analysis and modelling.

? GUIDING QUESTIONS:

- *What kind of data do you need?*
- *Who can provide that data?*
- *Do the data have the quality you need (format, temporal and spatial coverage)?*
- *How are you going to structure and store the data?*
- *How are you documenting your data with metadata and/or fact sheets?*

→ *For detailed guidance on data acquisition see Vulnerability Sourcebook, p. 88–103.*

APPLICATION EXAMPLE: Data acquisition and management

■ *What kind of data is needed?*

As the risk assessment within the context of EbA aims for spatial-explicit outputs, georeferenced data – either pixel based or referenced to administrative areas – was needed. The best quality information available to describe an indicator ought to be sourced. This information may be quantitative or qualitative.

Baseline geographic, recent climate, environmental, socio-economic and spatial planning data was required, including land cover (globally available as gridded data), river network, municipality boundaries and the extent of the flood-prone area. Regarding climate data, precipitation measured in mm from weather stations over the last 30 years (minimum ten years) was needed. Environmental data on forest, river and wetland management, socio-economic data on the number of people, buildings, critical infrastructures, on the ratio of people employed in the various economic sectors, the number of people living below the poverty line and spatial data on dam locations, elevated buildings and municipalities participating in the planning process – all theses datasets had to be obtained. In addition, information describing the quality of River Basin Committees (RBCs) had to be based on expert judgements, and thus suitable experts had to be found.

Exposure of people, of critical infrastructure and of buildings to flooding was determined by means of spatial analysis in a Geographic Information System (GIS), combining spatial data (representing areas affected by flooding) and data on gridded (i.e. pixel-based) population obtained from global data repositories with data on the location of buildings and critical infrastructures obtained from the local government.

■ *Who can provide that data?*

A data search and enquiry at the various institutions identified the following data sources: National Survey Office, Meteorological Office, Regional Statistical Office, Ministry for Environment, Regional Spatial Planning Department, National Office for Disaster Management, Regional University. At the Regional Spatial Planning Department, the experts were asked to rate the quality of River Basin Committees.

■ *Do the data have the quality that is needed (format, temporal and spatial coverage)?*

Regarding the spatial scale, data should be as detailed as possible. Most of the data was referenced to the districts; more detailed, sub-district information was available on land cover/use (raster information with 30m resolution). The information gathered had to cover all of the river basin and should not be older than two years. Spatially referenced, reasonably scaled data covering the six districts of the basin could be obtained for all indicators.

■ *How to structure and store the data?*

A data naming convention was defined and a logical folder structure created. Initially during data collection, all datasets were stored in a folder structure organised by source. Subsequently, once the data was being used, a folder structure organised by topic was created, and all data and metadata that ought to be used actively was copied in

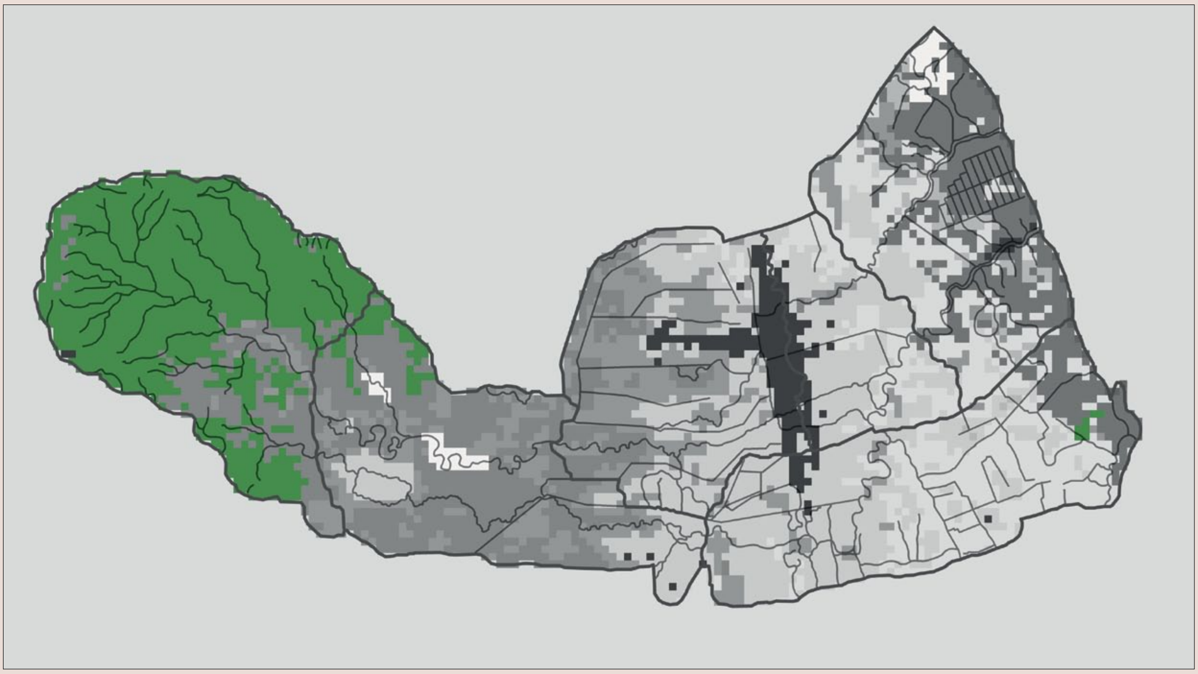
there. Thus a copy of the original data in its original state remained, which may be of interest as a reference at a later stage.

How to document the data?

Data and metadata was stored and managed using GIS. The metadata was stored together with original data. For documentation purposes, factsheets (one-page descriptions with a standardised structure) were created for all datasets used in the assessment.

Figure 13 shows a map of the land cover information for the river basin. From this dataset, the percentage of area covered by forest per district could be extracted. Table 4 shows the attributes for each indicator and district.

Figure 13: Visualisation of original data following data acquisition (forest cover extracted from land cover dataset)



Cropland (rainfed)	Shrubs	Wetlands
Cropland (irrigated)	Sparse vegetation	Rivers
Mosaic cropland/natural vegetation	Tree cover (flooded, saline water)	Districts
Mosaic natural vegetation/cropland	Settlements	River basin
Forest	Water bodies	

m4

G U I D E L I N E S

Table 4: Original data for the different indicators – attributes for each district

Component	Factor	Indicator	District 1	District 2	District 3	District 4	District 5	District 6
Hazard	Too much precipi-tation in wet season	Number of days with precipitation ≥ 100mm	2	3	4	4	5	4
	Too much precipi-tation in wet season	Number of days with precipitation ≥ 100mm	2	3	4	4	5	4
Exposure	People living in flood-prone areas	Number of people per km² in flood-prone area	30	210	2760	2530	1300	1170
	Property & buildings in flood-prone areas	Number of buildings per km² in flood-prone areas areas	12	68	970	1100	450	280
	Critical infrastructure in flood-prone areas	Number of critical infrastructure in flood-prone area	0	1	3	2	1	0
Vulnerability	Wetland degradation	Percentage of area covered by wetlands	0	9	0	0	0	0
	Missing buffer strips	Percentage of river line aligned by buffer strips	3	12	5	0	0	3
	Deforestation	Percentage area cov-ered by natural forest	73	7	0	0	0	4
	Lack of protected forest areas	Percentage of forest area protected	50	0	0	0	0	0
	River ecosystems disconnected	Number of dams and weirs per km river length	0.01	0.05	0.05	0.1	0.1	0.1
	Absence of flood resistant housing	Percentage of elevated buildings in the flood zone	0	0	13	3	23	20
	Lack of water and wetland manage-ment capacity	Quality of operational RBCs	4	5	2	1	3	4
	Strong dependency on agricultural income	Percentage of house-holds depending on agriculture for income	60	42	23	34	67	53
	Lack of urban planning	Percentage of munici-palities with participa-tion in planning process	50	25	100	100	75	50
	Lack of financial resources of people	Percentage of popula-tion with income below national poverty line	27	17	6	12	32	18

m5

Module 5
Normalisation of indicator data

This module explains how to transfer (normalise) the different indicator datasets into unitless values with a common scale from 0 (optimal, no improvement necessary or possible) to 1 (critical, system no longer functions). Normalisation converts numbers into a meaning by evaluating the criticality of an indicator value with respect to the risk. Assigning indicator values to numbers ranging from 0 to 1 requires setting thresholds. For some indicators these thresholds are obvious. For example, in the case of 'percentage of area covered by natural forest', the value '0 %' is critical and represents the upper threshold of the normalisation range: during the process of normalisation it will be transformed to the value '1'. The value '100 %' is optimal and represents the lower threshold of the normalisation range: it will be transformed to the value '0'.

In other cases, the allocation of thresholds is less evident. For instance, in a drought-prone area a region with an annual precipitation of 600 mm/year may be '0' (optimal), while a region with precipitation of 200 mm may be '1' (critical). Precipitation values between 200 mm and 600 mm will be allocated to respective values between 0 and 1. Values exceeding this range will be either allocated to 0 (in this example all values > 600 mm will receive the number 0) or to 1 (all values < 200 mm) (see also Step 2). For this normative step, it is highly recommended to involve experts to agree on a suitable evaluation scheme.

m5

Step 1
Determine the scale of measurement

In order to normalise the data, you first have to determine the scale of measurement for each indicator (see Table 5).

Step 2
Normalise your indicator values

Indicator values can be normalised using two different approaches, depending on the scale of measurement. In the case of metric values, you need to check the 'direction' of the *value* range and define *thresholds*.

The values of indicators measured using a metric scale are allocated to numbers between 0 and 1, with '0' representing an optimal and '1' representing a critical state. Identified thresholds define the range of indicator values that represent this range of criticality levels (see introduction of Module 5 above). In our application example of the river basin, the value '2 days with precipitation ≥ 100 mm in the wet season' was allocated the meaning 'optimal rainfall conditions', while '10 days with precipitation ≥ 100' as 'critically high'.

Thus, the thresholds for this indicator are 2 and 10. Make sure that the meaning for an increase or decrease in value represents the respective change in criticality with respect to the risk. For instance, a *higher* value of the vulnerability indicator 'percentage of area covered by wetlands' indicates a *lower* vulnerability and vice versa, so that in the normalisation process, smaller numbers of this indicator must be allocated to higher values in the range between 0 and 1. Therefore, the direction of the indicator's value range is negative.

The stretch of indicator values between the minimum and maximum threshold follows Equation 1. Indicator values smaller than x_{Tmin} will be allocated to the value x_{Tmin} and indicator values exceeding x_{Tmax} will be allocated to the value x_{Tmax}.

Table 5: Example of indicators and their scales of measurement

Indicator options	Measurement unit	Scale of measurement
Amount of precipitation	mm	metric
Land cover land use	None (descriptive classes)	ordinal
Forest cover	Percentage	metric

The formalised rules are:

For $x_i \leq x_{Tmin} \rightarrow x_{Tmin}$
For $x_i \geq x_{Tmax} \rightarrow x_{Tmax}$
For $x_i \geq x_{Tmin}$ AND $x_i \leq x_{Tmax}$

$$x_{norm} = \frac{x_i - x_{Tmin}}{x_{Tmax} - x_{Tmin}}$$

Equation 1: Allocation of a normalised value to an indicator value with 'xnorm' for the normalised value, xi for the indicator value, xTmin for the lower threshold and xTmax for the upper threshold of the normalisation range

Indicators specified by categorical values and an ordinal scale (e.g. land cover, soil type, government efficiency) are normalised applying a five-class evaluation scheme. This evaluation scheme follows a *rating scale* by *defining classes* with a meaning applicable to the risk assessment from class value 1 = optimal to class value 5 = critical (see Table 6). Experts in the respective field should allocate the various characteristics for each indicator (such as 'forest' or 'built-up' in the case of land cover) to the different classes. Indicators for which no measured or observed data is available (for example 'quality of operational River Basin Committees') may obtain their values based on expert opinion, also using five classes and a description of each class according to Table 6.

In preparation for the aggregation of all indicator values, the five-class scheme, too, needs to be transformed into the 0 to 1 range, which is used for the metric variables (see Table 6).

→ *For details on how to normalise indicators see Vulnerability Sourcebook, p. 106–119.*

Table 6: Class scheme for variables with ordinal scale

Categorical class values within the range of 1 to 5	Class value within range of 0 to 1	Description
1	0.1	Optimal (no improvement necessary or possible)
2	0.3	Rather positive
3	0.5	Neutral
4	0.7	Rather negative
5	0.9	Critical (could lead to severe consequences)

APPLICATION EXAMPLE:
Normalisation of indicator data

Step 1
Determining the scale of measurement

It was found that the majority of indicators were measured in metric values. One indicator – 'quality of operational River Basin Committees (RBCs)' – had an ordinal scale of measurement.

Step 2
Normalising the indicator values

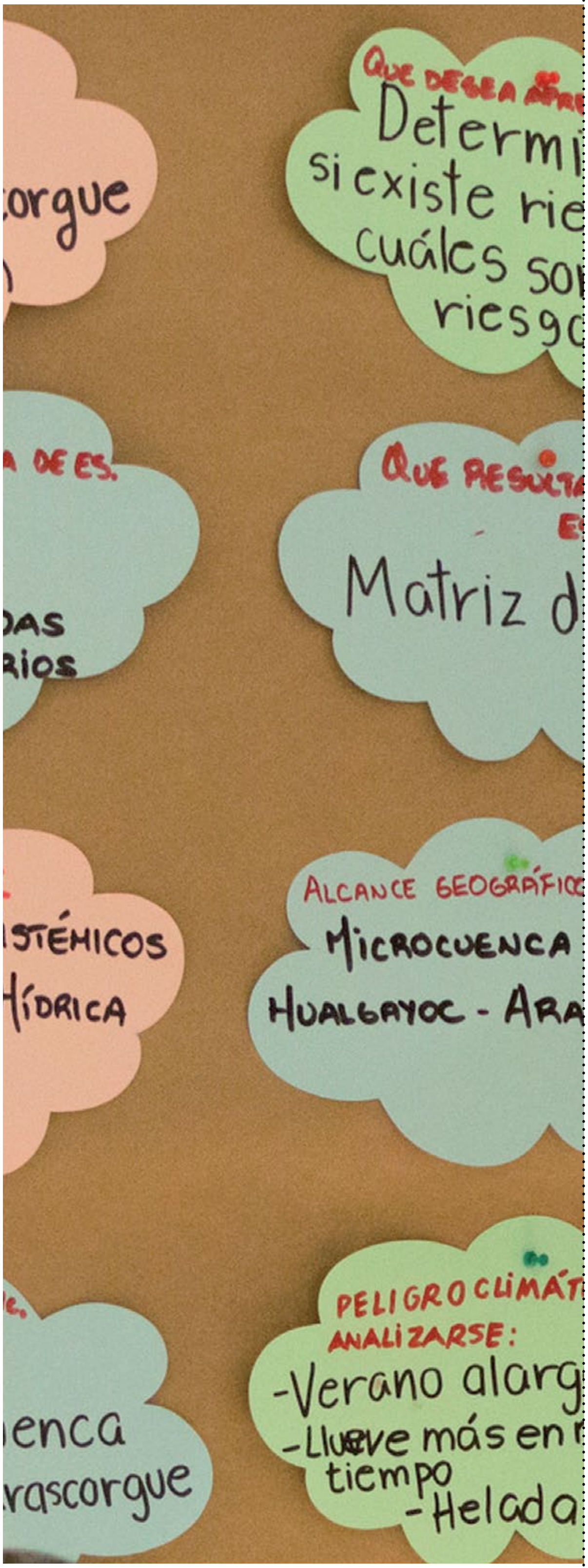
First, the direction of the indicators with a metric scale were determined, and subsequently (by applying thresholds representing optimal and critical states for each indicator) the values were transformed into a standardised score between 0 and 1. Table 7 shows the direction, the minimum and maximum value of the data and the defined threshold representing an optimal state (Threshold [min]) and a critical state (Threshold [max]) for each indicator. The results of the calculation for these normalisation steps are shown in Table 8.

Table 7: Direction, min-max values and defined thresholds for each indicator

Indicator	Direction	Min	Max	Threshold (min)	Threshold (max)
Number of days with precipitation ≥ 100mm	+	2	5	2	10
Number of days with precipitation ≥ 120mm	+	1	4	0	8
Number of people per km² in flood-prone area	+	30	2760	0	3000
Number of buildings per km² in flood-prone areas	+	12	1100	0	1500
Number of critical infrastructure in flood-prone area	+	0	3	0	2
Percentage of area covered by wetlands	-	0	9	0	10
Percentage of river line aligned by buffer strips	-	0	12	0	50
Percentage of area covered by natural forest	-	0	73	0	100
Percentage of forest area protected	-	0	50	0	75
Number of dams and weirs per km river length	+	0.01	0.1	0	0.1
Percentage of elevated buildings in the flood zone	-	0	23	0	100
Quality of operational River Basin Committees (RBCs)	-	1	5	1	5
Percentage of households depending on agriculture for income	+	23	67	25	75
Percentage of municipalities with participation in planning process	-	25	100	0	100
Percentage of population with income below national poverty line	+	6	32	0	30

Table 8: Normalised data for the different indicators

Component	Indicator	District 1	2	3	4	5	6
Hazard	Number of days with precipitation ≥ 100mm	0.00	0.13	0.25	0.25	0.38	0.25
	Number of days with precipitation ≥ 120mm	0.13	0.25	0.38	0.50	0.50	0.25
Exposure	Number of people per km² in flood-prone area	0.01	0.07	0.92	0.84	0.43	0.39
	Number of buildings per km² in flood-prone areas	0.01	0.05	0.65	0.73	0.30	0.19
	Number of critical infrastructure in flood-prone area	0.00	0.50	1.00	1.00	0.50	0.00
Vulnerability	Percentage of area covered by wetlands	1.00	0.10	1.00	1.00	1.00	1.00
	Percentage of river line aligned by buffer strips	0.94	0.76	0.86	1.00	1.00	0.94
	Percentage of area covered by natural forest	0.27	0.93	1.00	1.00	1.00	0.96
	Percentage of forest area protected	0.33	1.00	1.00	1.00	1.00	1.00
	Number of dams and weirs per km river length	0.10	0.20	0.10	1.00	1.00	1.00
	Percentage of elevated buildings	1.00	0.99	0.83	0.97	0.77	0.80
	Quality of operational River Basin Committees (RBCs)	0.70	0.90	0.30	0.10	0.50	0.70
	Percentage of households depending on agricul-ture for income	0.70	0.24	0.00	0.18	0.24	0.56
	Percentage of municipalities with participation in planning process	0.50	0.75	0.00	0.00	0.25	0.50
	Percentage of population with income below national poverty line	0.90	0.57	0.13	0.40	1.00	0.60



Module 6

Weighting and aggregating indicators

This module demonstrates how to weigh indicators if some of them are considered to have a greater or smaller influence on a risk component than others. The module also explains how to aggregate individual indicators of the three risk components.

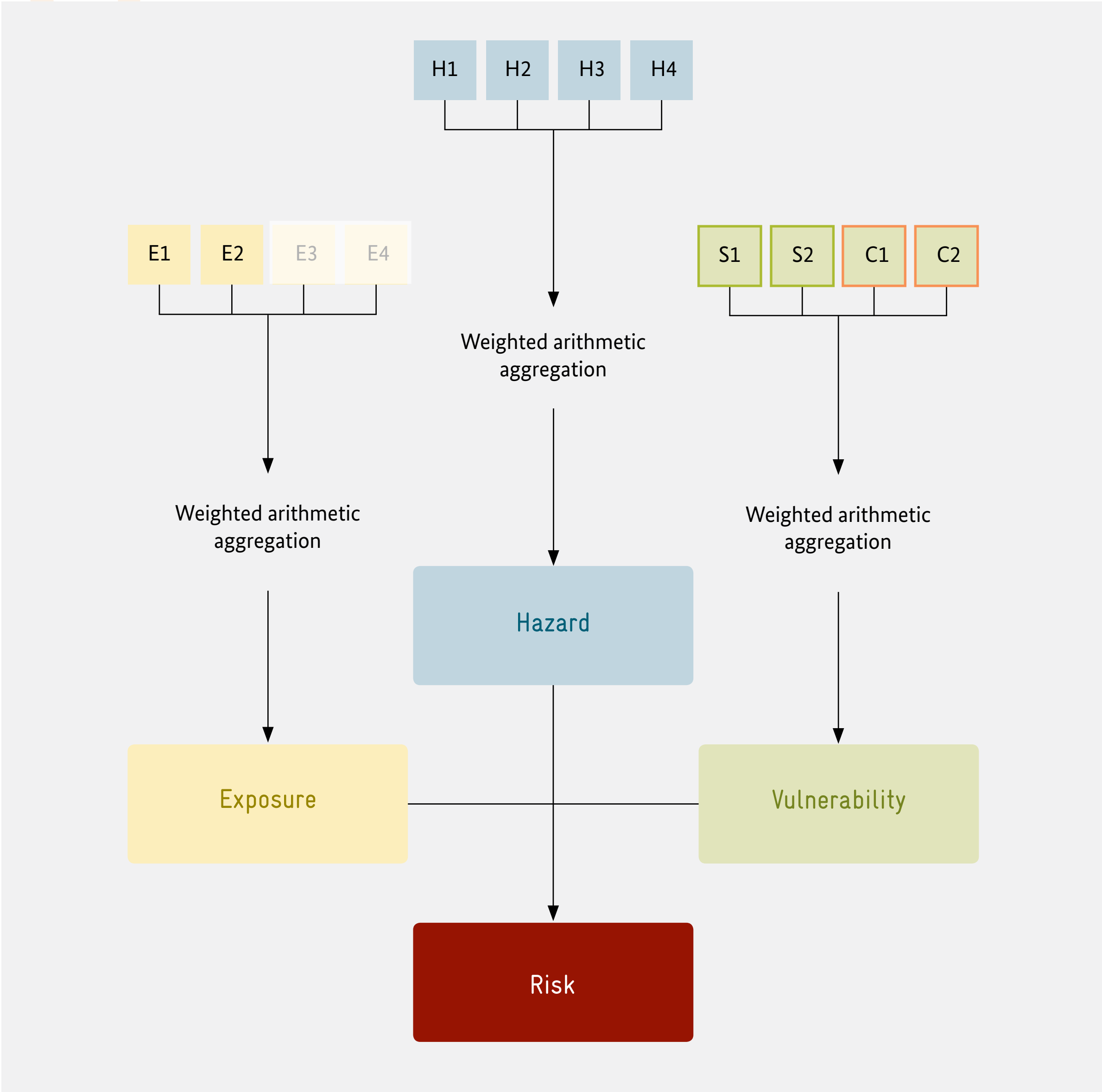
Step 1
Weighting indicators

Weighting indicators helps you describe the risk components *hazard*, *vulnerability* and *exposure*. The different weights assigned to indicators can be derived from existing literature, stakeholder information or expert opinion. There are different procedures for assigning weights: from sophisticated statistical procedures (such as principal component analysis) to participatory methods.

Step 2
Aggregating indicators

Aggregation allows you to combine the normalised indicators into a composite indicator representing a single risk component (see Figure 14).

Figure 14: Aggregating single factors to risk components (in practice the number of indicators may derivate from the count of indicators shown in this conceptual visualisation)



There are various aggregation methods (see *Vulnerability Sourcebook*, Expert box 16, p. 129). This Guidebook follows the Sourcebook approach, which recommends 'weighted arithmetic aggregation': Individual indicators are multiplied by their weights, summed and subsequently divided by the sum of their weights to calculate the composite indicator of a risk component (Equation 2). If there is no difference in weight, indicators are simply summed and divided by the number of indicators. All indicators must be aligned in the same way towards the risk (see Module 5).

$$CI = \frac{(I_1 * w_1 + I_2 * w_2 + \ldots I_n * w_n)}{\sum_1^n w}$$

Equation 2: Aggregating single indicators to a risk component

→ *For detailed guidance on weighting and aggregating indicators see Vulnerability Sourcebook, p. 122–131, and the Vulnerability Sourcebook Template: Indicator Aggregation.*

APPLICATION EXAMPLE: Weighting and aggregating indicators

Step 1 Weighting indicators

For the purpose of keeping the example simple, it was decided to apply equal weights for all indicators.

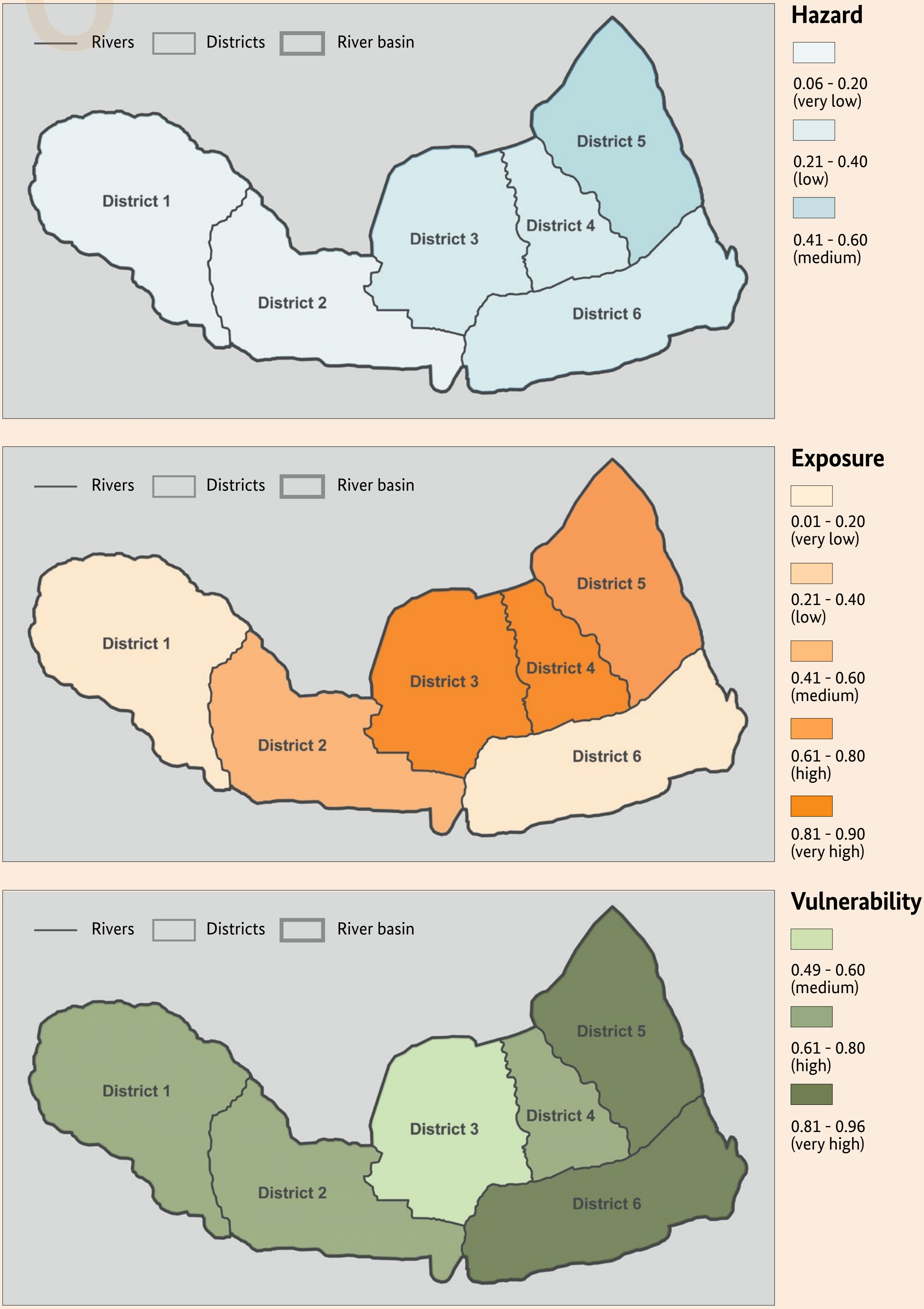
Step 2 Aggregating of indicators

The normalised indicator values were aggregated to composite indicators for each component. The results for the districts of the river basin are listed in Table 9 and visualised cartographically in the maps in Figure 15.

Table 9: Aggregated indicators (hazard, exposure, vulnerability)

Risk component	District 1	District 2	District 3	District 4	District 5	District 6
Hazard	0.06	0.19	0.31	0.38	0.44	0.25
Exposure	0.01	0.21	0.86	0.86	0.41	0.19
Vulnerability	0.57	0.65	0.49	0.66	0.89	0.84

Figure 15: Maps of the six districts and their aggregated hazard, exposure and vulnerability values



Module 7

Aggregating risk components to risk

This module explains how to aggregate the three risk components *hazard*, *vulnerability* and *exposure* into a single composite risk indicator. There are various possible ways to do so. Here a one-step approach using the weighted arithmetic mean is proposed, which is consistent with the IPCC AR5 risk concept. The advantage of this approach lies in its simplicity. Its main disadvantage is that a positive value of one component may conceal the fact that the value of another component is critical. This may lead to an undesired concealment of critical issues within a system. When applying this approach, weighting factors can easily be introduced (Equation 3), but are not considered in our application example.

$$Risk = \frac{(Hazard * w_H) + (Vulnerability * w_V) + (Exposure * w_E)}{w_H + w_V + w_E}$$

Equation 3: Aggregation of risk components

The results of this aggregation can be assigned to risk classes as proposed in Table 10.

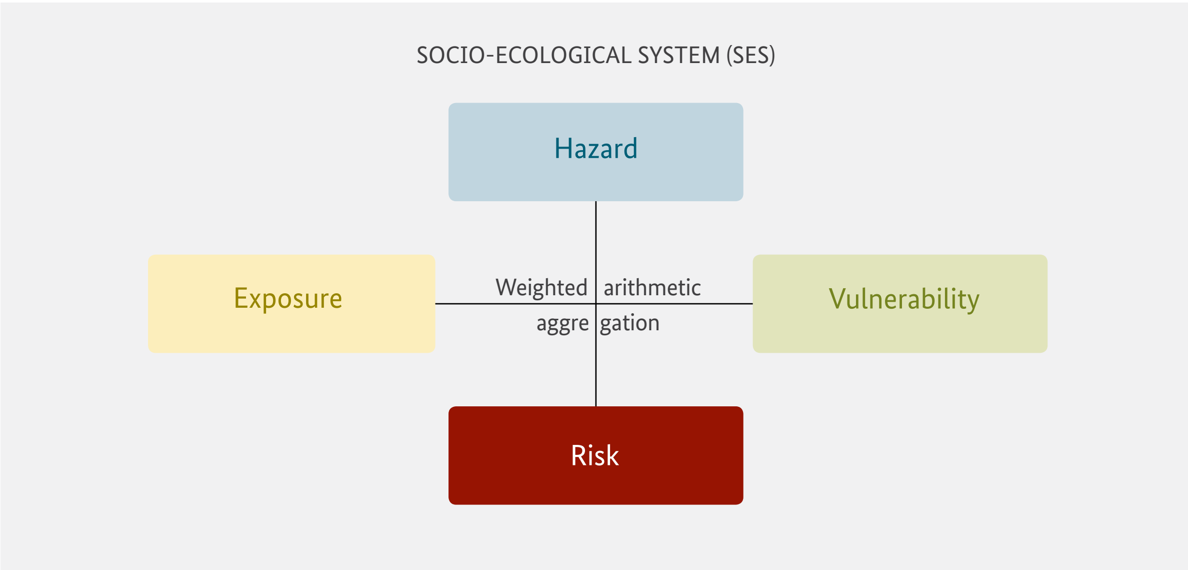
Table 10: Risk classes

Metric risk class value within range of 0 to 1	Risk class value within the range of 1 to 5	Description
0 – 0.2	1	Very low
> 0.2 – 0.4	2	Low
> 0.4 – 0.6	3	Medium
> 0.6 – 0.8	4	High
> 0.8 – 1	5	Very high

It is possible to combine several sub-risks into an overall risk. This may be useful depending on the context and the aim of your assessment. For an aggregation of sub-risks to an aggregated risk, we recommend to use the same formula (weighted arithmetic mean) as proposed in the *Vulnerability Sourcebook* for the aggregation of sub-vulnerabilities (p. 140–141). An alternative approach for aggregation with the help of an evaluation matrix is provided in the *Risk Supplement*, p. 54.

→ *For further details on the aggregation of the various components of a specific concept see Risk Supplement, p. 52–54, and Vulnerability Sourcebook, p. 134–141.*

Figure 16: Scheme for aggregating the risk components



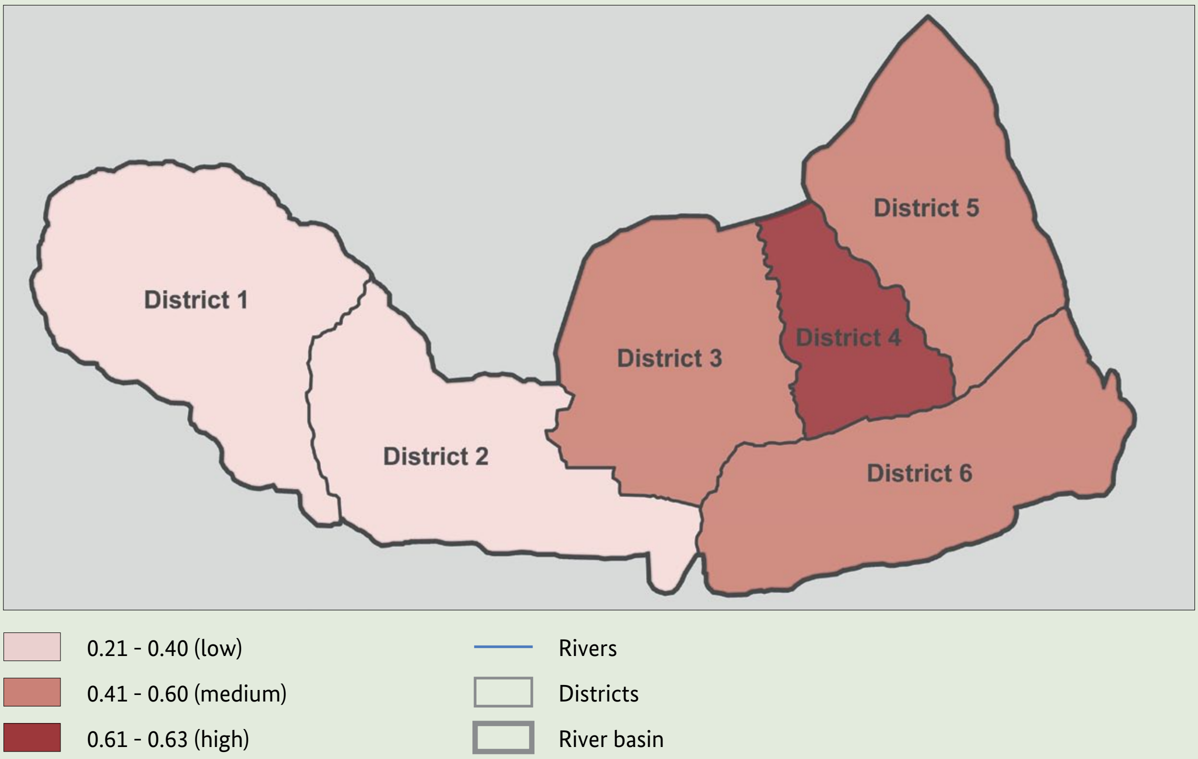
APPLICATION EXAMPLE:
Aggregating risk components to risk

The values of the three risk components were aggregated by applying the arithmetic aggregation method. Table 11 shows the results of this calculation. These risk values are visualised cartographically in Figure 17.

Table 11: Risk scores

	District 1	District 2	District 3	District 4	District 5	District 6
Risk	0.21	0.35	0.55	0.63	0.58	0.43

Figure 17: Aggregated risk index



Module 8

Presenting and interpreting the outcomes of the risk assessment

This module shows you how to present and interpret the results of the risk assessment. You visualise what you have learned from the assessment, considering the objectives set out initially. You need to present the findings in a way that is appropriate for your target audiences. Visualising both the aggregated results and the individual underlying datasets allows you to recognise the key drivers of risk.

Your findings should be described in an assessment report. The descriptive text is accompanied with figures visualising the outcomes. The assessment report should provide a clear description of the objectives of the risk assessment, of the methods applied and the key findings. You should write the report in a readily accessible way, giving your audience an overview of the assessment and providing them with all the background information they need to interpret and comprehend the results according to their information needs.

Step 1

Plan your climate risk assessment report

? GUIDING QUESTIONS:

- *What were the objectives of your assessment?*
- *What methods did you use?*
- *How did you collect the required information?*
- *What calculations did you carry out?*
- *How should the report be phrased to respond to your audience's needs?*
- *What are the lessons learned?*

When you start writing the report, you should first recapitulate the objectives on the basis of which you carried out the risk assessment: give a clear, extensive description of the methodology you applied, including the individual steps and assessment methods (for example the number of expert workshops you carried out), the indicators you selected, how the information was acquired and of the detailed calculations you carried out.

Subsequently you need to consider which content, style and language is appropriate for your target audience(s) and which graphical presentations are most suitable to help visualise the results. If the findings are targeted at external decision makers, it is essential to consider their objectives and which information (e.g. in terms of extent and level of detail) they need. The vocabulary and the way you explain the concept(s) should be accommodated to the skills and expertise of the target group, e.g. you should only use those technical terms that are appropriate (understandable) to the readers.

Lessons learned are valuable and should be included in the assessment report. By describing unanticipated findings and the challenges you encountered, you not only support others facing similar obstacles, but also help the audience understand the results.

Step 2
Describe your assessment

When structuring the assessment, keep the four core sections in mind:

- *context and objectives*
- *methodology and implementation*
- *findings*
- *conclusions and lessons learned.*

The beginning of your report should clearly state the context, objectives and underlying assumptions. This includes in particular the points addressed in Module 1. A detailed report will also describe the resources and timeframe of the assessment to help the reader review assessment inputs and outputs accordingly.

Next, outline the methods used in the assessment, thus providing a summary of what was done in Modules 2 to 7. This is key to the audience's interpretation of the findings. If the assessment is used for monitoring and evaluation (M&E), it should include a more extensive description with indicator and data factsheets.

The subsequent main part of the report presents the results of the assessment. This is the place to describe how your findings should be interpreted, to present the values for individual indicators, aggregated risk components and the overall risk, to recapitulate the challenges and opportunities you encountered throughout the assessment and to describe the 'lessons learned'. Here, you should also discuss uncertainties in your assessment transparently, as knowing about knowledge gaps on climate change and its impacts will foster the audience's understanding of your findings.

Step 3
Illustrate your findings

Illustrations attract the reader's attention and make texts more comprehensible. Maps, diagrams and graphs are valuable and compelling tools for illustrating assessment findings. It is crucial to choose the right type of illustration.

Maps are an excellent way to visualise geographic information and facilitate comparisons of regions. A cartographic visualisation of assessment results allows your readers to immediately detect the variation of climate risks across regions. Maps are especially valuable in participative processes and very well suited to involving local stakeholders in the risk assessment.

Various types of diagrams and graphs – such as radar, pie, bar or line charts – can be used to illustrate the findings of the risk assessment graphically.

→ *For further details on presenting the outcomes of the assessment see Vulnerability Sourcebook, p. 144–154.*

m8

APPLICATION EXAMPLE: Presenting and interpreting the outcomes of the risk assessment

Step 1
Plan your climate risk assessment report

The writing of the assessment report started by first re-visiting the objectives and planned outcomes as defined in the initial phases of the assessment – 'What is the risk of river flooding for people's lives, damage to property and critical infrastructures, and (how) can it be reduced through adaptation, including EbA measures. Which potential co-benefits and trade-offs may EbA options have?' (see Module 1, Step 2) – and the envisaged outcome of the assessment: 'a map of flood risk hotspots and related ecosystem services, a list of indicators and datasets, a narrative analysis of the risk and its determining factors.'

Regarding methods, it was decided to use an *approach based on impact chains, EbA and composite, spatially explicit indicators*. The required information came from a variety of sources and included quantitative as well as qualitative information. Indicators were aggregated with equal weights, applying an arithmetic aggregation method – first to the risk components hazard, vulnerability and exposure, subsequently to an overall risk. Thus, the outcomes consisted of numeric values with a spatial reference on a district level.

The target audience for this climate risk assessment was the local community, i.e. all residents and especially landowners, leaders and farmers, regional government, the relevant administrations and departments. The report was thus written in a way that suited the information needs of regional decision-makers and those who were responsible for implementing the measures at the district and local level.

Step 2
Describing the results of the assessment

During a series of workshops, an impact chain (as shown in Figure 18) was developed by identifying factors that lead to the risk of damage of property and loss of lives due to flooding. Based on a good understanding of the situation in the river basin and the construction of a simplified (reduced amount of factors, links and feedback loops for the purpose of this Guidebook) overview of cause and effect relationships, the following five EbA options were determined: wetland restoration (1), retention ponds (2), riparian zone restoration (3), afforestation/reforestation (4) and buffer strips (5).

By identifying indicators, collecting and preparing the corresponding datasets, each factor could be quantified. The indicator values were normalised on a scale between 0 and 1, so that they could be aggregated (by means of arithmetic aggregation) to the three risk components (hazard, vulnerability and exposure), which, in a final step (also by means of arithmetic aggregation) were aggregated to an overall risk value.

The visualisation of the overall risk value and its components shows that Districts 3, 5 and 6 have an intermediate risk, while District 4 – mostly due to high exposure and high vulnerability – has the highest risk of damage due to flooding

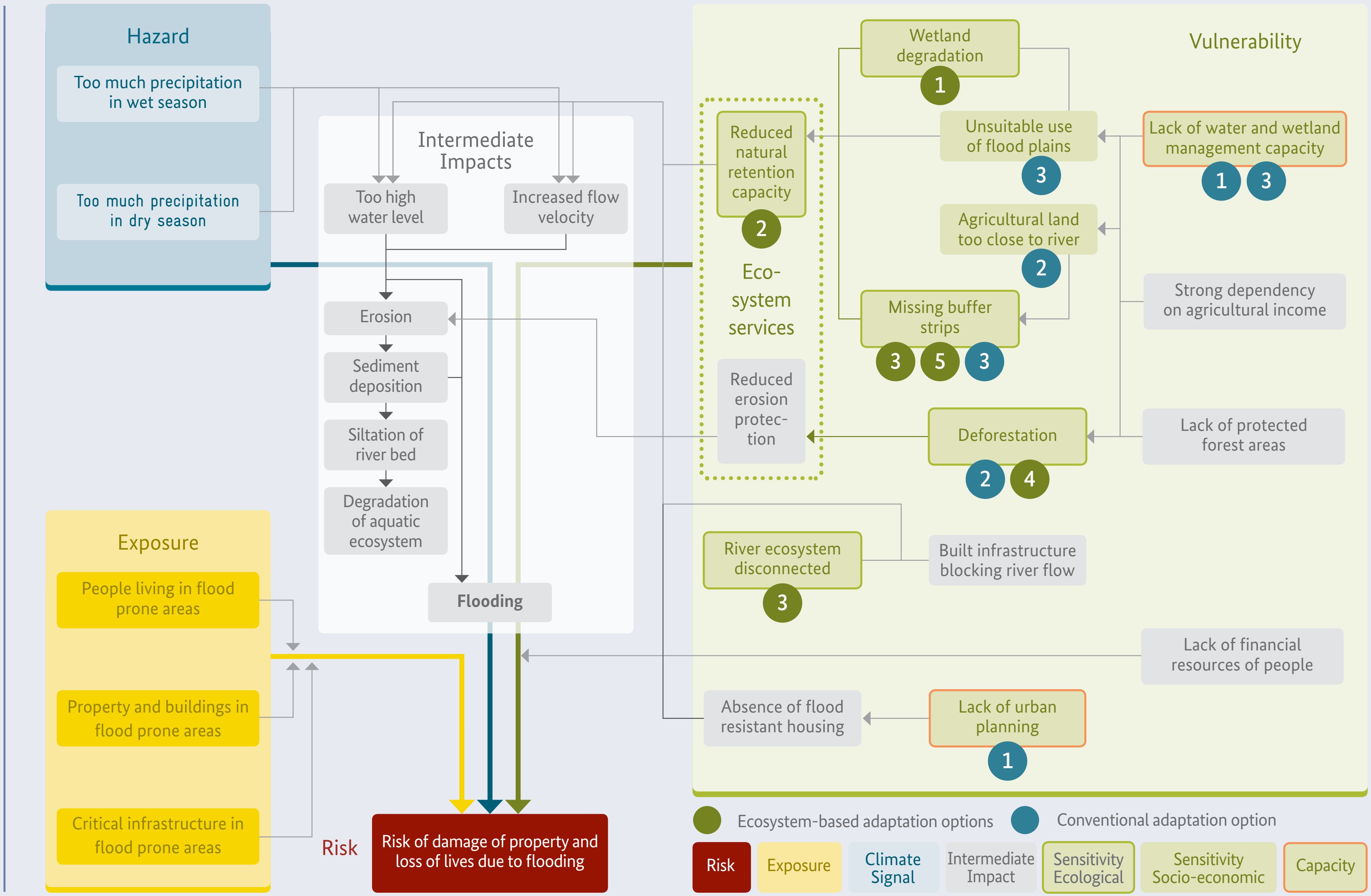


Figure 18: Cause and effect relationships describe the situation and helped identify potential adaption measures

(see Figure 19): There are by far more people living in District 3 and 4 than in any other district. Moreover, District 4 has the highest density of buildings in flood-prone areas. The results indicate that the districts downstream, due to a larger human presence in flood-prone areas, are more at risk than the area upstream in the mountains.

Lessons learned: The fact that, from the start, all relevant stakeholders from different administrative levels and different sectors as well as local experts were involved, not only provided valuable inputs and datasets for the assessment, but also ensured co-ownership and acceptance of the results.

Step 3
Illustrating the findings

Figure 20 shows the values of the risk components as a complex bar chart. We can easily notice how the six districts compare. District 4 shows the overall highest risk, and its largest contributing component is exposure. District 3 is equally exposed, yet it has a lower overall risk than District 4. Figure 20 clarifies that this is mainly due to the lower vulnerability of District 3, which can mostly be attributed to more buffer strips along the river, the fact that more than five times as many build-

Figure 19: Map showing the overall risk value and the contributions of each risk component per district

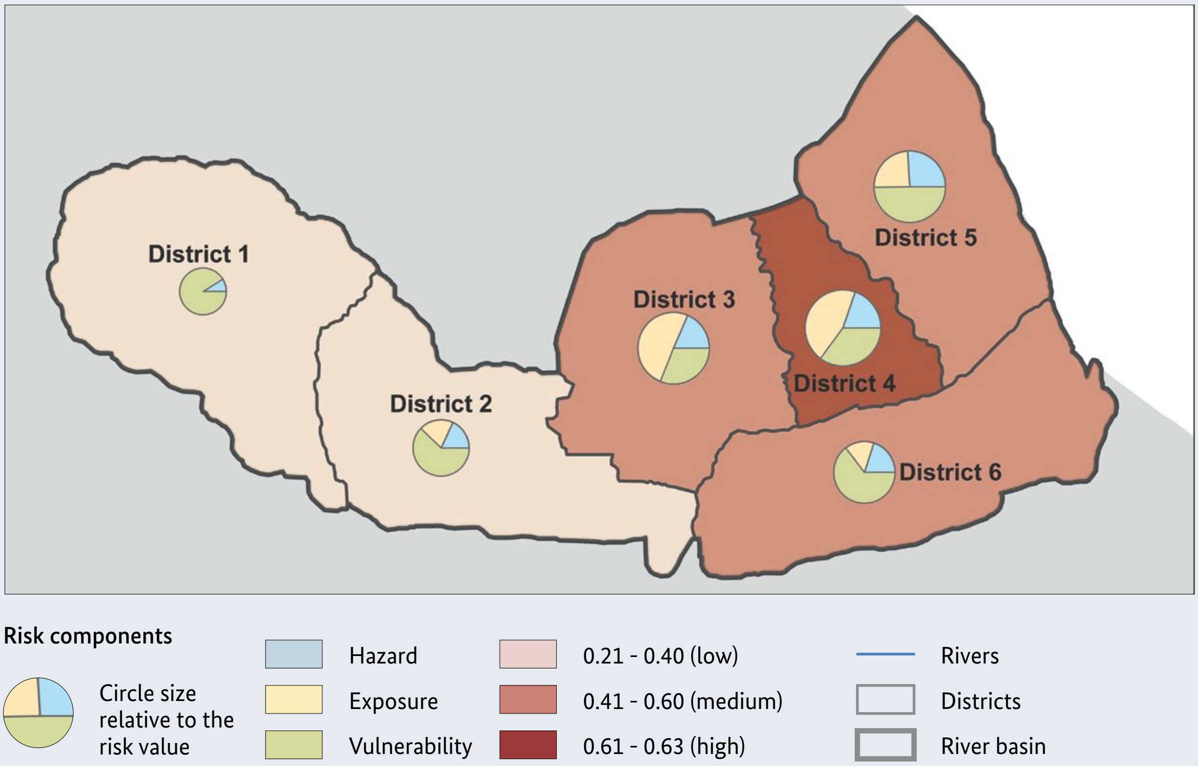
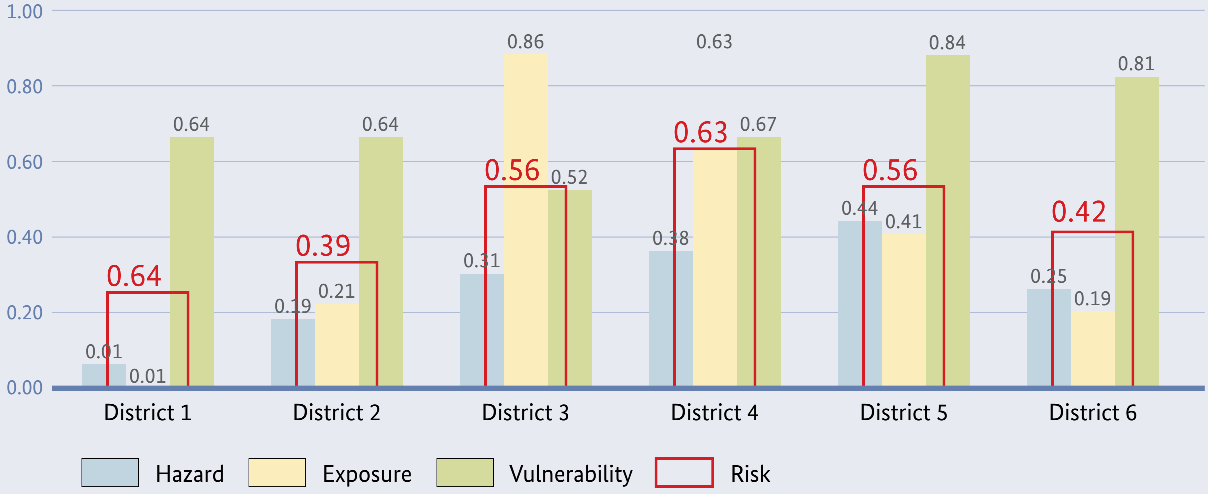
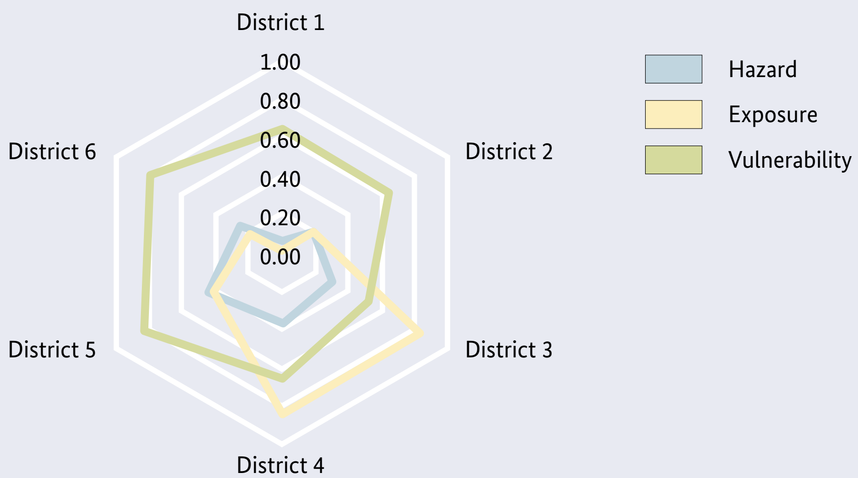


Figure 20: Aggregated risk components and overall risk for all six districts of the river basin shown as a bar chart



ings in the flood zone are elevated and that the poverty rate is two third below the rate in District 4. District 5 has a similarly high overall risk as District 3 and 4, but this is due to a very high vulnerability: as a result of the highest proportion of people living below the national poverty line and the highest proportion of households depending on income from agriculture, District 5 has the highest vulnerability. Figure 21 shows the same information presented as a spider diagram.

Figure 21: Aggregated risk components visualised for all six districts of the river basin as radar chart



In order to understand the underlying reasons for the aggregated values of the risk component, it is required to look at the individual indicator values. They can be found in the respective table, but often a diagram makes it easier to grasp them. For the visualisation of many indicator values, e.g. for the vulnerability component, it is recommended to use a spider diagram. The individual normalised values of the vulnerability indicators of the two districts with the highest aggregated risk values, i.e. Districts 3 and 4, are shown in Figure 23. With one glance on this chart you can see that the higher vulnerability of District 4 is mainly due to the number of dams and weirs along the river and – to a lower extent – to the quality of RBCs and the number of elevated buildings. If there are only few indicator values that need to be graphically presented, a bar chart is a more suitable means of representation: Figure 22 e.g. allows to make a statement about the factors contributing to the exposure in District 3 and District 5. District 3 has a much higher Exposure than District 5 as more people, more buildings and more critical infrastructures are located within the flood-prone area.

Figure 22: Comparing exposure indicator values of District 3 and District 5 visualised in a bar chart

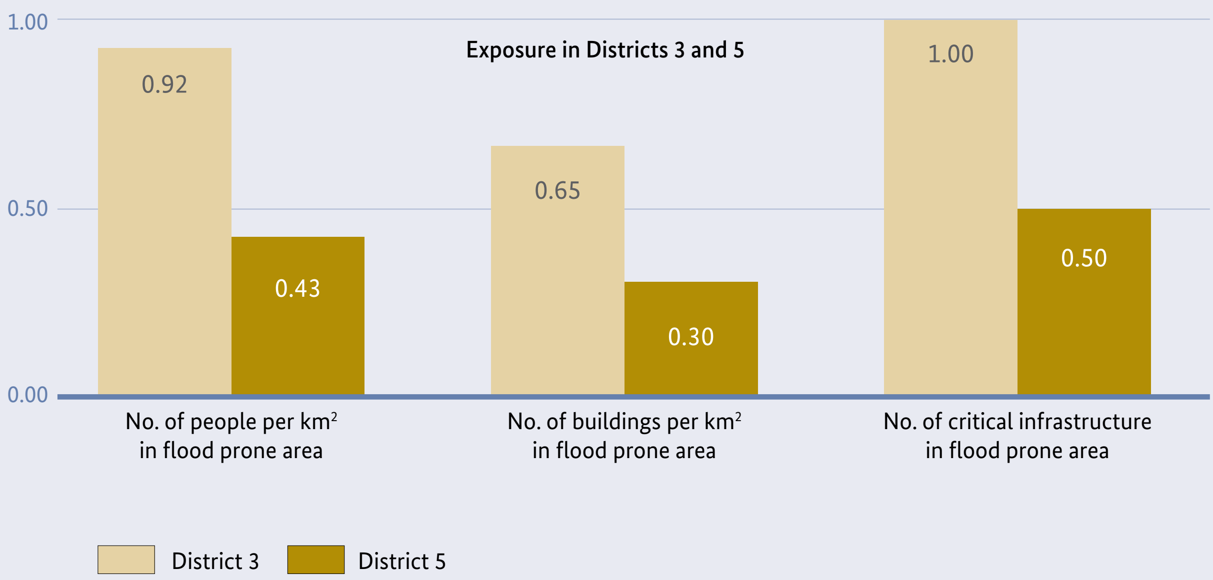
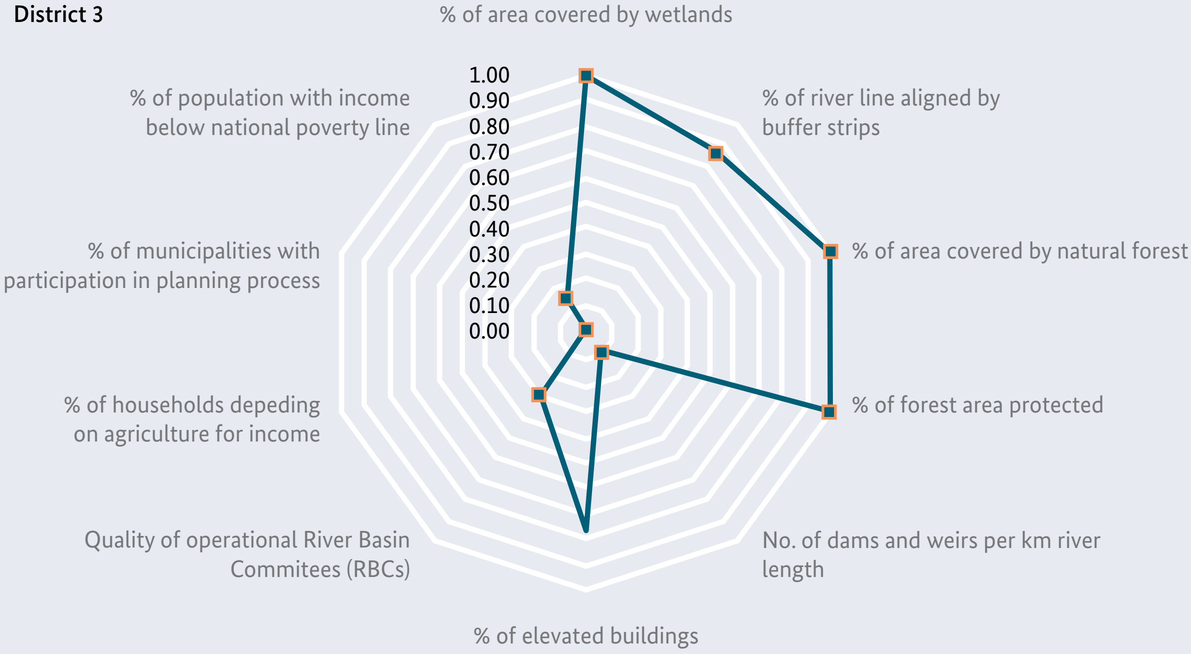
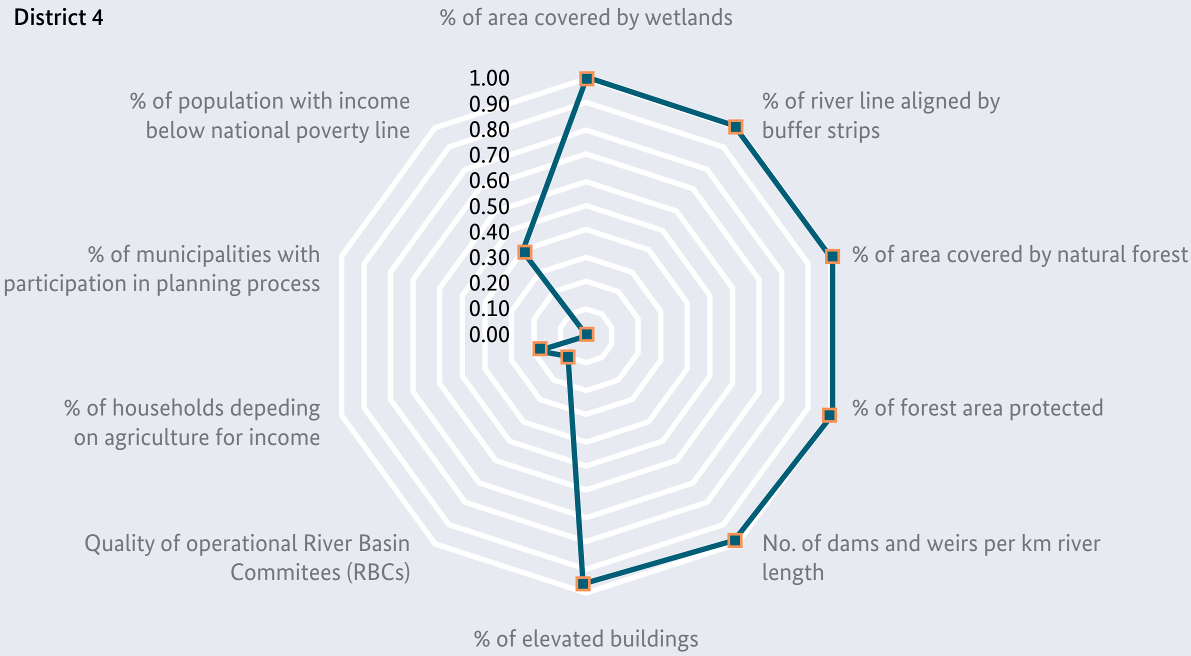


Figure 23: Vulnerability indicator values for District 3 and District 4 shown as a spider diagram. Note that for District 3 the two indicators 'percentage of households depending on agriculture for income' and 'percentage of municipalities with participation in planning process' are displayed as one dot, since they both have the value 0.

District 3



District 4



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G U I D E L I N E S

Module 9
Identifying adaptation options

This module elaborates how climate risk assessments can support the identification of adaptation options – including EbA – as part of an overall adaptation strategy. First, it discusses how impact chains and risk assessments can support the identification and spatial planning of EbA options. Then it explains the concept of 'EbA co-benefits' and describes how these can be specified during the assessment process. Finally, it provides information on required next steps towards implementing EbA measures based on a further prioritisation and selection process.

Responding to the need to link risk assessments more directly with adaptation planning, this module, which is described neither in the *Vulnerability Sourcebook* nor its *Risk Supplement*, has been added to the Guidebook.

Using impact chains and risk assessment to identify adaptation options

As indicated in Module 2, impact chains can provide entry points and first guidance for the identification of adaptation options, including conventional hard/'grey' (e.g. engineering-based), soft (e.g. training, insurance, etc.), ecosystem-based/'green' and hybrid (combined grey and green) solutions. If the assessment aims to identify *where* to implement EbA measures, then spatial information is needed on risk hotspots (i.e. areas of particularly high exposure, vulnerability and/or risk), on the status of key ecosystems and on how their services contribute to the ecological dimension of vulnerability.

Depending on the scope of the assessment, the conditions in the area and the social ecological system under consideration, there are two main ways in which vulnerability and risk maps can support the planning and spatial prioritisation of EbA measures:

- *1. service provision area = service benefit area*

  ESS are produced in the same area where the benefit is realised (e.g. soil formation benefitting farmers).

  Measures are implemented in areas of particularly high exposure, vulnerability and risk (e.g. focusing on restoration of degraded ecosystems and their services or even creation of new ecosystems).

- *2. service provision area ≠ service benefit area*

  ESS are produced beyond the area where benefits manifest themselves (e.g. water regulation, flood prevention).

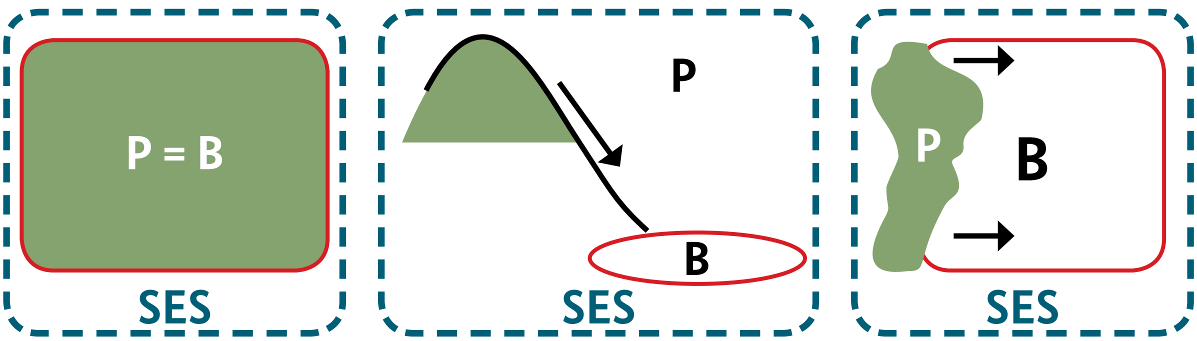
Measures are implemented in areas of low or medium vulnerability and risk as target regions, which provide key ecosystem services to areas with high exposure, vulnerability and risk (e.g. focusing on the conservation and sustainable management of existing natural ecosystems and their services).

Assessing specific key components and underlying drivers of risks can further support the planning of adaptation measures by pointing out which drivers are particularly contributing to high levels of vulnerability and risk and hence should be targeted by appropriate measures. Thus, it is important to acknowledge that the drivers of risk can vary spatially in a study area, requiring place-based approaches to risk reduction and adaptation planning.

Regardless of which approach is chosen (i.e. option 1, option 2, or a combination of both), priority should be given to measures that have effects at both the local and the landscape level (FEBA 2017). For example, afforestation/reforestation upstream in a catchment not only reduces erosion levels locally and provides a buffer for floods, but by doing so also protects downstream areas.

Further, the Guidebook emphasises the need for integrated 'adaptation packages', comprising conventional infrastructure-based, ecosystem-based, hybrid, and political solutions to ensure the sustainability and effectiveness of adaptation measures. For example, strategic reforestation as an ecosystem-based solution can enhance the ecosystem service 'flood regulation' and thus reduce the flood risk significantly. However, if trees are planted in a region where (informal) livelihoods depend on cutting wood (e.g. for fire wood, etc.), the success of the measure may be threatened by potential deforestation. This is why integrated adaptation packages in the form of combined reforestation and livelihood diversification programmes can significantly enhance the sustainability and adaptation benefits of the measure.

Figure 24: Different spatial relationships between ecosystem service provision areas (P) and ecosystem service benefiting areas (B) within social-ecological systems (SES) (Source: adapted from Fisher et al, 2009)

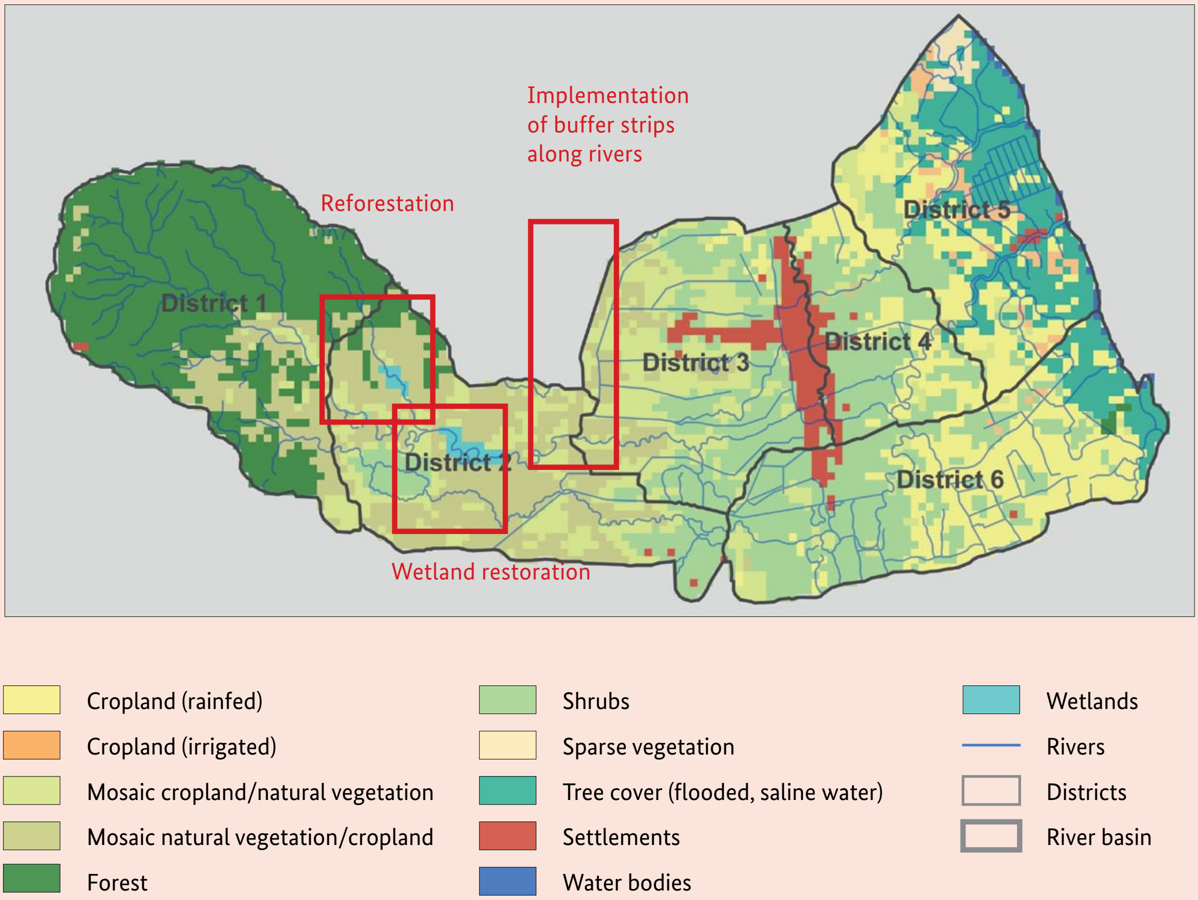


APPLICATION EXAMPLE: Identifying adaptation options

The information generated during the risk assessment in the river basin (i.e. exposure, vulnerability and risk, particularly risk maps and profiles which reveal how the underlying indicators contribute to the overall risk scores) supports the planning of potential EbA measures in the spatially explicit social-ecological system (as identified during the development of impact chains; see Module 2).

The exposure, vulnerability and risk maps presented in Module 7 and the risk profiles developed in Module 8 show that risk is highest in District 4 (0.63 in a scale from 0 to 1), largely driven by high exposure of people, infrastructure

Figure 25: Suggested EbA measures to tackle flood risk in District 4, based on the findings described above



and buildings to flooding (0.86), but also by high vulnerability of its social-ecological system (0.66).

The risk profile shows that multiple factors contribute to the district's high vulnerability, including the lack of wetlands and buffer strips. Flood risk in District 4, which is located in the downstream part of the river basin, is further aggravated by deforestation and the lack of wetlands and retention areas in upstream areas, such as District 2 and District 3.

It was decided that these measures should be complemented by additional soft, hard or hybrid as well as political and social measures, e.g. education campaigns and livelihood diversification programmes, as identified during the development of the impact chain.

Identifying co-benefits and feedback loops

Compared to conventional 'grey' engineering solutions (e.g. dams, dykes, etc.), ecosystem-based 'green' solutions can generate additional social, economic or cultural/recreational co-benefits that go beyond adaptation benefits (CBD 2009). Depending on the type of EbA measure, potential co-benefits include, but are not limited to, positive effects on health and well-being (e.g. clean air, increased food provision and nutrition, etc.), additional livelihood opportunities and sources of income (e.g. mangrove forests serving as nursery grounds for fish and shrimp, eco-tourism, etc.) and environmental benefits (e.g. water purification, carbon sequestration, climate regulation), while at the same time contributing to the conservation of biodiversity. Further, EbA measures are often cost-effective adaptation solutions. Mangrove restoration, for example, has proven to be more cost-effective than maintaining conventional hard structures such as dykes (UNEP, UNDP & IUCN 2012). Consequently, EbA options are considered to be so-called 'low-regret' solutions.

However, trade-offs and unintended consequences may also arise, for example when an EbA measure protects one group of people at the expense of another, favours one ecosystem service over another (UNFCCC 2017), or increases existing health threats (e.g. serving as breeding ground for vector-borne diseases). Assessing and monitoring the (co-)benefits of EbA is, therefore, not sufficient. Instead, potential trade-offs, synergies, and unintended consequences should be considered during the identification, evaluation, design and implementation of EbA measures (CBD 2016; UNFCCC, SBSTA 2017). Thus, impact chains can be a valuable tool to identify such measures in a structured, participatory manner following a sequence of key steps:

Step 1
Identify potential co-benefits

? GUIDING QUESTIONS:

- *What would be potential co-benefits of a specific EbA measure?*

For each EbA measure identified and visualised in the impact chain (Module 2), you should brainstorm on possible social, economic and ecological co-benefits that could affect the different risk components (intermediate impacts, exposure, vulnerability). The factors identified for these components can serve as a starting point for such a brainstorming exercise.

Step 2
Identify potential unintended consequences or drawbacks

? GUIDING QUESTIONS:

- *Which unintended consequences (trade-offs) might a specific EbA measure have?*

Repeat the exercise described for Step 1, this time for potential unintended consequences or drawbacks of each identified EbA option.

APPLICATION EXAMPLE:
Identifying adaptation options

For the previously identified EbA measure 'wetland restoration' (see Figure 26), the following direct benefits, co-benefits and unintended consequences were identified:

1. *Direct adaptation benefits or effects include increased ground water storage, increased water regulation during the dry season, and better water quality.*

2. *A number of co-benefits were identified, affecting both factors within the risk components (e.g. wetland restoration leading to increased biodiversity, which in turn can result in more eco-tourism and additional income for people living in the river basin), but also 'outside' of the risk components (e.g. wetland restoration leading to increased carbon sequestration and hence to mitigation of climate change which in turn can have a long-term effect on precipitation patterns in the basin).*

3. *It was determined that, due to the tropical climate in the region, increase of vector-borne diseases (e.g. dengue, malaria) and loss of agricultural land are potential (unintended) consequences that could adversely affect human health and well-being in the river basin.*

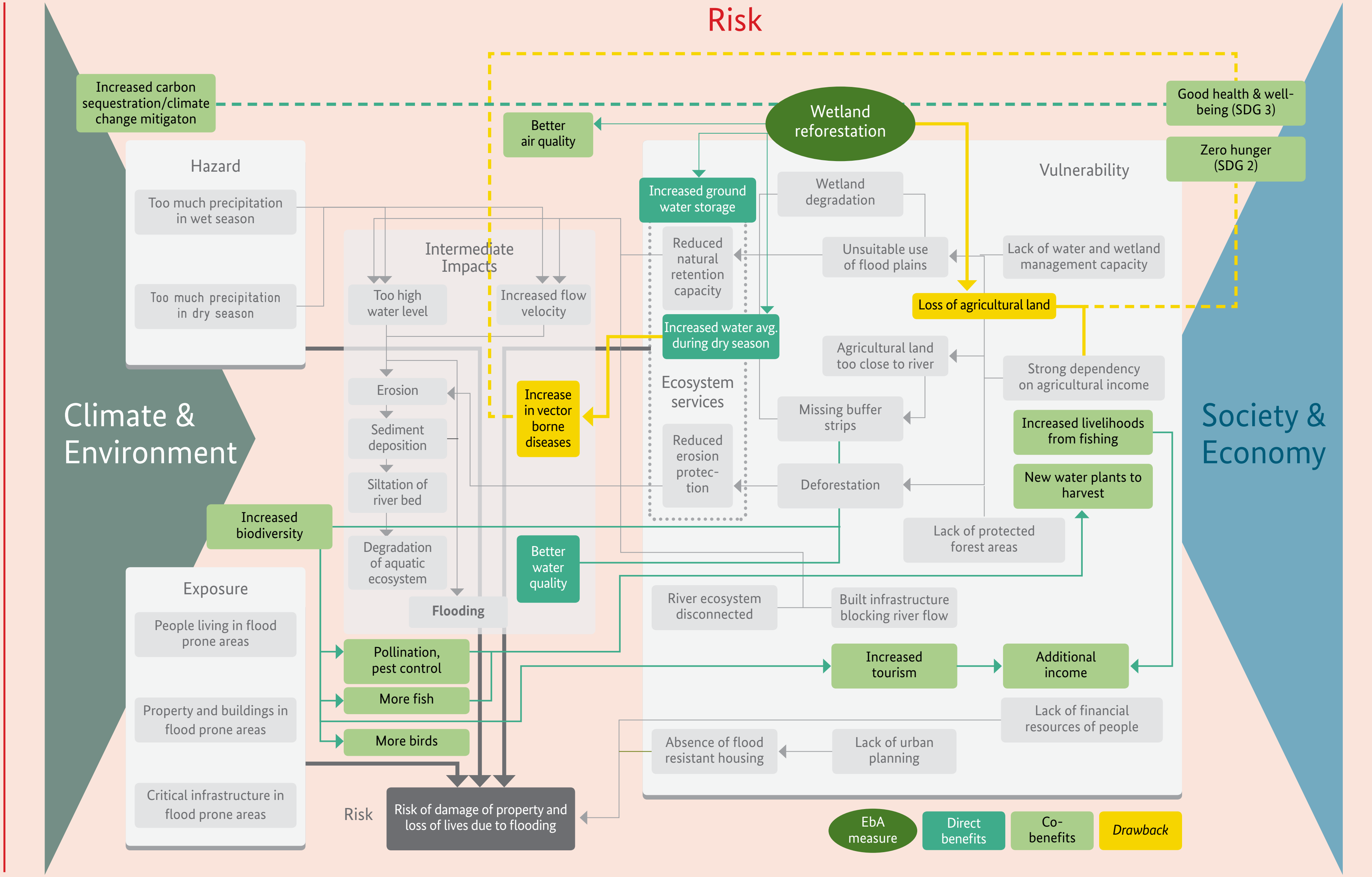


Figure 26: Co-benefits and potential unintended consequences of EbA measures (example: wetland restoration)

Next steps towards the implementation of EbA measures

Consider what additional steps are required in order to effectively plan and implement EbA options. Depending on the spatial resolution of the risk assessment (e.g. district level in the application example), further in-depth and spatially explicit analysis may be useful to identify where measures should be implemented in order to unfold the maximal direct adaptation benefit. For example, hydrological models taking into account climate data (precipitation, evaporation, etc.), existing flood control measures, topography, soil conditions, land use and river geometry can be useful tools to simulate the effects of potential adaptation measures (incl. EbA) on flood hazards and hence support their planning and prioritisation.

Assessing the (economic, environmental, and social) costs, benefits and impacts of adaptation measures is crucial for the planning stage of the adaptation process. Additionally, it helps you decide on where and when to implement measures and how to efficiently prioritise and allocate limited financial and technological resources. Once sites are selected, you can engage with stakeholders to ensure that the proposed EbA options are acceptable to community members.

When evaluating EbA options, take into account how they contribute to the project adaptation goals and define measurable criteria for assessing this contribution, such as efficiency, effectiveness, equity, urgency, flexibility, robustness, practicality, legitimacy, and coherence with other strategic objectives. Economic assessments of EbA options may be necessary to secure investments and funding for projects, but they can also help to promote the use of EbA measures at a larger scale.

There are various approaches to assess the adaptation options, including cost-benefit analysis (CBA), cost-effectiveness analysis (CEA), and multi-criteria analysis (MCA). They can be combined, so as to consider environmental, social and economic costs and benefits in order to make the best recommendations.

CBAs should follow best practices to establish priorities in implementing EbA measures. They should quantify benefits of ecosystem services as well as costs associated with management. However, planners need to take into account the inherent challenges involved in assigning economic values to system components that cannot be translated into monetary terms (e.g. cultural services – spiritual and aesthetic). Incorporating rapid ecosystem services appraisals into assessments is one way to assess not only current ecosystem services and co-benefits, but also how these might change in the future.

Ultimately, assessing costs and benefits of EbA options allows planners to make informed decisions about what measures will best meet the needs of stakeholders. However, to support and encourage the further implementation of EbA measures and their upscaling, further information on the costs, benefits and economic incentives is needed.

While various valuation methods are available, there are still multiple challenges for implementing and upscaling EbA measures. One challenge is the need for additional evidence that EbA approaches can reduce biophysical risks as effectively as grey infrastructure and delivering other ecosystem service co-benefits. Another challenge is that many valuation methods for assessing the costs and benefits of adaptive infrastructure projects or ecosystem services have not yet been widely applied in EbA contexts. Further, ecosystem services and other direct and indirect benefits offered by EbA measures tend to be underestimated, which prejudices the adaptation decision-making process.

GIZ has developed a *Sourcebook* on valuing the benefits, costs and impacts of EbA measures (GIZ 2018). It aims to assist in building awareness, knowledge and capacity about why, how and in which contexts EbA valuation can be used to inform, guide and influence adaptation decision-making. The sourcebook combines information on valuation theory and methods with real-world examples, showing step-by-step how to commission, design and implement EbA valuation studies.

m9

IV How to use the risk assessment for monitoring and evaluation

In addition to the question of whether and how risk assessments can inform the identification, planning and prioritisation of EbA options, the discussion around monitoring and evaluation (M&E) of adaptation in general (and of EbA in particular) has gained attention over the past years.

Performing M&E is particularly important in climate change adaptation, as decisions for adaptation measures are typically taken under uncertainty. M&E can support required adjustments in the adaptation strategy. It also helps to identify future needs and trigger points for adaptive management, i.e. changing strategies or methods to manage future uncertainties. Within an EbA context, M&E allows managers to understand which progress has been made and which obstacles still have to be overcome. There are a number of considerations for effective M&E of implemented EbA measures. It should incorporate appropriate methods to check whether management approaches are effective, taking into account the amount of time particular EbA measures need before they are established and before they can provide their intended benefits and co-benefits. M&E does not only involve tracking indicators that measure adaptation outcomes, but also engaging with stakeholders to incorporate feedback. Overall, it should be regarded as a tool that helps you understand which EbA measures can most effectively improve future implementation.

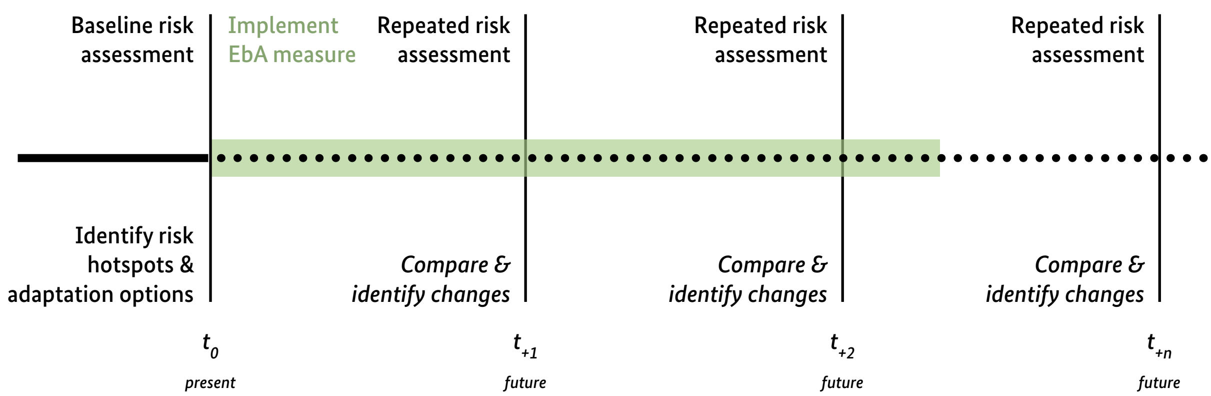
Indicator-based risk assessments, as suggested in this Guidebook, can contribute to an overall M&E framework by using climate risk assessments as one of multiple tools to support the M&E of adaptation – including EbA. Initial risk assessments provide baselines for understanding changes in risk levels before the implementation of adaptation measures. Post-implementation risk assessments inform about the overall change of risk in an area.

As risk scores are highly aggregated, M&E must consider changes in the risk component (exposure and vulnerability) and their individual factors. This is crucial in order to understand changes in the underlying factors and whether and to which degree they are affected by the implementation of adaptation measures. However, M&E based on risk assessments has a clear limitation: attributing positive or negative trends or outcomes to particular, previously implemented measures is difficult, as a large number of factors can influence the outcome (for example overall changes in the social-ecological system which are independent from the measure implemented).

Despite these limitations, repeated risk assessments can inform about overall progress in the climate risk reduction of a region, even if it may not be unequivocally attributable to a certain EbA measure.

By using an adaptive management approach, risk assessments can facilitate adjustments or further implementation needs. Subsequently, EbA measures can be modified as needed and resources reallocated to measures that produce the most positive results.

Figure 27: M&E of adaptation through repeated risk assessment (Source: UNU, EURAC)



Concluding remarks

This Guidebook relies at its center on an example, outlining how to apply climate risk assessments in the context of Ecosystem-based Adaptation (EbA) as part of an overall adaptation strategy. The Guidebook addresses typical elements of EbA which – in the context of climate change adaptation – intends to make use of the relationships between society, economy and ecosystems, constituting a social-ecological system (SES).

Of particularly noteworthy importance are the spatial characteristics of any risk assessment aiming to support EbA. Unlike many other risk reduction or adaptation measures, EbA needs to be based on a spatially explicit 'landscape approach'. Therefore, the question 'where' is even more indispensable than in other cases when going through the various analysis steps.

Through the application example the Guidebook demonstrates how EbA options make use of spatial information, can be identified and specified within the risk assessment process and used as starting points for further adaptation planning.

For a successful implementation and uptake of climate risk assessments – as for any risk assessments following the Vulnerability Sourcebook-approach – the participation of a wide range of actors is pivotal. This approach has already been applied in more than 20 different contexts, and it was possible to derive the following conclusions:

Participation of different stakeholder groups in climate risk assessments

- *helps to better understand the social-ecological system and its interaction by making use of both local and scientific knowledge and combining a diversity of sector experience;*
- *strengthens knowledge and awareness among the different actors involved;*
- *supports ownership by relevant stakeholders, from government to affected communities.*

Impact chains (cause-effect relationship)

- *help decision makers to better understand the relation between climate risks and sustainable development;*
- *support transparency and credibility of climate risk assessment results;*
- *increase political support for identified adaptation actions.*

This publication presents one possible method for implementing a climate risk assessment focusing on EbA. It intends to provide general systematic guidance; the specific details need to be adapted to the circumstances in the region under consideration.

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* You can find a link in the online version of this document.

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IPCC 2014b: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Cambridge University Press.
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UNFCCC/SBSTA 2017: Adaptation planning, implementation and evaluation addressing ecosystems and areas such as water resources. UNFCCC/Subsidiary Body for Scientific and Technological Advice.
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Vicarelli M.; Kamal, R. and Fernandez, M. 2016: Cost Benefit Analysis for Ecosystem-Based Disaster Risk Reduction Interventions: A Review of Best Practices and Existing Studies. In: Renaud et al. (eds.), Ecosystem-Based Disaster Risk Reduction and Adaptation in Practice. Springer.

* You can find a link in the online version of this document.

VI The EbA Guidebook Annex

Qualification criteria and quality standards for EbA – the FEBA example

The climate risk assessments carried out following this Guidebook result in a comprehensive picture of the risk under consideration. They provide knowledge about cause and effect relationships, spatial risk hot spots, the underlying factors contributing to the risk, and subsequently they enable the identification and spatial planning of suitable EbA options. The FEBA (Friends of Ecosystem-based Adaptation) assessment framework summarised below can be used to improve the quality of EbA measures, it can help correct your course during the implementation phase, and it can be used as a basis for reporting.

A technical paper published by FEBA provides guidance on criteria and quality standards for an effective EbA (FEBA 2017). We highly recommend to consult the FEBA criteria when designing, implementing and monitoring EbA measures also in the context of climate risk assessments.

The FEBA criteria are based on practical experiences in various regions, ecosystems and levels of governance. The first important step is to check whether an envisaged approach qualifies as EbA. For this to be the case, all three elements of the CBD definition of EbA (CBD 2009) need to be fulfilled: A) it helps people adapt to climate change B) by an active use of biodiversity and ecosystem services C) in the context of an overall adaptation strategy. In order to determine, practically, whether a measure meets the requirements of EbA, the FEBA paper provides five qualification criteria covering all three elements of the EbA definition (see Table_Anx 1).

The EbA Guidebook can be used as a tool to determine which qualification criteria are fulfilled. For example, the reduction of vulnerabilities (criteria 1) could be evaluated using the EbA

Table_Anx 1: FEBA EbA qualification criteria (Source: FEBA 2017)

Elements of CBD definition:	Qualification Criteria:
A) EbA helps people to adapt	1. reduces social and environmental vulnerabilities,
	2. generates societal benefits in the context of climate change adaptation,
B) EbA makes active use of biodiversity and ecosystem services	3. restores, maintains or improves ecosystem health,
C) EbA is part of an overall adaptation strategy	4. is supported by policies at multiple levels,
	5. supports equitable governance and enhances capacities.

Guidebook approach by making use of repeated risk assessments over time (see Chapter IV). Societal benefits in the context of climate change adaptation (criteria 2) can be assessed using the impact chain methodology as discussed in Module 9.

After having answered the question whether the measure qualifies as EbA, the FEBA paper proposes a practical framework that allows users to assess the quality of the EbA initiative by drawing on a set of quality standards, which are each linked directly to one of the five qualification criteria listed above. The assessment results in one of four categories – from very weak to very strong EbA. The quality of an EbA initiative is measured with indicators.

FEBA propose some example indicators for each of the quality standards and the four categories (Figure_Anx 1). Indicators should be measurable, be it in a quantitative or a qualitative way. The assessment framework not only helps you determine whether a strategy is weak or strong in terms of EbA quality, but also provides a baseline

Figure_Anx 1: Example assessment framework of EbA quality standards for Element A 'helping people to adapt' and qualification criteria 1 (Source: FEBA 2017)

Qualification Criteria	Quality Standards	Continuum of EbA quality: Very strong	Strong	Weak	Very weak	Example indicators
Reduces social and environmental vulnerabilities	1.1 Use of climate information	Yes, short-, medium- and long-term			Very limited or not at all	▪ Extent of information about future climate change used ▪ Quality of climate data sources
	1.2 Use of local and traditional knowledge	Yes			Very limited or not at all	▪ Extent of relevance of local resources consulted (individuals, communities, NGOs) ▪ Participation of affected natural resource users during planning process ▪ Quality of consultation process
	1.3 Taking into account findings of vulnerability assessement	Yes, clearly integrating findings of climate change vulnerability assessements			Yes, but only marginally	▪ Extent to which information from VA is being considered ▪ Consideration of climate risk reduction ▪ Extent to which ecosystem services are assessed by the VA
	1.4 Vulnerability reduction at the appropriate scale	Land/seascape scale or larger			Local scale	▪ Number or percentage of population with reduced vulnerability ▪ Effects from different scales of ecosystems are considered

on how an EbA approach can be improved. Thus the framework can be applied during Module 9 of this Guidebook when initially planning EbA options. Additionally, it provides a tool that is useful both during the implementation and during the monitoring and evaluation (M&E) of the EbA measure.

Additional sources where EbA measures are presented

This section provides an overview of additional online and literature sources where EbA measures are presented and discussed, organised by continent. It should be noted that many of the reports listed here draw on older conceptual framings of vulnerability and risk under the IPCC AR4 (IPCC 2007) or AR5 (IPCC 2014), rather than the adapted AR5 risk concept in the context of social-ecological systems (SES) presented in this Guidebook. The section provides only examples without being exhaustive. See Table_Anx 2 for online database sources.

Literature sources

Africa

Bourne et al. (2012). *Climate Change Vulnerability Assessment for the Namakwa District Municipality. Conservation International, South Africa.*

This vulnerability assessment addresses climate change risks and impacts, identifies priorities areas for EbA and conservation actions, and makes recommendations for EbA actions. The report includes two prioritisation tools, including an EbA priority areas map to support spatial planning for measures and maximise potential benefits. EbA options presented include managing and restoring wetlands and river corridors for biological diversity and the prevention of soil erosion, restoring wetlands and terrestrial vegetation to secure groundwater recharge, and conserving water catchments for key ecosystem services delivery and to build climate change resilience.

https://www.conservation.org/publications/Documents/CI-CASCADE-Namakwa-Vulnerability-Assessment.pdf

Asia

GIZ (2015). *Pre-selection and Preparation of Ecosystem-based Measures in the Pilot Areas Huai Sai Bat and Tha Di (Thailand) for discussion and final decision-making in collaboration with local water committees. GIZ.*

Final design and implementation of ecosystem-based measures requires a careful preselection of potential measures and locations all of which are based on results of a vulnerability assessment (VA). This report contains an overview about general EbA options suitable for implementation in the pilot areas from which potential locations associated with measures are derived.

http://www.ecoswat-thailand.com/download/2015_05_25_ecoswat_eba_preselectionreport.pdf

Mant et al. (2014). *Opportunities for using climate change mitigation and adaptation measures to make progress towards the CBD Aichi Biodiversity Targets: Guangxi Province, China. UNEP-WCMC.*

This report examines opportunities for forest-based climate change mitigation and adaptation in Guangxi Zhuang Autonomous Region in southern China. It provides information on how spatial analyses can contribute to identifying the best areas to implement potential measures. Forest management options include, for example, conservation of existing forests, establishing protected areas, and undertaking reforestation.

https://www.uncclearn.org/sites/default/files/inventory/12052015unepchi2.pdf

Adhikari, B.R. and Suwal, M.K. (2013). *Hydrogeological Study in Bangsing Deurali VDC, Syangja: An Ecosystem-based Adaptation in Mountain Ecosystem in Nepal. IUCN.*

This study attempts to understand the effects of hydrogeological factors on the recharge of the springs of Bangsing Deurali VDC of Syangja district in Nepal in order to develop feasible options for rational use of water available and EbA options for sustainable water supply of springs and watersheds. Measures such as retention ponds are explored.

https://www.iucn.org/sites/dev/files/content/documents/hydrogeological_study_in_bangsing_deurali_vdc_syangja.pdf

Etzold, J. (2015). *Ecosystem-based Adaptation in Central Asia: Vulnerability of High Mountain Ecosystems to Climate Change in Tajikistan's Bartang Valley – Ecological, Social and Economic Aspects – with references to the project region in Kyrgyzstan. GIZ.*

This report is part of a project that aims to identify and establish adaptation measures to climate change in selected regions of Kyrgyzstan and Tajikistan. Identified measures included floodplain forests and brush land with patches of wet meadows, forests of steep tributary valleys, and pastures and hay meadows.

Baig et al. (2016). *Cost and Benefits of Ecosystem Based Adaptation: The Case of the Philippines. IUCN.*

This report aims to increase the knowledge base regarding the effectiveness of EbA in order to enhance information-based decisions. It asserts that assessing the costs and benefits of EbA options helps highlight the potential benefits of conservation, restoration, and sustainable management. Examples from the Philippines include mangrove ecosystem restoration, the creation and management of marine sanctuaries, and coral reef and wetland management.

https://portals.iucn.org/library/sites/library/files/documents/2016-009.pdf

Australia/Oceania

Mataki et al. (2013). *Choiseul Province climate change vulnerability and adaptation assessment report: securing the future of Lauru now. SPC/GIZ/SPREP.*

The report stresses the importance of ecosystem services for the adaptive capacity of the province at community levels. It details how water catchment management is an important EbA response to address watershed degradation that has led to an increase in flooding events. Coastal vegetation, such as mangrove ecosystems, are presented as key measures in coastal protection and disaster risk reduction. Additional EbA measures addressed include management of tidal wetland systems for coastal defense, management of slope vegetation for landslide risk, and the establishment of diverse agricultural and agroforestry systems in agricultural land.

https://www.weadapt.org/sites/weadapt.org/files/legacy-new/placemarks/files/52d3d4b75546achoiseul-vulnerability-assessment.pdf

Franco et al. (2017). *Application of Cost-Benefit Analysis to Ecosystem based Adaptation (EbA) solutions for climate change: final results. The Nature Conservancy.*

This report details how cost-benefit analysis can be applied to evaluate EbA options. Included are some options identified during a project in Micronesia and Melanesia to help communities and ecosystems adapt to climate change in low lying atoll islands and high islands watersheds. Possible EbA measures identified by communities included green buffer strips, shoreline revegetation, coral reef conservation, sea grasses restoration, giant clam gardening, etc.

Europe

Doswald, N. and Otsi, M. (2011). *Ecosystem-based approaches to adaptation and mitigation - good practice examples and lessons learned in Europe. Bundesamt fur Naturschutz (BfN) - Federal Agency for Nature Conservation.*

This report explores good practice examples of ecosystem-based approaches to climate change mitigation and adaptation in Europe. The study compiled 101 case studies, including 49 EbA examples, with the majority coming from the United Kingdom, Germany, and the Netherlands. These case studies were divided into the following areas: inland waters, coastal zone, agriculture and forestry, and cities with examples of EbA measures including river restoration, sand nourishment, and dune restoration.

https://www.bfn.de/fileadmin/MDB/documents/service/Skript_306.pdf

South America

Dourojeanni et al. (2016). *Vulnerability Assessments for Ecosystem-based Adaptation: Lessons from the Nor Yauyos Cochas Landscape Reserve in Peru. In: Salzmann N., Huggel C., Nussbaumer S., Ziervogel G. (eds) Climate Change Adaptation Strategies – An Upstream-downstream Perspective. Springer.*

This study compares three different vulnerability assessment approaches, which were carried out simultaneously in the same location in Peru. All three sought to identify appropriate EbA measures based on ecological and social vulnerabilities. Selected measures included community-based grassland management, domestic livestock husbandry, and conservation and management of upper micro-watersheds, wetlands and watercourses.

Online database sources

Table_Anx 2 provides a selection of open sources where ecosystem-based adaptation and related examples from around the globe are presented.

Table_Anx 2: Sources of online databases containing EbA measures

Title/geographic range of measures	Description/web link
Database on ecosystem-based approaches to Adaptation (UNFCCC) Global	This is an initiative under the Nairobi work programme to provide examples of ecosystem-based approaches to adaptation, supplementing information to FCCC/SBSTA/2011/INF.8, mandated by the SBSTA at its thirty-fourth session under the Nairobi work programme. *http://www4.unfccc.int/sites/NWP/Pages/ecosystems-page.aspx*
Climate Change Adaptation Database – Integrating Biodiversity into Climate Change Adaptation Planning (CBD) Global	The database provides web-based guidance on the integration of biodiversity within adaptation planning. It gathers information tools and case studies from a number of relevant partners. It provides links to scientific studies and other resources on biodiversity-related climate change adaptation. These examples can assist managers and governments to find adaptation options that will not have a negative impact on biodiversity. *https://adaptation.cbd.int/options.shtml#sec1*
WOCAT Global Database on Sustainable Land Management (UNCCD) Global	The Global Database on Sustainable Land Management (SLM) of WOCAT (the World Overview of Conservation Approaches and Technologies) provides free access to the documentation of field-tested SLM practices – many of which are relevant for climate change adaptation. An SLM practice can be either an SLM Technology (a physical practice that controls land degradation and/or enhances productivity, consisting of one or several measures) or an SLM Approach (ways and means used to implement one or several SLM Technologies, including technical and material support, stakeholder engagement, and other). *https://qcat.wocat.net/en/wocat/*
PANORAMA – Solutions for a healthy planet (GIZ, IUCN, UN Environment, GRID Arendal, Rare) Global	This is an interactive platform and database of specific, applied examples of successful NBS, EbA and Eco-DRR processes or approaches structured according to regions, ecosystems, specific thematic areas, governance and hazards addressed. It is useful for identifying different targets (Aichi, Sendai Framework, SDGs, NDC) and outlining challenges. *http://panorama.solutions/en/portal/ecosystem-based-adaptation*
Natural Water Retention Measures catalogue (EU) Europe	NWRM cover a wide range of actions and land use types. Many different measures can act as NWRM by encouraging the retention of water within a catchment and, through that, enhancing the natural functioning of the catchment. The catalogue of measures is sorted by sector. It has been developed in the NWRM project, representing a comprehensive but non prescriptive wide range of measures. *http://nwrm.eu/measures-catalogue*
Adaptation Solutions Portal (ICIMOD, Hi-AWARE, CAS) Hindukush & Himalaya Region	The portal brings the story of climate change in the Hindu Kush Himalaya to life, mapping climate change impacts through hazards (floods, droughts, heat, fire, landslides) for the whole region. It exchanges local solutions from different river basins to increase adaptive capacity. *http://www.cas-platform.com/hi-aware/*
Naturally resilient communities (US National Planning Association) North America	This database allows to explore over 50 solutions and case studies on nature-based solutions and included case studies of successful projects from across the US to help communities learn more and identify which nature-based solutions might work for them. The explorer allows to filter by cost, region, hazards, and more. *http://nrcsolutions.org/*

Application example 2:

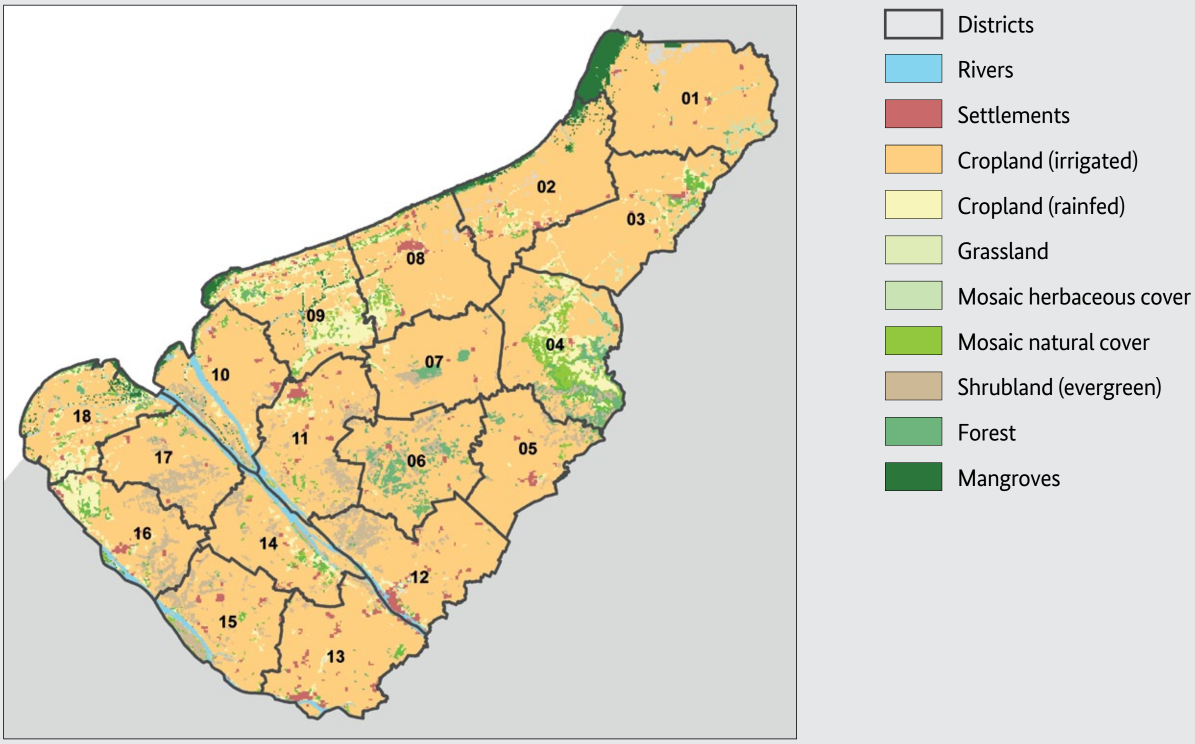
Adaptation to salinity intrusion in low elevation coastal zones

This annex provides a second application example of how the Guidebook approach can be applied. The case study presents a coastal area, including a river delta, experiencing high risk for the loss of agricultural livelihoods due to salinity intrusion.

Description of the coastal area including social-ecological features:

The region is characterised by a tropical, monsoonal climate with temperatures ranging from an average low of 20 °C to an average high of 33 °C. During the rainy season from May to November, the area experiences monthly rainfall between 200 mm and 350 mm, whereas during the dry season from December to April, monthly

Figure_Anx 2: Land use along the coastline



average rainfall ranges from 10 mm to 100 mm. The average annual humidity is 80% and the rainfall 1,600 mm. The long coastline has a length of 200 km and approximately 6.5 million people are living in the study area, which is sub-divided into 18 administrative districts (Figure_Anx 2).

The coastal area is characterised by a river delta with fertile soils, which is mainly covered by croplands. Approximately 60% of the GDP is generated from agricultural products and fishing. Some districts face high poverty rates and rely heavily on income from agriculture as they lack other types of economic opportunities.

Adaptation challenges:

As a low-lying coastal region, the region is particularly susceptible to salt-water intrusion resulting from a combination of sea level rise and land subsidence due to groundwater extraction. In the dry season and during times of drought, a deficit in rainfall in the basin results in low river flows contributing to increased duration and levels of salinity intrusion. Additionally, during drought periods demand for irrigation water increases, as less water is stored in fields. Due to intensified agricultural production and infrastructure development, land has been and continues to be converted to crop land – both upstream and in the coastal zones. Furthermore, groundwater is extracted in order to decrease salinity levels of needed water in the short term, which feedbacks into an overexploitation of natural resources in the long term. Increased salinity intrusion is one of the drivers of land use changes, e.g. the conversion of rainfed or irrigated crop systems into saline aquaculture. This generates several potential environmental problems such as increased pollution or degradation of soils and wetlands.

The districts located by the sea (district 1, 2, 8, 9, 10 and 18) are partly covered by mangrove forests along the coastline. Those forests are essential for shoreline protection and provide important ecosystem services for the region. Yet, mangroves are severely threatened due to the increasing demand for farmland and aquaculture. The conversion of wetlands and forests triggers erosion, threatening existing farmlands. The area is characterised by intensive agriculture, mainly consisting of irrigated croplands, with a few extents of natural vegetation, in particular natural forests, shrubs and herbaceous cover. The remaining mangrove forests are protected, but have severely decreased in extent within the last decades. Wetlands along the river have been degraded, and the river bed and delta have been modified to generate additional space for farmland, which has led to decreased retention capacity and higher flood levels during the wet season. In general, the remaining ecosystems in the study area are poorly managed and do not contribute to a reduction of risk.

Most farmers are not trained in land management, which leads to an increased risk of soil degradation. Climate change puts increasing pressure on the agriculture-based production system in the study area. On a communal level, water management plans are available to deal with water scarcity. National support and water management plans, however, are lacking. Furthermore, the water regime downstream has changed due to increased upstream development (including land use changes), increasing irrigation water extraction and hydropower development. Transboundary river basin agreements are in place.

Module 1
Preparing the risk assessment

Step 1
Understanding the context of a climate risk assessment for adaptation

At a national level, adaptation to increasing salinity intrusion is high up on the political agenda, but requires a detailed baseline risk assessment to identify hotspots (in all its dimensions of hazard, exposure, and vulnerability) and evaluate social-ecological conditions. For this particular region, this was the first climate risk assessment being conducted. It was expected that salinity intrusion would continue to increase due to changes in precipitation, fluctuations in river flows and rising sea levels combined with land subsidence. This required the planning of adaptation measures to prevent crop failure and loss of livelihoods.

The high dependency of local communities as well as national food security on rainfed and irrigated agriculture makes adaptation to changing salinity levels imperative. Amongst the key actors are the Department of Water Management and Environment at the district level, the National Ministry of Agriculture, as well as representatives from affected communities.

Step 2
Identifying objectives and expected outcomes

The assessment aimed at providing answers to the following key questions:

- *What is the risk of loss of agricultural livelihoods due to salinity intrusion in the study area, and (how) can it be reduced through adaptation, including EbA measures?*
- *What are potential co-benefits and trade-offs associated with EbA options?*

Step 3
Determining the scope of the assessment

The assessment aimed at analysing the risk of loss of agricultural livelihoods in a coastal zone due to salinity intrusion and at identifying suitable adaptation (including EbA) measures. It focused on two risk factors contributing to increased duration and levels of salinity intrusion: the hazard of increasing rainfall deficits in the basin resulting in low river flows during dry season and times of drought; and a higher sensitivity of the population due to increasing demand for irrigation water during drought periods, when less water is stored in fields.

The assessment covered all 18 districts in the study area and focused on current risks.

Step 4
Preparing an implementation plan

It was decided that local stakeholders ought to be included in the assessment (in order to be able to draw on local knowledge and create ownership of the process), that an international development agency working with local experts would be coordinating the process, and that local universities would give input and help with data collection (qualitative and quantitative). Participatory approaches were to be used to identify local perceptions of climate risks and existing adaptation practices to increased salinity intrusion. All stakeholders within the region were to be included with a special focus on farmers and landowners, and further measurements undertaken throughout the year to determine the extent of salinity intrusion in both wet and dry season. The risk assessment should be completed after 18 months, revealing potential risk hotspots and suitable sites for (ecosystem-based) adaptation measures.

Module 2
Developing impact chains

Step 1
Identify potential climate impacts and risks

Loss of agricultural livelihoods due to salinity was identified as the main risk.

Step 2
Determine hazard(s) and intermediate impacts

The key hazard – deficit in rainfall in the basin, leading to reduced water flows, sinking groundwater tables, reduced water storage in the field and increased irrigation needs – was added to the impact chain (Figure_Anx 3). It was concluded that contribution of relative sea level rise to this process is minor to date, but will likely exacerbate in the future.

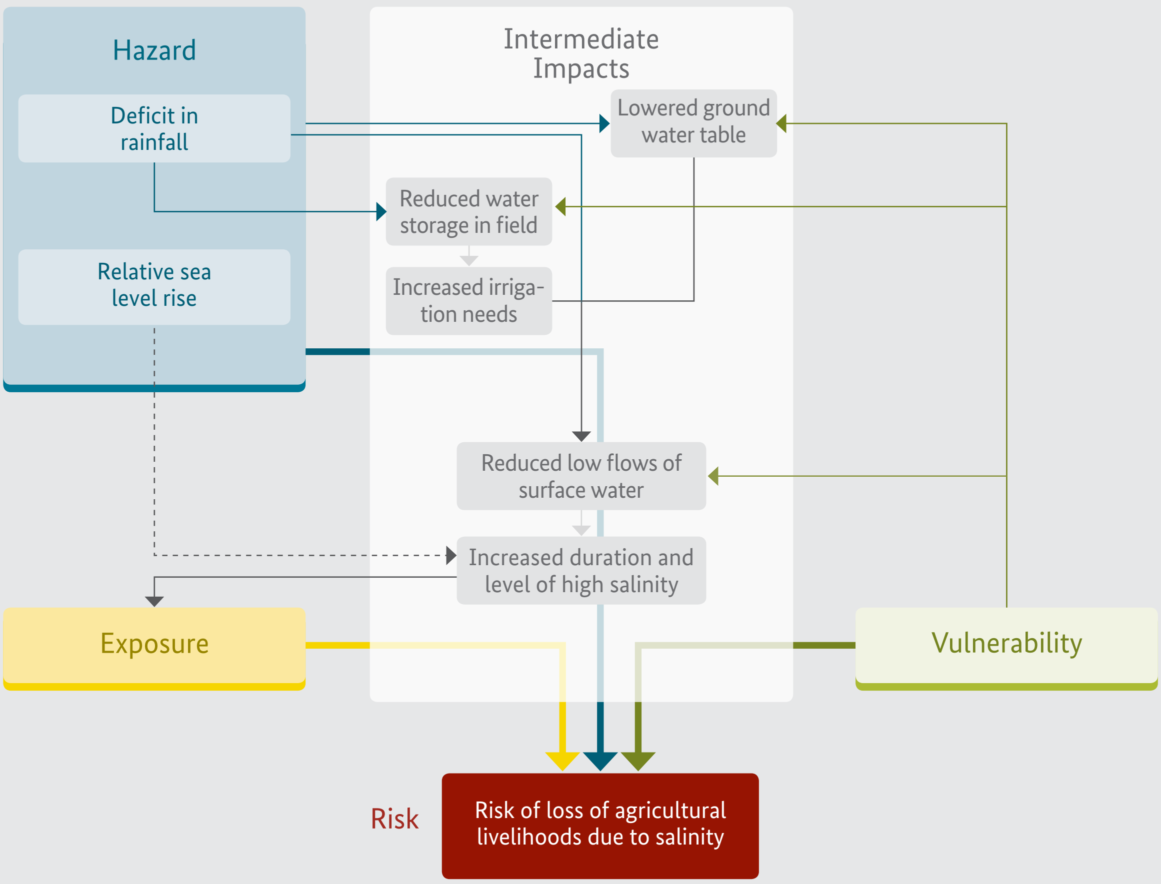
Step 3
Determine the vulnerability of the social-ecological system

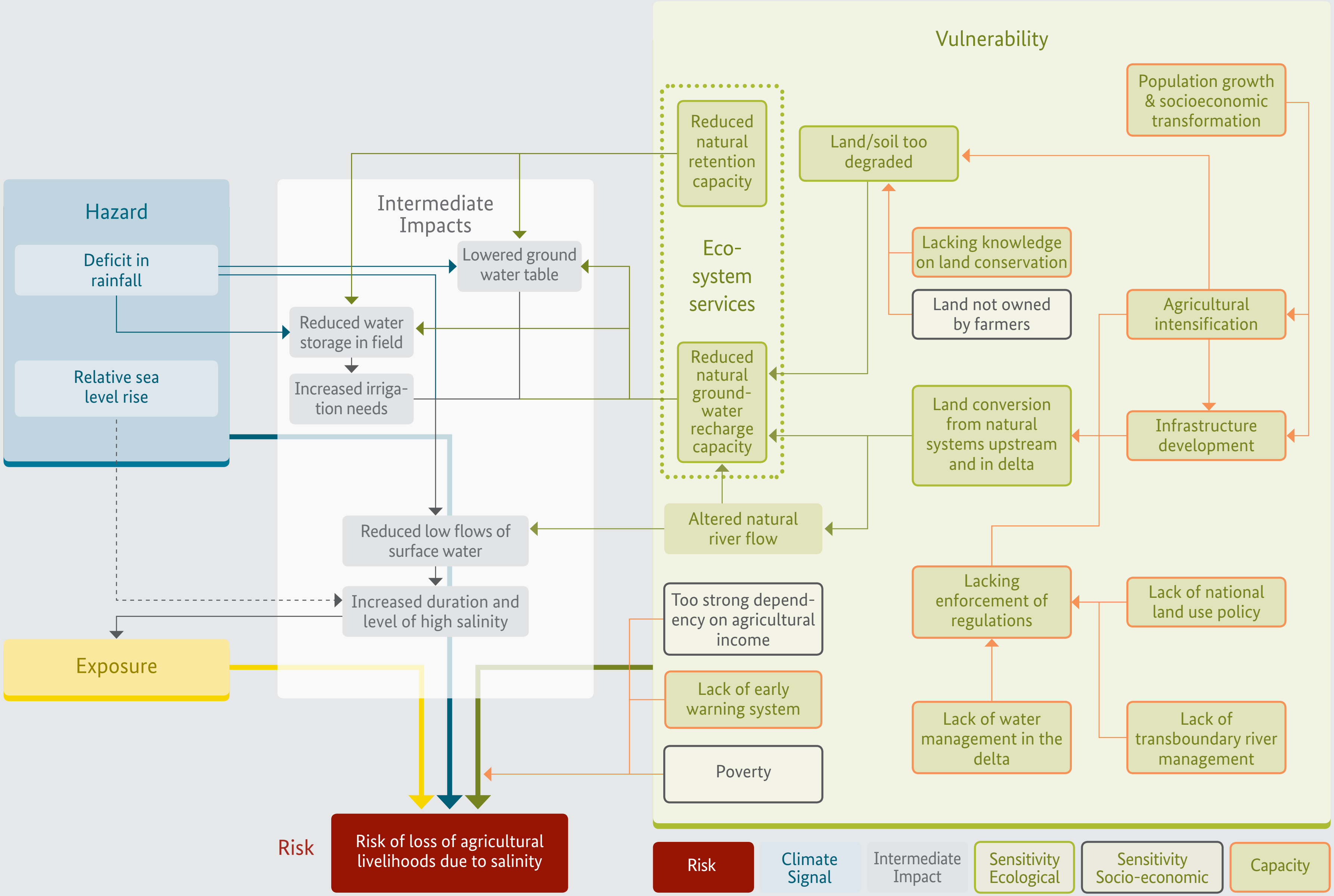
Relevant factors determining the vulnerability of the social-ecological system (SES) were identified. As shown in Figure_Anx 4, the factors determining vulnerability affect the intermediate impacts and the overall risk of loss of agricultural livelihoods due to salinity. A loss of the ecosystem services 'retention capacity' and 'groundwater recharge capacity', for example, leads to lowered ground water tables. The loss of these services is caused by a combination of social and ecological changes, such as land conversion and soil degradation driven by e.g. lack of knowledge of land conservation or lack of land tenure. For example, stakeholders highlighted that agricultural intensification in the study area has led to a degradation of land and soil with impacts on natural groundwater recharge capacity.

Step 4
Determine exposed elements of the social-ecological system

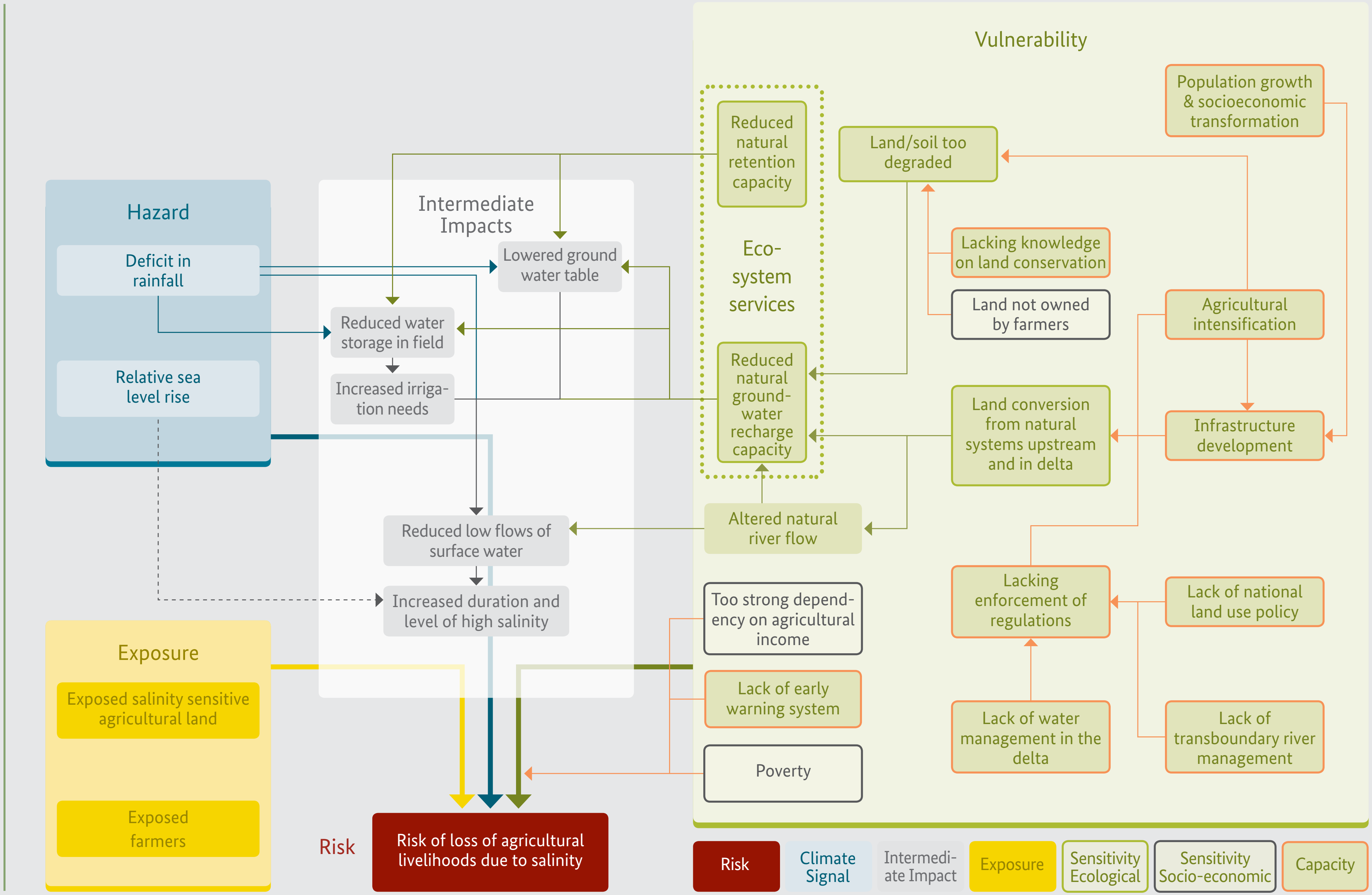
Exposure of relevant elements of the social-ecological system to salinity intrusion was evaluated, with the exposed elements at risk being salinity sensitive agricultural land and farmers whose livelihoods are affected (Figure_Anx 5).

Figure_Anx 3: Impact chain with intermediate impacts and hazard factors identified

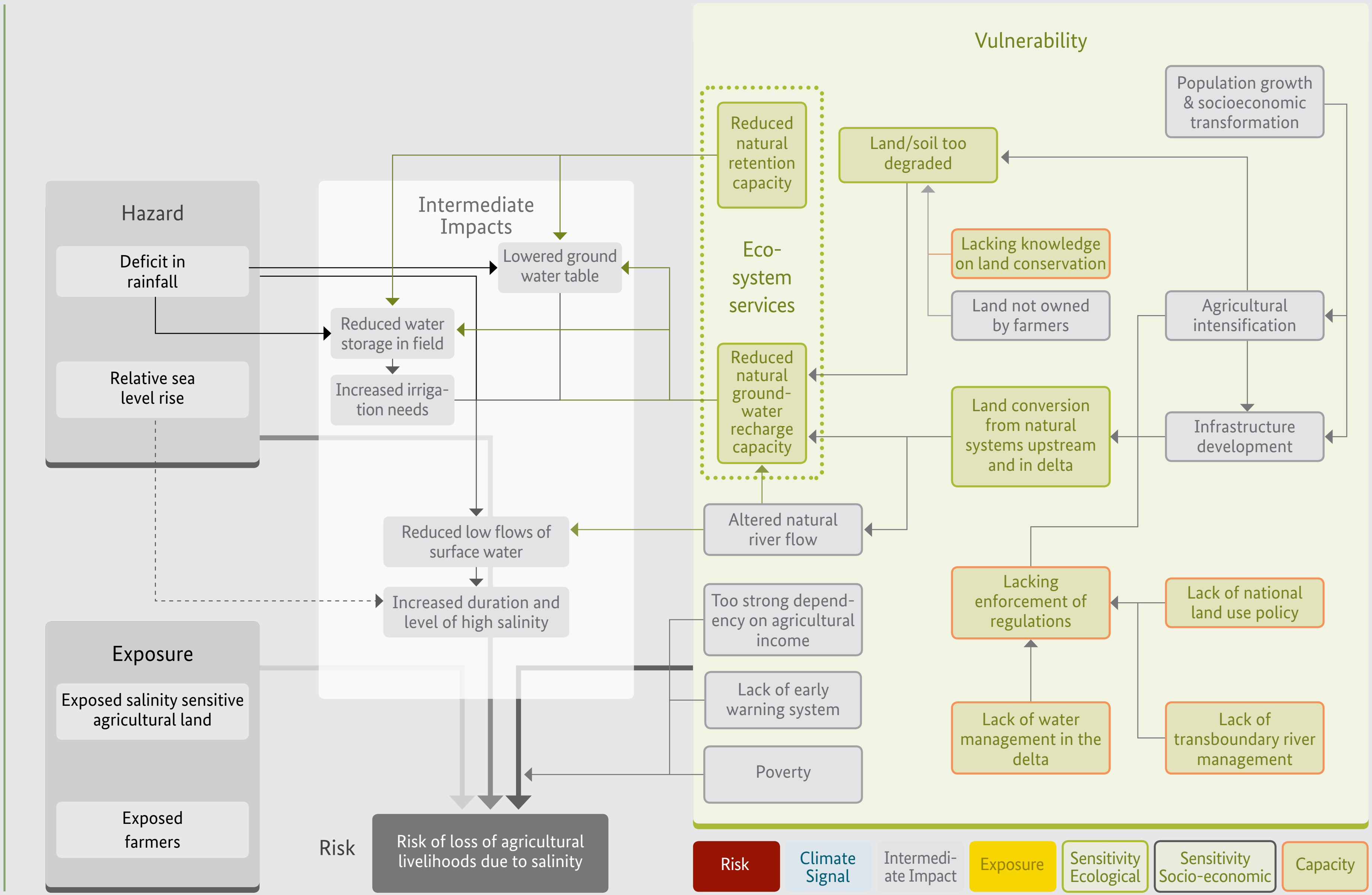




Figure_Anx 4: Impact chain with vulnerability factors added, including ecological and social sensitivity and capacity



Figure_Anx 5: Impact chain with exposure added



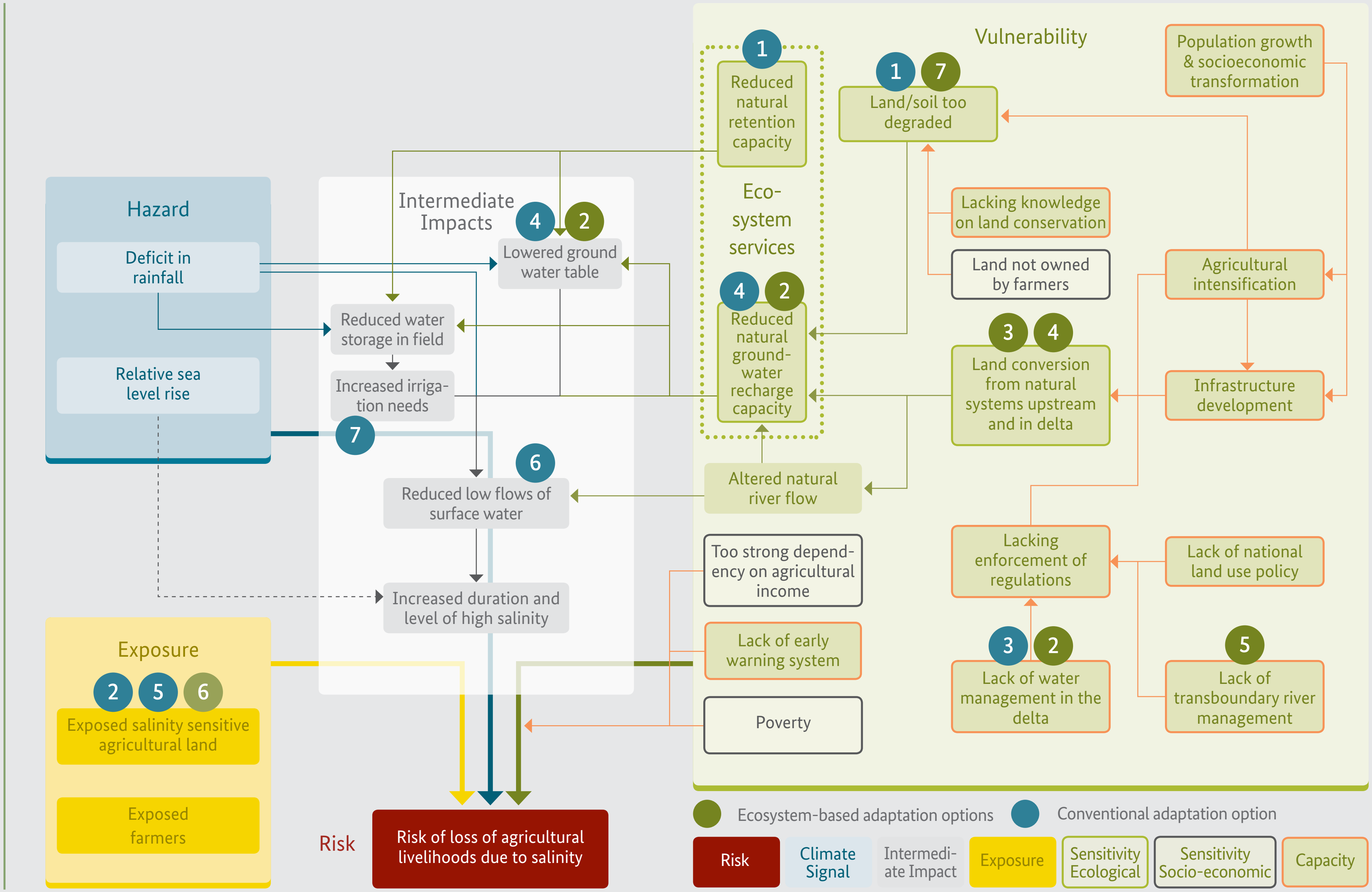
Figure_Anx 6: Entry points for adaptation practitioners and planners working on natural resource conservation and management (green coloured boxes)

After the identification of hazard, exposure and vulnerability factors, entry points for (ecosystem-based) adaptation measures or 'adaptation packages' (see Module 9) were identified by the participants. Figure_Anx 6 highlights elements of the impact chain that could potentially be targeted by adaptation measures. Factors related to ecological sensitivity, as well as to socio-economic sensitivity and capacity, can be entry points for the identification of adaptation measures.

Table_Anx 3 and Figure_Anx 7 present potential adaptation options, both EbA and conventional, which in turn comprise soft (e.g. raising awareness for sustainable land management practices) and hard/engineering-based approaches (e.g. construction of a sea wall).

Table_Anx 3: Ecosystem-based (green dots) and conventional (blue dots) adaptation options

	Ecosystem-based adaptation options	Conventional adaptation options
1	Wetland restoration	Construct reservoirs
2	Floodplain restoration & reconnection	Construction of a sea wall
3	Protection/restoration of forests upstream	Separate freshwater and brackish water zones with sluice gates
4	Protection/restoration of coastal vegetation (incl. mangroves)	Artificial groundwater recharge during the rainy season
5	Reconnect lower estuary ecosystem incl. salt marches	Change the crop to more saline tolerant crops incl. halophytes
6	Diversify agricultural system to maintain genetic diversity of crops and increase robustness against uncertain salinity conditions	Bring fresh river water to saline region: divert water from upstream to downstream (large scale infrastructure measure for water diversion)
7	Improve soil quality incl. methods of soil conservation, land preparation	Establish irrigation procedures that help to maintain high soil moisture and wash out the soil salinity periodically



Figure_Anx 7: Visualisation of potential adaptation measures (incl. EbA measures) in the impact chain

Module 3

Identifying and selecting indicators for risk components

Step 1
Selecting indicators for hazards

Following the Guidebook approach, one indicator was identified for each factor in the impact chain. The number of days with precipitation below a critical relevant threshold is an important factor partly determining the agricultural productivity in the study area. Local experts and farmers had to be consulted in order to define a locally relevant threshold for rainfall per day. In the dry season, there are sometimes several weeks without rainfall. Although the region is adapted to dry season conditions, a late onset of the rainy season or a too early start of the dry season leads to an increase of salinity levels. For salinity levels, the indicators 'percentage of area with salinity > 4 g/l' and the 'number of days with salinity > 4 g/l' were identified.

Step 2
Selecting indicators for vulnerability and exposure

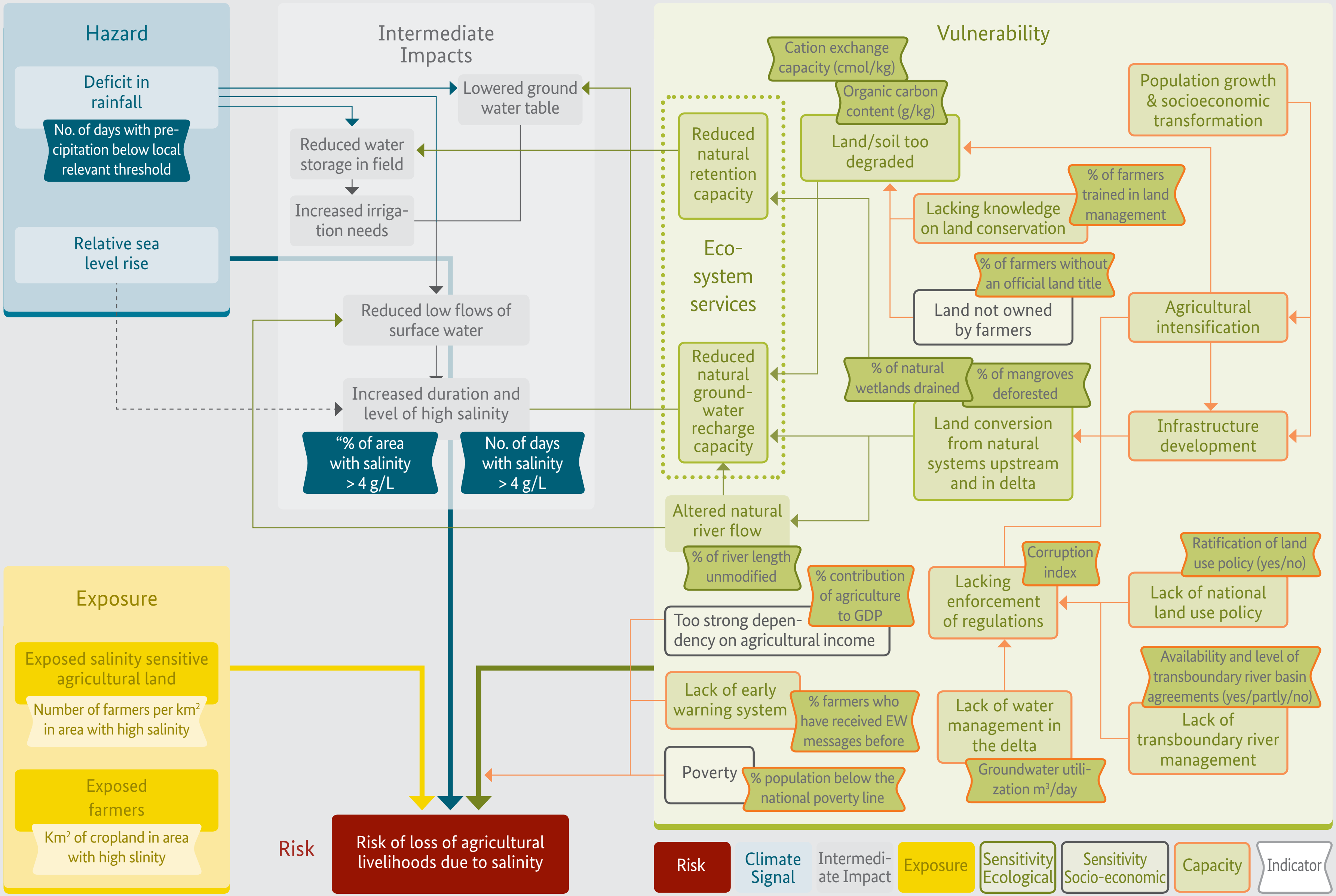
Following the identification of hazard indicators, indicators for vulnerability and exposure factors were selected according to Module 2. It was decided to use a variety of different indicators targeting environmental and societal aspects, as well as indicators directly referring to agriculture and land use, according to the setting of the case study. Some indicators, for example 'percentage of the contribution of agriculture to national GDP', might be perceived in another context as a positive development for the region, but in the application example it increases risk, as it reveals a strong dependency on agricultural income and thus in turn potentially high losses due to salinity intrusion. Figure_Anx 8 shows the impact chain with indicators for the hazard, exposure and vulnerability components.

Step 3
Checking if the indicators are specific enough

As outlined in the Guidebook, it is important that every indicator has a clear direction with a determined negative or positive contribution to risk and is precisely measurable. The 'percentage of mangroves deforested' can be measured and monitored continuously with satellite data, whereas the indicator 'lack of transboundary river management' is a process of policy negotiations and is valid for the whole region, equally contributing to the vulnerability and risk of each district. Spatial resolution and precise data at local level remains a key challenge for the determination of some indicators, e.g. the corruption index, as data is only available at national level. Here expert judgement can help to acquire information on corruption levels across the 18 districts.

Step 4
Creating a list of provisional indicators for each factor

Next all indicators were listed in a table, including the unit of measurement, as well as their direction in relation to risk (Table_Anx 4).



Figure_Anx 8: Impact chain with indicators

Table_Anx 4: Indicators for each risk component (hazard, exposure and vulnerability) with increasing tendency (+) and decreasing tendency (-)

Component	Factor	Indicator	Direction
Hazard	Deficit in rainfall	Number of days with precipitation below local relevant threshold per year	+
Exposure	Exposed farmers	Number of farmers per km² in area with high salinity	+
	Exposed salinity sensitive agricultural land	Km² of cropland in area with high salinity	+
Vulnerability	Land/soil too degraded	Organic carbon content (g/kg)	-
		Cation exchange capacity (cmol/kg)	-
	Land conversion from natural systems upstream and in delta	Percentage of natural wetlands drained	+
	Land conversion from natural systems upstream and in delta	Percentage of mangroves deforested	+
	Altered natural river flow	Percentage of river length unmodified	-
	Lacking knowledge of land conservation	Percentage of farmers trained in land management	-
	Land not owned by farmers	Percentage of farmers without an official land title	+
	Too strong dependency on agricultural income	Percentage of contribution of agriculture to GDP	+
	Lack of early warning systems	Percentage of farmers who have received early warning (EW) messages before	-
	Poverty	Percentage of population below national poverty line	+
	Lacking enforcement of regulation	Corruption index (1-5 with 1-very low, 5-very high)	-
	Lack of national land use policy	Ratification of land use policy (yes/no)	-
	Lack of transboundary river basin agreements	Availability and level (binding or voluntary) of transboundary river basin agreements (3-available and legally binding, 2-available but non-binding, 1-not available)	-
	Lack of water management in the delta	Groundwater utilisation (m^3/day)	-

Module 4
Data acquisition and management

The measurement and data collection might differ significantly depending on the specific indicator. As the risk assessment within the context of EbA aims at a spatially explicit output, georeferenced data was considered to be particularly useful. It can be pixel-based information or referenced to administrative areas. For baseline information about the region, geographic, environmental, climatic, socio-economic and spatial data was collected. Baseline geographic data for the application example includes administrative data about the districts, current land use, water bodies, information on soil properties and the extent and level of salinity. Socio-economic data marks an important component as well as including census data, poverty estimations or education levels. For the hazard component, precipitation data was obtained from local weather stations.

Accordingly, data was acquired from meteorological offices, regional statistics offices, ministries and municipalities, regional research institutes/universities or publically accessible data portals providing geographic data and satellite images. Collecting data on district level not older than two years is sometimes very challenging and cannot be achieved for all factors. For example, census data is not provided every year, but in intervals of five to ten years. Even though data might not be as spatially differentiated or not available for the requested time period, it can still reveal regional differences in the study area or historic changes of certain factors. In this example, exposure of farmers and agricultural land to salinity was determined by means of spatial analysis in a Geographic Information System (GIS), combining spatial data representing areas affected by salinity > 4g/l and data on land use/land cover and gridded (i.e. pixel-based) population data obtained from global data repositories.

Table_Anx 5 shows the attribute values of each indicator per district.

Component	Factor	Indicator	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16	D17	D18
Hazard	Deficit in rainfall	Number of days with precipitation below local relevant threshold per year	24	22	24	19	18	19	22	16	23	24	23	17	18	20	19	21	21	22
Exposure	Exposed farmers	Number of farmers per km² in area with high salinity	68,729	55,449	73,969	37,796	0	3,970	2,825	62,085	70,674	43,763	49,080	0	0	4,025	6,745	28,644	13,264	41,232
	Exposed salinity sensitive agricultural land	Km² of cropland in area with high salinity	960	760	770	320	0	25	35	470	710	540	310	0	0	120	45	150	215	650
Vulnerability	Land/soil too degraded	Organic carbon content (g/kg)	183	138	210	126	57	62	48	72	68	64	60	75	55	83	70	70	51	61
		Cation exchange capacity (cmol/kg)	60	61	63	62	57	55	56	58	60	57	57	56	58	58	61	57	54	56
	Land conversion from natural systems upstream and in delta	Percentage of natural wetlands drained	15	9	8	14	7	7	4	8	11	10	9	8	7	8	7	7	8	10
	Land conversion from natural systems upstream and in delta	Percentage of mangroves deforested	21	12	0	0	0	0	0	9	11	16	5	2	1	4	3	5	8	18
	Altered natural river flow	Percentage of river length unmodified	89	87	98	96	97	98	97	97	90	66	71	75	78	55	76	79	61	92
	Lacking knowledge of land conservation	Percentage of farmers trained in land management	22	18	20	15	17	21	24	19	18	21	19	20	18	16	14	17	19	16
	Land not owned by farmers	Percentage of farmers without an official land title	45	55	38	35	37	36	36	51	48	39	37	31	42	38	32	52	36	53
	Too strong dependency on agricultural income	Percentage of contribution of agriculture to GDP	52	55	66	44	63	48	47	59	62	61	46	56	54	58	65	63	59	66
	Lack of early warning systems	Percentage of farmers who have received EW messages before	45	31	36	25	34	38	42	31	34	28	43	39	36	27	32	34	31	26
	Poverty	Percentage of population below the national poverty line	20	15	15	10	10	10	15	20	20	20	20	23	10	10	10	15	15	20
	Lacking enforcement of regulation	Corruption index (1-5 with 1-very low, 5-very high)	3	4	3	2	4	5	4	3	2	4	4	4	3	2	2	3	3	2
	Lack of national land use policy	Ratification of land use policy (yes/no)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Lack of transboundary river basin agreements	Availability and level of transboundary river basin agreements	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	Lack of water management in the delta	Groundwater utilisation (m³/day)	135	63	135	63	50	50	95	63	95	95	95	50	11	11	142	142	142	142

Table_Anx 5 : Raw data for the different indicators (excl. intermediate impacts) – attributes for each district (D1-D18)

Module 5
Normalisation of indicator data

Step 1
Determining the scale of measurement

After data acquisition it was found that the majority of the indicators can be measured in metric values.

Step 2
Normalising the indicator values

After clarifying the direction of each indicator, data was transformed into a standardised score between 0 to 1 by applying thresholds representing optimal and critical states for each indicator. Table_Anx 6 shows for each indicator the direction, the minimum and maximum value of the data and the defined threshold, as identified by the workshop participants. The results of the normalisation step are displayed in Table_Anx 7.

Table_Anx 6: Direction, min-max values and defined thresholds for each indicator

Indicator	Direction	Min	Max	Thresold (min)	Thresold (max)
Number of days with precipitation below local relevant threshold per year	+	16	24	7	28
Km² of cropland in area with high salinity	+	0	960	0	1000
Organic carbon content (g/kg)	-	48	210	0	450
Cation exchange capacity (cmol(kg)	-	54	63	0	240
Percentage of natural wetlands drained	+	4	15	0	25
Percentage of mangroves deforested	+	0	21	0	25
Percentage of river length unmodified	-	55	98	0	100
Percentage of farmers trained in land management	-	14	24	0	100
Percentage of farmers without an official land title	+	31	55	0	100
Percentage of contribution of agriculture to GDP	+	44	66	25	75
Percentage of municipalities with participation in planning process	-	25	45	0	100
Percentage of population with income below the national poverty line	+	10	23	0	30
Corruption index (1-5 with 1-very low, 5-very high)	-	2	1	5	5
Ratification of land use policy (yes/no)	-	0	0	0	1
Availability and level (binding or voluntary) of transboundary river basin agreements (3-available and legally binding, 2-available but non-binding, 1-not available)	-	2	2	1	3
Groundwater utilisation (m³/day)	-	11	142	0	140

Component	Factor	Indicator	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16	D17	D18
Hazard	Deficit in rainfall	Number of days with precipitation below local relevant threshold per year	0.81	0.71	0.81	0.57	0.52	0.57	0.71	0.43	0.76	0.81	0.76	0.48	0.54	0.62	0.57	0.67	0.67	0.71
Exposure	Exposed farmers	Number of farmers per km^2 in area with high salinity	0.98	0.79	1.00	0.54	0.00	0.06	0.04	0.89	1.00	0.63	0.70	0.00	0.00	0.06	0.10	0.41	0.19	0.59
	Exposed salinity sensitive agricultural land	Km^2 of cropland in area with high salinity	0.96	0.76	0.77	0.32	0.00	0.03	0.04	0.77	0.71	0.54	0.31	0.00	0.00	0.12	0.05	0.15	0.22	0.65
Vulnerability	Land/soil too degraded	Organic carbon content (g/kg)	0.59	0.69	0.53	0.72	0.87	0.86	0.89	0.84	0.85	0.86	0.87	0.83	0.88	0.82	0.84	0.84	0.89	0.86
		Cation exchange capacity (cmol/kg)	0.75	0.75	0.74	0.74	0.76	0.77	0.77	0.76	0.75	0.76	0.76	0.77	0.76	0.76	0.75	0.76	0.78	0.77
	Land conversion from natural systems upstream and in delta	Percentage of natural wetlands drained	0.60	0.36	0.32	0.56	0.28	0.28	0.16	0.32	0.44	0.40	0.36	0.32	0.28	0.32	0.28	0.28	0.32	0.40
	Land conversion from natural systems upstream and in delta	Percentage of mangroves deforested	0.84	0.48	0.00	0.00	0.00	0.00	0.00	0.36	0.44	0.64	0.20	0.08	0.04	0.16	0.12	0.20	0.32	0.72
	Altered natural river flow	Percentage of river length unmodified	0.11	0.13	0.02	0.04	0.03	0.02	0.03	0.03	0.10	0.34	0.29	0.25	0.22	0.45	0.24	0.21	0.39	0.08
	Lacking knowledge of land conservation	Percentage of farmers trained in land management	0.78	0.82	0.80	0.85	0.83	0.79	0.76	0.81	0.82	0.79	0.81	0.80	0.82	0.84	0.86	0.83	0.81	0.84
	Land not owned by farmers	Percentage of farmers without an official land title	0.45	0.55	0.38	0.35	0.37	0.36	0.36	0.51	0.48	0.39	0.37	0.31	0.42	0.38	0.32	0.52	0.36	0.53
	Too strong dependency on agricultural income	Percentage of contribution of agriculture to GDP	0.54	0.60	0.82	0.38	0.76	0.46	0.44	0.68	0.74	0.72	0.42	0.62	0.58	0.66	0.80	0.76	0.68	0.82
	Lack of early warning systems	Percentage of farmers who have rseceived EW messages before	0.55	0.69	0.54	0.75	0.66	0.62	0.58	0.69	0.66	0.72	0.57	0.61	0.64	0.73	0.68	0.66	0.69	0.74
	Poverty	Percentage of population below the national poverty line	0.67	0.50	0.50	0.33	0.33	0.33	0.50	0.67	0.67	0.67	0.67	0.77	0.33	0.33	0.33	0.50	0.50	0.67
	Lacking enforcement of regulation	Corruption index (1-5 with 1-very low, 5-very high)	0.50	0.25	0.50	0.75	0.25	0.00	0.25	0.50	0.75	0.25	0.25	0.25	0.50	0.75	0.75	0.50	0.50	0.75
	Lack of national land use policy	Ratification of land use policy (yes/no)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Lack of transboundary river basin agreements	Availability and level of transboundary river basin agreements	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
	Lack of water management in the delta	Groundwater utilisation (m^3/day)	0.04	0.55	0.04	0.55	0.64	0.64	0.32	0.55	0.32	0.32	0.32	0.64	0.92	0.92	0.00	0.00	0.00	0.00

Table_Anx 7: Normalised data for the different indicators (excl. intermediate impacts) – attributes for each district (D1-D18)

Module 6
Weighting and aggregating indicators

Step 1
Weighting indicators

For the sake of simplicity, it was decided to apply equal weights for all indicators.

Step 2
Aggregating of indicators

Then the normalised indicator values were aggregated to composite indicators for each component (hazard, exposure, vulnerability) following the approach described in the Guidebook. The results are shown in Table_Anx 8. The maps in Figure_Anx 9 represent these results for the 18 districts in the study area.

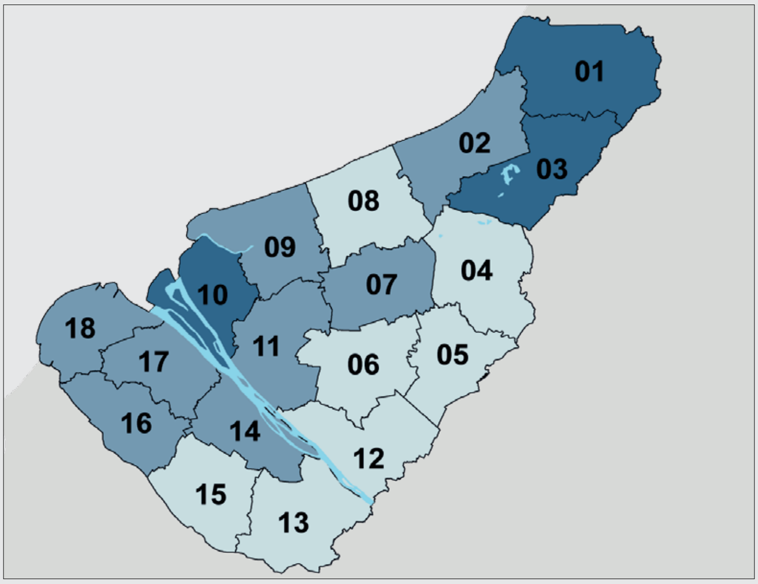
Module 7
Aggregating risk components to risk

The values of the three risk components (hazard, exposure, vulnerability) were aggregated into risk values by applying the arithmetic aggregation method. The results are shown in Table_Anx 8 as well. These risk values were also visualised in a map (see Figure_Anx 10).

Table_Anx 8: Aggregated indicators (hazard, exposure, vulnerability) and risk scores

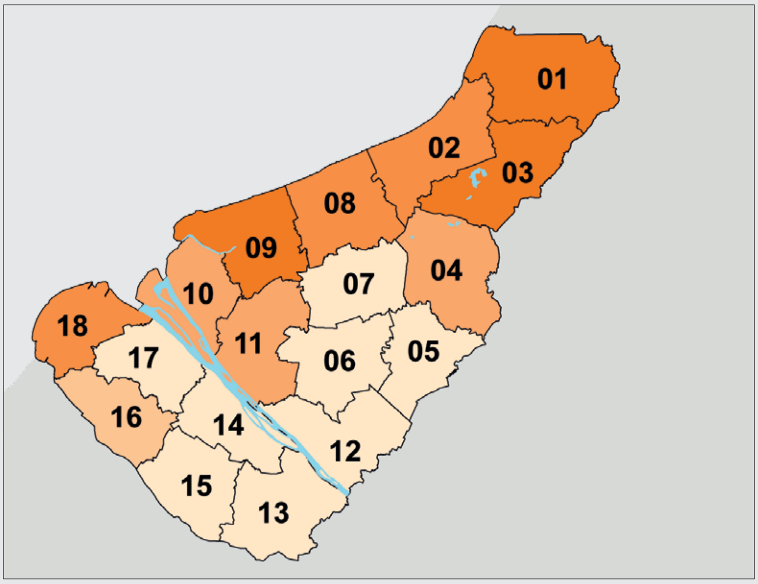
District	Hazard	Exposure	Vulnerability	Risk
District 1	0.81	0.97	0.57	0.78
District 2	0.71	0.78	0.56	0.68
District 2	0.81	0.89	0.48	0.73
District 3	0.57	0.43	0.54	0.51
District 4	0.52	0.00	0.52	0.35
District 5	0.57	0.04	0.47	0.36
District 6	0.71	0.04	0.47	0.41
District 7	0.43	0.68	0.59	0.56
District 8	0.76	0.86	0.61	0.74
District 9	0.81	0.58	0.60	0.66
District 10	0.76	0.51	0.53	0.60
District 11	0.48	0.00	0.55	0.34
District 12	0.52	0.00	0.56	0.36
District 13	0.62	0.09	0.62	0.44
District 14	0.57	0.07	0.53	0.39
District 15	0.67	0.28	0.54	0.50
District 16	0.67	0.20	0.55	0.47
District 17	0.71	0.62	0.62	0.65
District 18	0.81	0.97	0.57	0.78

Figure_Anx 9: Visualisation of aggregated hazard, exposure and vulnerability component



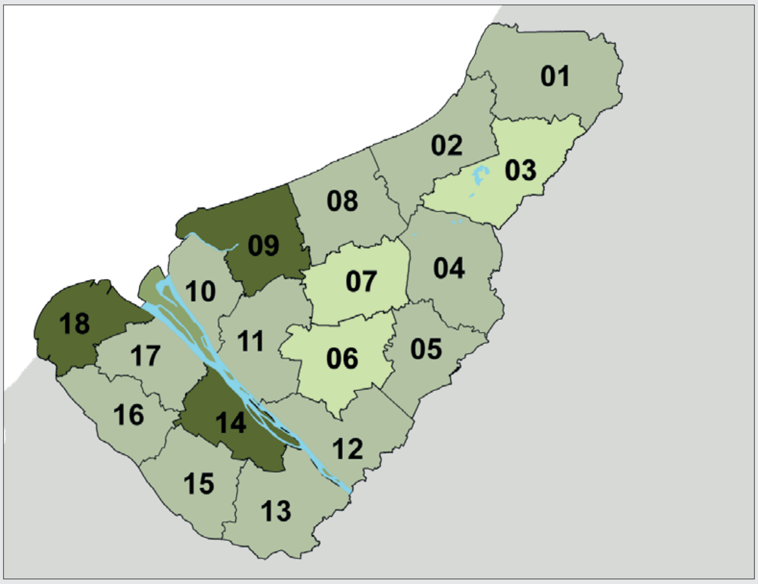
Hazard

- 0.43 - 0.60 (medium)
- 0.61 - 0.80 (high)
- 0.81 - 0.82 (very high)
- Rivers
- Districts



Exposure

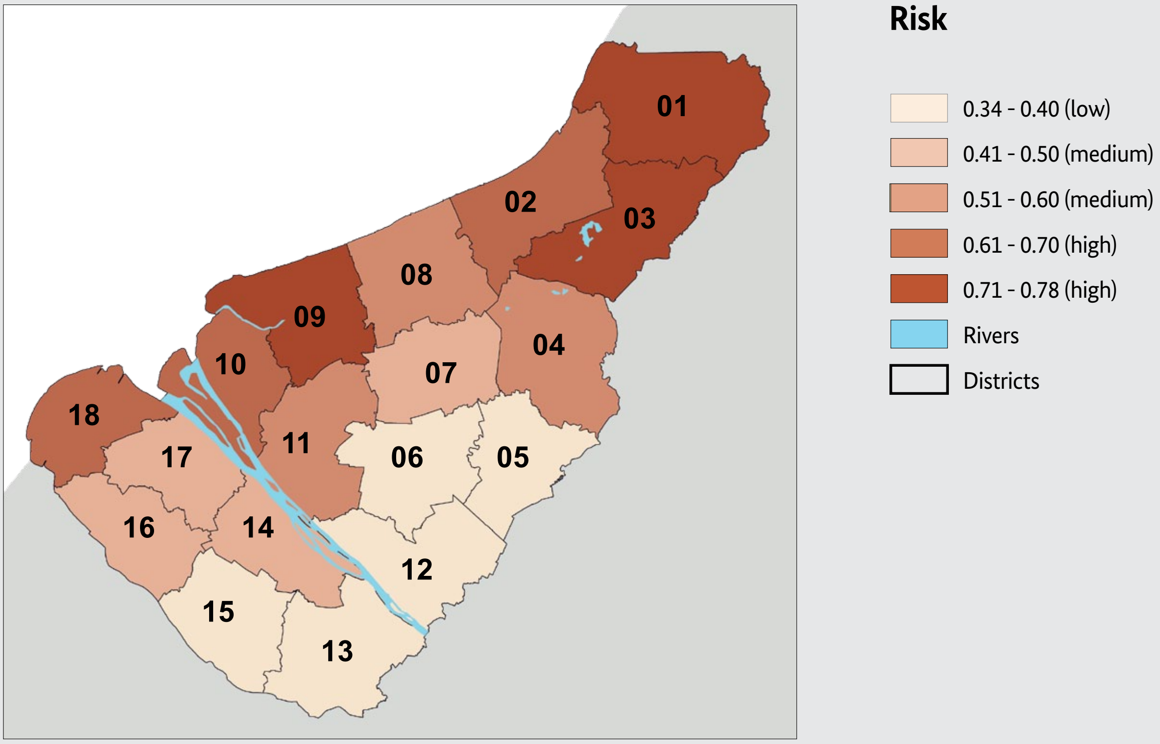
- 0.00 - 0.20 (very low)
- 0.21 - 0.40 (low)
- 0.41 - 0.60 (medium)
- 0.61 - 0.80 (high)
- 0.81 - 0.97 (very high)
- Rivers
- Districts



Vulnerability

- 0.47 - 0.50 (medium)
- 0.51 - 0.60 (medium)
- 0.61 - 0.62 (high)
- Rivers
- Districts

Figure_Anx 10: Aggregated risk components to a composite risk index



Module 8

Presenting and interpreting the outcomes of the risk assessment

As displayed above, the outcome of the assessment is a map for each component (hazard, vulnerability, exposure; Figure_Anx 9), as well as a risk map (Figure_Anx 10). Not all districts face the same risk of loss of agricultural livelihoods due to salinity. The risk assessment revealed that districts with a coastline (districts 1, 2, 8, 9, 10 and 18), but also several interior districts (districts 3, 7, 11 and 14), are severely affected by salinity intrusion. However, this does not automatically result in high risk values, as the components exposure and vulnerability are equally weighted in the risk assessment. The Guidebook (Module 8) provides further examples of how the results could be visualised to support the identification and spatial planning of adaptation options.

Module 9

Identification of adaptation (incl. EbA) options

Based on the impact chain a number of options were identified (Table_Anx 3). Figure_Anx 11 specifies areas within the study area where suggested EbA measures should be implemented to effectively tackle the risk of salinity intrusion.

Figure_Anx 12 illustrates i) direct adaptation benefits, ii) co-benefits, and iii) unintended consequences (or potential trade-offs) for the

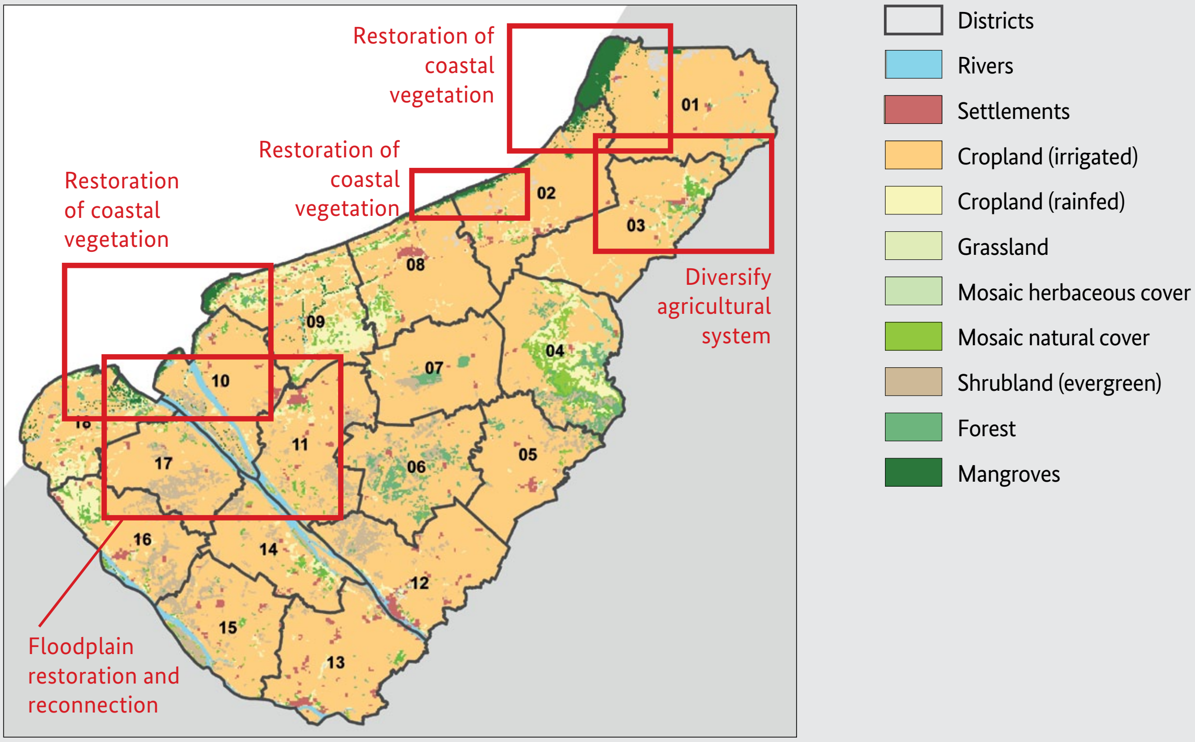
EbA measure 'Protection/restoration of coastal vegetation (incl. mangroves)':

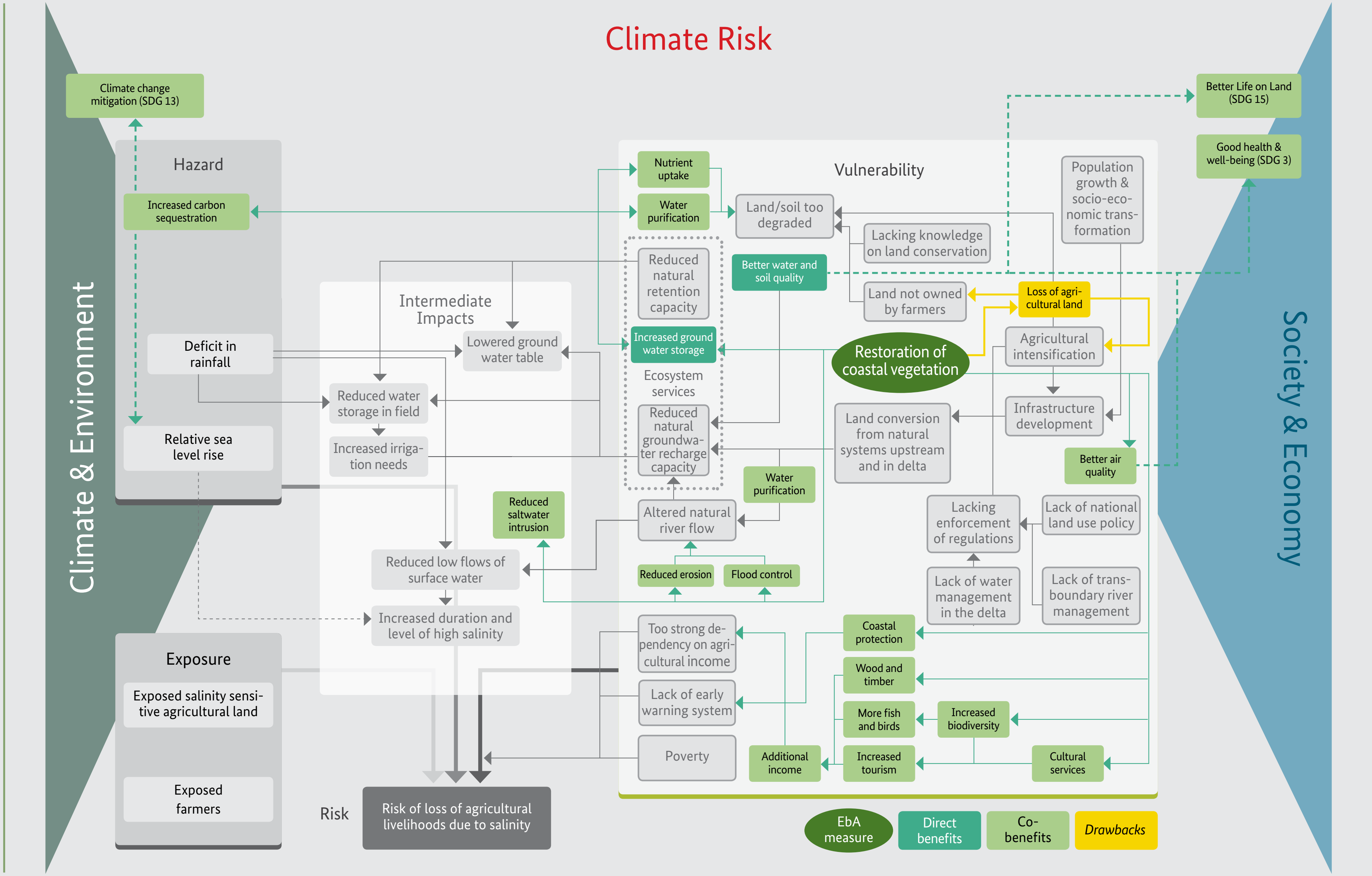
- *Direct adaptation benefits include shoreline stabilisation and, thus, protection of agricultural land and increased ground water storage.*

- *There are a number of co-benefits affecting both factors within the risk components (e.g. mangrove forest restoration leads to increased biodiversity and, in turn, results in more breeding grounds for birds and fish, creating additional income and alternative sources of food besides agriculture in coastal regions), but also 'outside' of the risk components (e.g. mangrove forests increasing carbon sequestration will contribute to climate change mitigation).*

- *As outlined in the Guidebook, potential drawbacks or trade-offs of adaptation measures must be considered as well (e.g. the loss of agricultural land due to forest restoration decreases the area of available farmland and might lead to further intensification of the agricultural production, because remaining space has to be used more efficiently).*

Figure_Anx 11: Suggested EbA measures to tackle salinity intrusion risk





Figure_Anx 12: Co-benefits and potential unintended consequences of EbA measures (example: restoration of coastal vegetation)