Climate Risk Sourcebook

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German Federal Ministry for Economic Cooperation and Development (BMZ)

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On behalf of

Federal Ministry
for Economic Cooperation
and Development

Climate Risk Sourcebook

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Foreword

Climate change is one of the most urgent challenges for people and ecosystems worldwide. The recently published sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC) stresses the occurrence of widespread adverse impacts of climate change. Increased frequency and intensity of extreme weather events, as well as slow-onset processes cause enormous losses and damages to human and natural systems. Marginalized groups and people in vulnerable situations are often disproportionally affected. While the impacts of climate change already become more tangible and threatening, action for addressing them remains insufficient. Adaptation to climate change is, thus, becoming a necessity for governments, companies, and private citizens.

To provide practical and scientifically sound guidance on how to conduct vulnerability assessments, GIZ published its Vulnerability Sourcebook in 2014. The Vulnerability Sourcebook was used in over twenty different GIZ partner countries and provides a step-by-step guidance for designing and implementing a vulnerability assessment. It is also one of the methodological foundations for the ISO 14091:2021 standard on vulnerability, impacts and risk assessment for climate change adaptation.

On behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ), GIZ mandated EURAC Research in cooperation with the International Institute for Applied Systems Analysis (IIASA), the University of Salzburg and the United Nations University, Institute for Environment and Human Security (UNU-EHS) to update the Vulnerability Sourcebook and include lessons-learnt from almost 10 years of application to develop the new Climate Risk Sourcebook.

The Climate Risks Sourcebook provides an updated methodological approach on how to design and conduct climate risk assessments and provides the necessary and state-of-the-art knowledge incorporating findings of the sixth Assessment Report of the IPCC. It is a user-friendly, step-by-step guide to operationalizing the theoretical concept of risk. The approach is location and context-specific and gives guidance on how climate risk assessments can inform and support evidence-based decision making. This includes impact chains as tailor-made conceptual models that illustrate key risks and their drivers for a specific context. The Climate Risk Sourcebook additionally offers expert material for further in-depth knowledge. Another novelty is its focus on communication, gender and vulnerable groups.

We truly believe that climate risk assessments, adapted to the respective context, and carefully executed, are an important prerequisite to identify climate change induced risks to regions, different actor groups and sectors, to manage climate risks effectively and derive options to adapt to the impacts of climate change. We are convinced that the Climate Risk Sourcebook provides a very useful basis for climate adaptation and risk management practitioners around the globe.

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Contents

List of Tables

List of Figures

List of Boxes

List of Formulas

Abbreviations

AHP	Analytic Hierarchy Process
AR6	IPCC Sixth Assessment Report 2021/2022
BAU	Business-as-usual
CBA	Cost-Benefit Analysis
CC	Climate Change
CCA	Climate Change Adaptation
CEA	Cost-Effectiveness Analysis
CHELSA	Climatologies at high resolution for the earth's land surface areas
CI	Composite Indicator
CMIP	Coupled Model Intercomparison Project
CR	Climate Risk
CRA	Climate Risk Assessment
CR-SB	Climate Risk Sourcebook
CRM	Climate Risk Management
CRVA	Climate Risk and Vulnerability Assessment
DRR	Disaster Risk Reduction
EbA	Ecosystem-based Adaptation
EcoDRR	Ecosystem-based Disaster Risk Reduction
EVCA	Enhanced Vulnerability and Capacity Assessment
FAO	Food and Agriculture Organization of the United Nations
GCMs	Global Circulation Models
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Geographic Information System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GMT	Global Mean Temperature
IDP	Internally displaced people
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
JRC	Joint Research Centre
LGBTIQ+	Lesbian, gay, bisexual, trans, intersex and queer persons
M&E	Monitoring and Evaluation
MCA	Multi-Criteria Analysis
NAP	National Adaptation Plan
NbS	Nature-based Solution
NDC	Nationally Determined Contribution
NGO	Non-governmental organisation
OECD	Organisation Economic Co-operation and Development
OHCHR	Office of the High Commissioner for Human Rights
PGIS	Participatory GIS
PLA	Participatory Learning and Action
PRA	Participatory Rural Appraisal
PVA	Participatory Vulnerability Analysis
RCMs	Regional Circulation Models
RCP	Representative Concentration Pathway
RKR	Representative key risk
SAPs	Sectoral Adaptation Plan
SDG	Sustainable Development Goal
SEM	Stakeholder Engagement Mechanism
SSP	Socio-economic Pathway
ToC	Theory of Change
ToR	Terms of Reference
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
UNDRR	United Nations office for Disaster Risk Reduction
WGII	Working Group Two

Quick Guide

The Sourcebook uses text elements for structuring the content.
Figure 1 gives an overview over the meaning of certain text elements and crosscutting icons.

Figure 1 : Text elements and icons

Definitions and introduction

TIP

Tips for the reader

Examples from existing CRA studies

OUTCOME OF THE MODULE

Reference to the website

Stakeholder engagement

Data information and knowledge

Adaptation

Gender and differential vulnerability

Communication

Box – X – Boxes with condensed information

Reference to the Expert Material

About this Publication

The Climate Risk Sourcebook (CR-SB) delivers a conceptual framework for a comprehensive climate risk assessment (CRA) together with modular instructions on how it can be conducted. It is divided into three parts:

1. Sourcebook
2. Expert Material
3. Additional information on the webpage

The CR-SB provides an overview of the conceptual framework and a manual on CRA, covering eight modules, which can be used:

- as a 'beginners guide' on CRA,
- for a rapid risk assessment on a sub-national to local scale, to obtain an overview of the most relevant climate risks, or to prepare a more in-depth risk assessment and/or
- for training purposes.

The Expert Material, the second part of this document, delivers further in-depth information, deeper discussion on the conceptual framework, and instructions for in-depth risk assessments, such as:

- how to work with a more data-driven assessment,
- a composite-indicator approach proposed in the original Vulnerability Sourcebook (see Box A),
- how to communicate risks and underlying risk drivers,
- guidelines on how to get from risk assessments to Climate Change Adaptation (CCA) options/actions,
- the entire module on how risk and CCA should be monitored and evaluated over time, and
- standard impact chains for selected subsystems.

A dedicated sourcebook website - ***https://www.adaptationcommunity.net/climate-risk-assessment-management/climate-risk-sourcebook/*** (hosted on the Adaptation Community Website) contains:

- the PDF version of the CR-SB (Sourcebook + Expert Material),
- standard impact chains for selected subsystems (updated periodically),
- more case studies (updated periodically),
- more links to knowledge sources (updated periodically).

The CR-SB is an evolution of the original Vulnerability Sourcebook (Fritzsche et al., 2015) and its supplement, the Vulnerability Sourcebook Risk Supplement (Zebisch et al., 2017) that has been applied in more than 20 countries and is cited in ISO 14091 ***https://www.iso.org/obp/ui/#iso:std:iso:14091:ed-1:v1:en*** (Box A: Key innovations in the CR-SB). The CR-SB is the foundation for a suite of new tools for climate risk assessments provided by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH on behalf of German Federal Ministry for Economic Cooperation and Development (BMZ), e.g., the Climate Risk Planning & Managing Tool for Development Programmes in Agri-food Systems (CRISP) or the ValueLinks method: "Climate Smart Value Chains".

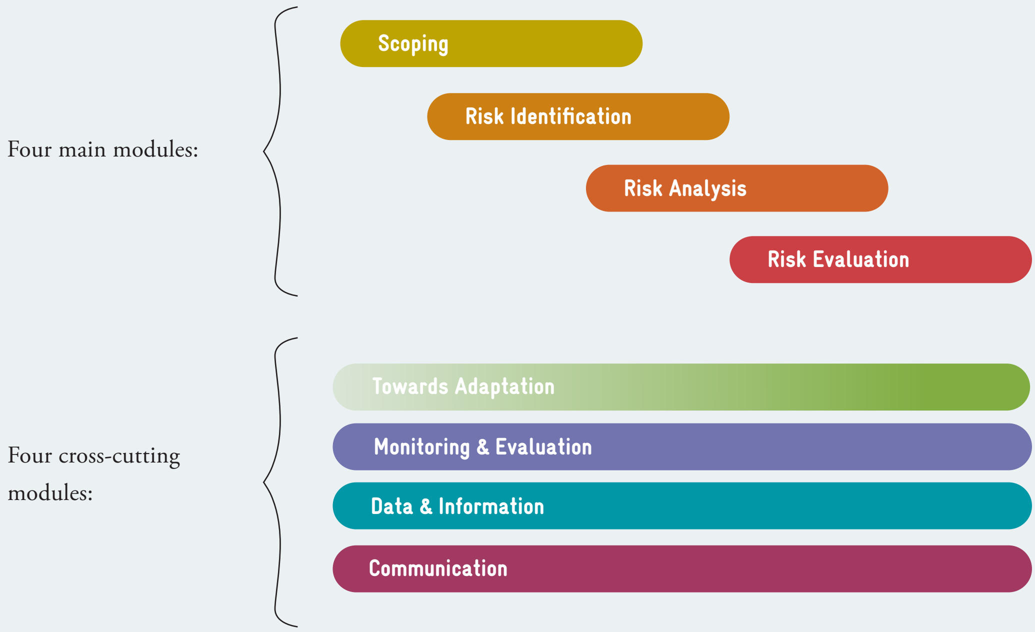
Box — A — Key innovations in the CR-SB

Key innovations in the CR-SB compared to the previous Vulnerability Sourcebook Risk Supplement (Zebisch et al., 2018).

Methodological framework

- Methodology updated to be consistent with the terminology and concepts of the most recent IPCC sixth assessment report (AR6), introducing external risk drivers, impact/risk cascades and systemic risks.
- New methodological chapter on how CRAs inform Climate Risk Management (CRM) by defining entry points for CCA.
- Updated and extended chapter on stakeholder engagement.
- Expanded chapter on gender and differential vulnerability.
- Detailed explanation of the concept of climate risk impact chains.
- Introduction to data and knowledge for climate scenarios and scenarios for non-climatic risk drivers.

Updated module structure



The CR-SB provides links to additional resources available online.

I.

Conceptual Framework

1.1. Climate Risk – Concepts and Definitions

1.1.1. Climate risks – key messages from the IPCC

Climate risk in the context of climate change can be defined as the potential for adverse consequences for human or ecological systems. […]
Relevant adverse consequences include those on lives, livelihoods, health and wellbeing, economic, social and cultural assets and investments, infrastructure, services (including ecosystem services), ecosystems and species (IPCC, 2021a).

Climate risks are strongly related, but not identical, to climate impacts. Climate impacts describe any type of consequences of extreme weather events (such as heavy rain events or droughts) or slow-onset processes related to climate change (such as increasing temperatures; desertification; loss of biodiversity; land and forest degradation; glacial retreat and related impacts; ocean acidification; sea level rise; and salinization). Such consequences can be direct (e.g. flood damaging infrastructure, heat impacts on human health) or indirect (e.g. cascading effects from damaged infrastructure), adverse (e.g. food insecurity) as well as beneficial (e.g. potentially increased yields in areas currently too cold for certain crops). Climate impacts can be observed (current or past impacts) or potential (impacts that could occur under certain conditions today or in the future). Observed or potential climate impacts can be described qualitatively or quantitatively.

Climate risk as a concept, on the other hand, describes how, to what extent and why climate change or climate-related extreme events could bring harm to specific human or ecological systems or functions. The description and assessment of climate risks build on the description of (potential) climate impacts and add further aspects, including a more value-based and system perspective.

- Climate risk is a system perspective on possible adverse consequences that considers the complex interplay of climatic and non-climatic risk drivers (hazard, exposure, vulnerability, and other underlying risk drivers) that lead to adverse consequences.
- Climate risk focuses on the adverse and severe consequences on relevant human and ecological systems that should be avoided or reduced. The choice of which aspects of the human and/or ecological systems are relevant, which consequences should be avoided, and when a consequence is classified as adverse or severe is based on the objectives, targets and values of a particular social and policy context and may differ for different social groups.

- Climate risk addresses the potential for adverse consequences and describes under which conditions they could arise or become adverse and, if possible, how likely certain adverse consequences are today or could become in the near or far future.
- The uncertainties of future climate development make it difficult to predict with absolute certainty the exact impact on our planet and its inhabitants.
- Climate risk as a concept explicitly addresses adverse consequences that need to be managed. Respectively, a CRA has the purpose of identifying key risks and underlying risk drivers, recognising the demand and discussing entry points for improved risk management and CCA.

In the CR-SB, we refer to 'current climate risks' as any risk related to the changing climate that can lead to extreme weather events and slow-onset processes. This includes both risks that are caused by climate change and those that are already present. 'Future climate risks' refer to any climate-related risks projected for a specific time period, such as until the middle of the century, or for a specific temperature increase scenario. This approach is slightly different from the IPCC's risk concept, which mainly looks at the additional risks caused by climate change. A practical way to think about the risks of climate is to examine the current weather extremes, regardless of whether they result from climate change. This method merges both the viewpoints of risk associated with natural hazards and the risks of climate change.

1.1.2. Causes of climate risks

Climate risks result from dynamic interactions between climate-related hazards with the exposure and vulnerability of the affected human and/or ecological system to these hazards. Hazards, exposure and vulnerability may each be subject to uncertainty in magnitude and likelihood of occurrence, and each may change over time and space due to socioeconomic changes and human decision-making (IPCC, 2021a).

The concept of climate risks as a function of hazard, exposure and vulnerability of people, assets, sectors or systems is visualised by the IPCC in the 'risk propeller' (Figure 2, left). For the CR-SB, an extended risk concept has been developed (Figure 2, right) that is more explicitly built on risk drivers and addresses risk resulting from potential cascading impacts ('impact chains'). This concept is well-suited for application in a CRA and forms the backbone of the CR-SB.

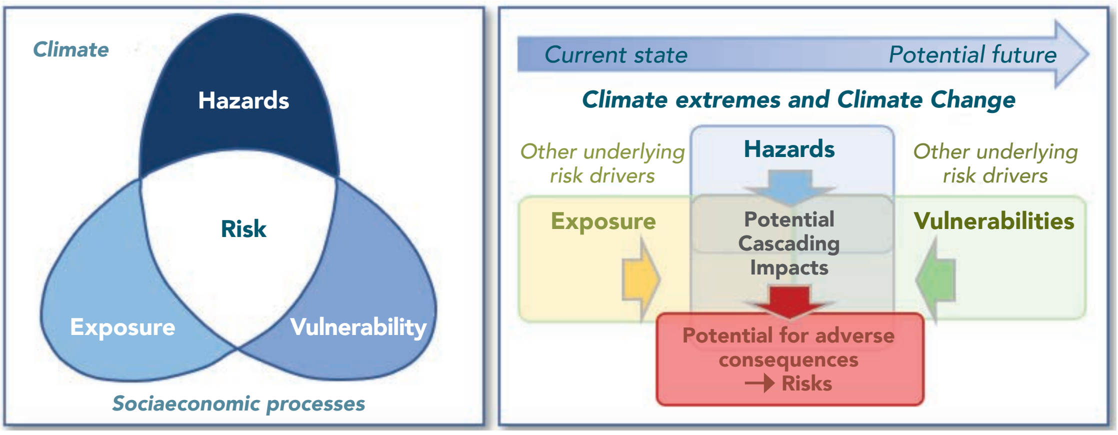
Example: Droughts (climate-related hazard) are affecting agriculture and food security (exposed system and function) by potentially leading to crop damage, yield failures and food insecurity (potential cascading impact). Crops that are highly sensitive to droughts, a lack of options for irrigation and a lack of financial reserves of farmers are contributing to a high vulnerability of the exposed system to droughts (vulnerability risk drivers). All elements together lead to a high risk to agriculture and food security due to droughts. Other underlying risk drivers, such as land degradation (leading to higher vulnerability) and the expansion of arable land on unsuitable areas due to increasing population (leading to an increase in exposure) are exacerbating the risk.

It is of utmost importance to know the risk drivers, their magnitude and dynamics, as well as underlying risk drivers, in order to:

- understand and assess the potential for adverse consequences (CRA),
- identify levers for managing and reducing risk through CRM and CCA.

Figure 2 : IPCC AR6 risk concept

(left, turned 90° clockwise) and the translation into a risk concept for the CR-SB (right). (left: adapted from (Lavell et al., 2012), right: own illustration)

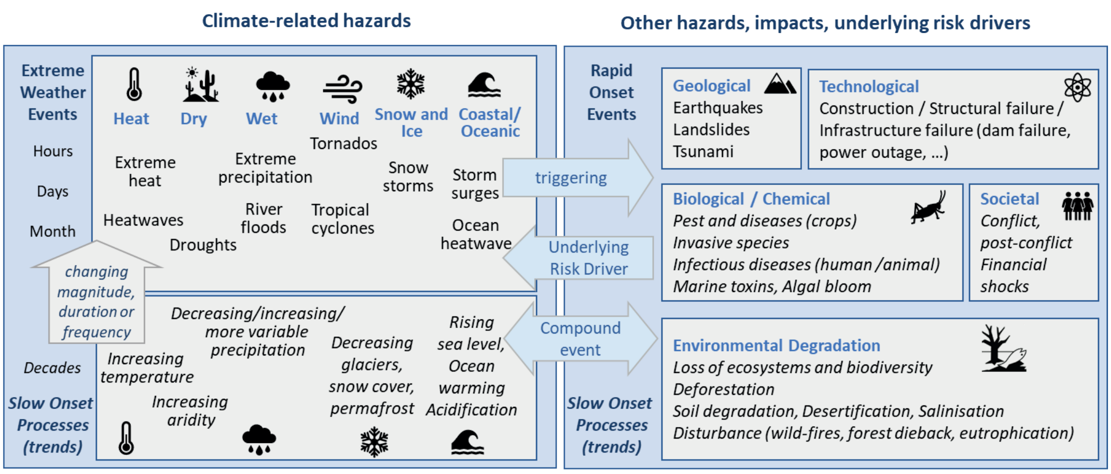


Hazard

Climate-related hazards include any type of extreme weather events (e.g. heatwaves, droughts, extreme precipitation events, storms, Figure 3 upper-left part) as well as climate-related slow-onset processes (e.g. increasing temperatures, increasing aridity, acidification, glacier melt or sea-level rise, Figure 3 lower right part) that are triggering adverse consequences for human or ecological systems.

Figure 3 : Climate change as underlying risk driver

Left side: extreme weather events (upper part) are climate-related hazards that can become more frequent and more intense with climate change. Right side: climate-related hazards can trigger other hazards (such as landslides or wildfires) or appear as a compound event (e.g. a heavy rain event after an earthquake). (own illustration)

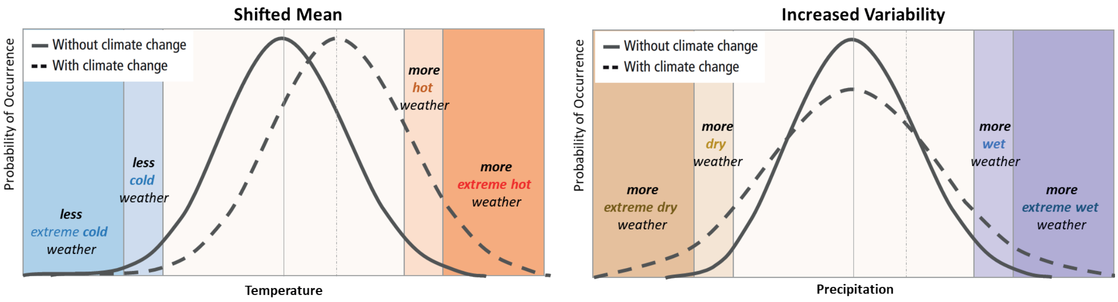


Non-climate-related hazards (e.g. geophysical, human-made) should be considered in a CRA as they have a relationship to climate-related hazards or contribute to the vulnerability of social-ecological systems (Figure 3 – right side). Non-climate hazards can, for instance be triggered by climate-related hazards (e.g. a heavy rain event can trigger landslides), and/or act as a compound event or underlying risk driver that increases vulnerability to climate-related hazards (e.g. soil degradation increases vulnerability to droughts; infectious diseases or a pandemic might further increase the social and economic vulnerability to climate impacts). Non-climate-related hazards can be classified into geological, environmental, technological, biological, chemical and societal hazards (UNDRR, 2020).

Slow-onset processes related to climate change (lower part in Figure 3) can be a hazard and/or can lead to a change in the magnitude, duration and frequency of extreme weather events. Other hazards can also act as underlying risk drivers for climate hazards (e.g. land degradation can aggravate droughts). They can independently exert their own impact and frequently modify the magnitude, duration, or frequency of extreme weather events, potentially resulting in an increase in occurrences of intense heatwaves, for instance (Figure 4)

Figure 4 : Climate change trends can alter the frequency, magnitude, and duration of extreme weather events

A shift in mean temperatures can lead to more (in terms of frequency as well as in magnitude) extreme hot weather events (left), increased variability in mean rainfall sums can lead to more (in terms of frequency as well as in magnitude) extreme dry weather as well as to more extreme wet weather (right) – modified from (IPCC, 2012)



Most regions globally are prone to multiple hazards; in these cases, different hazards may occur simultaneously, be cascading, or accumulate over time, thus leading to potential compounding effects. Compounding risks are more difficult to predict and manage compared to a single risk caused by one hazard only.

Exposure

Exposure describes first who or what is exposed. According to the IPCC, exposure is 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, 2021a).

Exposure describes:

- exposed systems (e.g. agriculture),
- exposed subsystems (e.g. crop production),
- exposed functions (e.g. food security),
- exposed elements (e.g. maize fields).

Second, exposure can be described in degree of exposure. This depends on attributes such as numbers, densities, or economic values. Examples of the degree of exposure include the number of people within a hazard-prone area (e.g. flood plain), the economic values accumulated within a flood plain or the number and extent of sensitive wetlands within a drought-prone region.

Exposure can also be indirect (i.e. effects are felt far from the area that is affected by a hazard) as a result of interdependency. For instance, people in one country or continent may be exposed to an increasing wheat price as an effect of climate impacts on another continent.

Vulnerability

Vulnerability is the propensity or predisposition to be adversely affected and includes all relevant environmental, physical, technical, social, cultural, economic, institutional, or policy-related factors. These contribute to and encompass a variety of concepts and elements, including sensitivity or susceptibility to harm, and/or lack of capacity to prevent, prepare, respond, cope and/or adapt (IPCC, 2021a).

Reducing climate risks through reducing vulnerability is one of the biggest levers in CRM.

Vulnerability is always related to a specific exposed system, subsystem, function or element and can be generic or impact specific.

- The agriculture system (exposed system) as such can be vulnerable to climate impacts in general (generic vulnerability) due to land degradation or a lack of support to farmers by regional authorities.
- Crop production (exposed subsystem) can be vulnerable to droughts (impact specific) due to an inefficient and poorly maintained irrigation system.
- Food security and nutrition (exposed functions) can be vulnerable to droughts due to losses in the crop production.
- Maize fields (exposed element) can be vulnerable to droughts due to their high water demand and the lack of drought resistance of maize.

Sensitivity and susceptibility are more direct attributes of exposed systems that make them vulnerable to climate change. Examples include a high drought sensitivity of certain croplands, a high vulnerability of poorly built houses to flood damage, or a high vulnerability of malnourished children to vector-borne diseases.

A lack of capacity could include the lack of: (specific) knowledge, (specific) technology or access to technology, financial resources, (specific) institutional structures and resources, (specific) legal frameworks, regulations or strategies.

CCA has the main purpose of reducing vulnerability.

Other underlying risk drivers

Other underlying risk drivers such as poverty, social inequities, power structures, demographic development, land degradation or conflict aggravate exposure and vulnerability. These are often as important as climate change for understanding and reducing climate-related risks. Often these underlying risk drivers have root causes stemming from structural conditions as well as social, economic, cultural and political conditions, practices, priorities, choices and values. In order for risk management to be effective and sustainable, it is imperative to comprehensively comprehend and proactively address these factors.

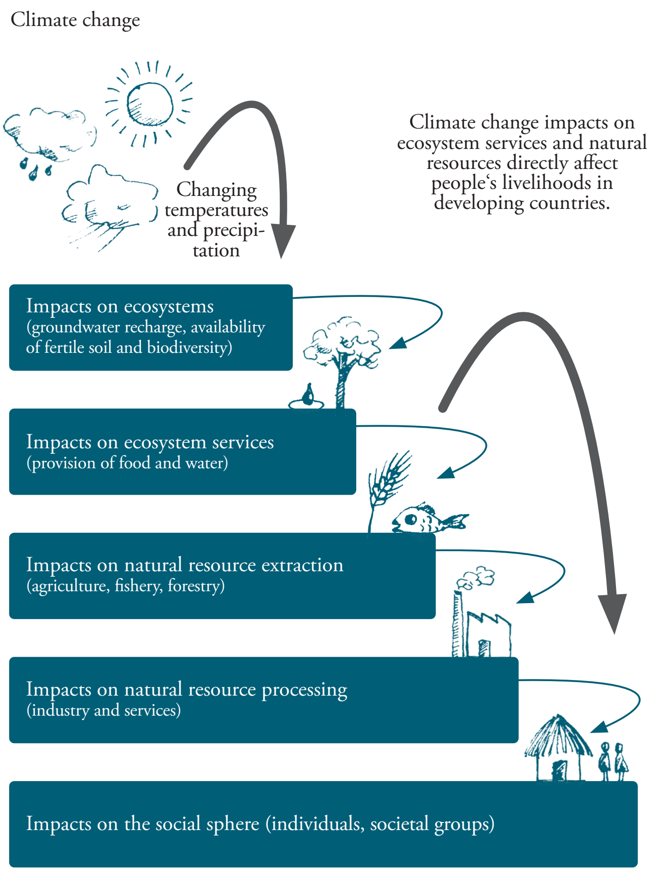
Risk is the result of dynamic interactions of risk drivers, impact and risk cascades

Severe risks are rarely driven by single determinants (hazard, exposure, vulnerability), but rather by a combination of conditions. In other words, climate risk is not a matter of only extreme weather events and slow-onset processes, but of the interaction between changing climate and changing social, economic and ecological conditions.

Consequently, when assessing future risks, scenarios should not only address potential future emission scenarios to calculate the probable future climate (climate projections) for near and far future (i.e. 2050, 2100) but also scenarios on the potential development of exposure and vulnerabilities of assets, sectors or systems, for at least the near future.

Climate risks are often also a consequence of cascading impacts across and within multiple interdependent systems and functions. Impact cascades often start with direct impacts of hazards on ecosystems, their functions and services and then cascade through the social-ecological systems because of critical interdependencies (Figure 5). These impact and risk cascades should be addressed in a CRA.

Figure 5 : Cascading impacts through systems, starting from ecosystem and ecosystem services
(Fritzsche et al., 2015)



Example: Drought-related risks are based on direct impacts of high temperature and lack of precipitation on soil moisture and water availability, which can have indirect impacts and adverse consequences for ecosystems (wetlands), food security (through yield losses), drinking water availability, energy production (through low hydropower production) and human health (through decrease of water quality and malnourishment).

Key risks – key impacts

The IPCC defines key risks as risks that have potentially severe adverse consequences for humans and social-ecological systems resulting from the interaction of climate-related hazards with vulnerabilities of societies and exposed systems (IPCC, 2021a). The IPCC further aggregates key risks into Representative Key Risks (RKR); RKRs summarise key risks for different exposed systems (Table 1).

Table 1 : Climate-related representative key risks (RKRs) according to IPCC AR6
(O'Neill et al., 2022a)

Code	RKR	Description
RKR-A	Risk to low-lying coastal social-ecological systems	Risks to ecosystem services, people, livelihoods and key infrastructure in low-lying coastal areas, and associated with a wide range of hazards, including sea level changes, ocean warming and acidification, weather extremes (storms, cyclones), sea ice loss, etc.
RKR-B	Risk to terrestrial and ocean ecosystems	Transformation of terrestrial and ocean/coastal ecosystems, including change in structure and/or functioning, and/or loss of biodiversity.
RKR-C	Risks associated with critical physical infrastructure, networks and services	Systemic risks due to extreme events leading to the breakdown of physical infrastructure and networks providing critical goods and services.
RKR-D	Risk to living standards	Economic impacts across scales, including impacts on gross domestic product (GDP), poverty and livelihoods, as well as the exacerbating effects of impacts on socio-economic inequality between and within countries.
RKR-E	Risk to human health	Human mortality and morbidity, including heat-related impacts and vector-borne and waterborne diseases.
RKR-F	Risk to food security	Food insecurity and the breakdown of food systems due to climate change effects on land or ocean resources.
RKR-G	Risk to water security	Risk from water-related hazards (floods and droughts) and water quality deterioration. Focus on water scarcity, water-related disasters and risk to indigenous and traditional cultures and ways of life.
RKR-H	Risks to peace and to human mobility	Risks to peace within and among societies from armed conflict as well as risks to low-agency human mobility within and across state borders, including the potential for involuntarily immobile populations.

Key risks fulfil one or more of the criteria below:

- Consequences with a high magnitude (e.g. severe impacts, large areas affected, irreversibility of consequences, cascading effects) and/or high likelihood;
- Consequences that affect essential systems and functions (e.g. food security, critical infrastructure, health);
- Consequences with a critical timing (e.g. severe impacts already occurring or could occur quickly in the near future);
- Consequences with a low ability for risk reduction through CCA, including consequences beyond the limits of CCA.

TIP

A good in-depth explanation of the IPCC risk concept can be found in the guidance on the risk concept by IPCC authors (Reisinger et al., 2020). The IPCC AR6 has identified 127 key climate risks, which can serve as inspiration to identify relevant risks for specific contexts. A list of key risks and impact chains for selected key risks can be found on the CR-SB website.

While impacts refer to the physical changes caused by climate change, consequences describe the broader effects that these changes inflict upon ecosystems, society, and the economy. In the CR-SB, we address both impacts and consequences as long as they potentially lead to key risks. The identification and assessment of impacts and consequences is the primary objective of a CRA. Example impact chains for selected key risks and a table with key risks can be found on the website. ***(https://www.adaptationcommunity.net/climate-risk-assessment-management/climate-risk-sourcebook).***

The above description of the RKRs will be used throughout the CR-SB to identify, assess, and evaluate key risks.

Systemic climate risks

The key to understanding the complex nature of risk is to understand how sectors and systems (and their subsystems) interact with each other, their underlying vulnerabilities, and where critical interdependencies lie. Climate risks can become systemic risks when they exceed a certain threshold and threaten core functions of a system or society that the society and the economy can no longer cope with (e.g. threatening food security of a whole country or leading to the collapse or breakdown of critical societal functions).

→ *Find more information on the system perspective in the Expert Material, chapter* ***E 1.1.***

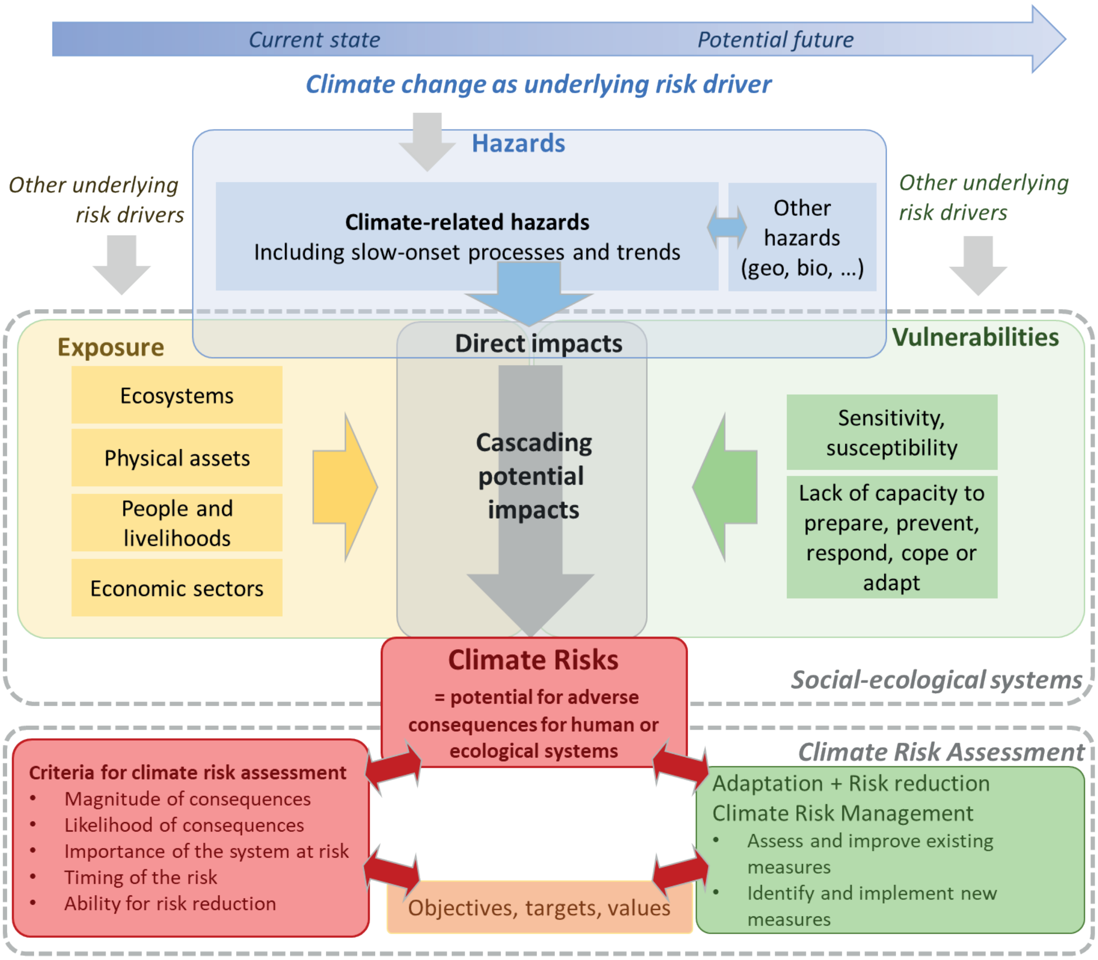
1.1.3. The risk framework of the CR-SB

An extended risk framework was developed for the CR-SB. It is based on the IPCC AR6 and the UNDRR technical guideline for comprehensive risk assessment (IPCC, 2022b; UNDRR, 2022) and also includes all previously introduced assessments (Figure 6).

The framework (Figure 6) is centred around climate risk and understands those as the potential for adverse consequences for human and ecological systems triggered by climate-related hazards in combination with other hazards leading to potential cascading impacts. In addition to hazards, climate risk is determined by exposure and vulnerability factors in addition to hazards. Climate risks are assessed for the current situation (based on observations) and for potential future situations with the help of scenarios.

Climate risk is assessed based on a set of risk criteria that reflect underlying objectives, targets and values and supports CCA, risk reduction and CRM.

Figure 6 : The entire risk framework of the CR-SB with its CRA components.
(own illustration)



1.2. Climate Risk Assessment (CRA)

What is a CRA?

In a CRA, risk drivers and their root causes, cascading potential impacts and adverse consequences are described and analysed (risk analysis) based on quantitative or qualitative information and evidence (e.g. data, expert knowledge). Risk itself is assessed and evaluated based on the risk analysis and various risk criteria that are, at least partly, value-based (e.g. answering questions such as: What consequences do we want to avoid? What do we consider 'severe' consequences? What is the importance of the system at risk?).

The major objectives of a CRA are to

- identify key risks;
- understand the underlying risk drivers (climate-related hazards, exposure, vulnerabilities, other risk drivers and their root causes) and the cascading impacts that might lead to adverse consequences for multiple systems;
- assess the current ability to adapt to adverse consequences and identify gaps in CCA;
- identify critical constellations such as highly vulnerable groups, spatial hotspots or local tipping points that might quickly increase risks (such as drying out of water sources);
- assess the magnitude, severity and likelihood of consequences and the severity of risks;
- identify factors that might potentially negatively impact or violate human rights (see also GIHR, 2022);
- identify entry points for improved CRM and CCA; and
- evaluate and prioritise the urgency of action.

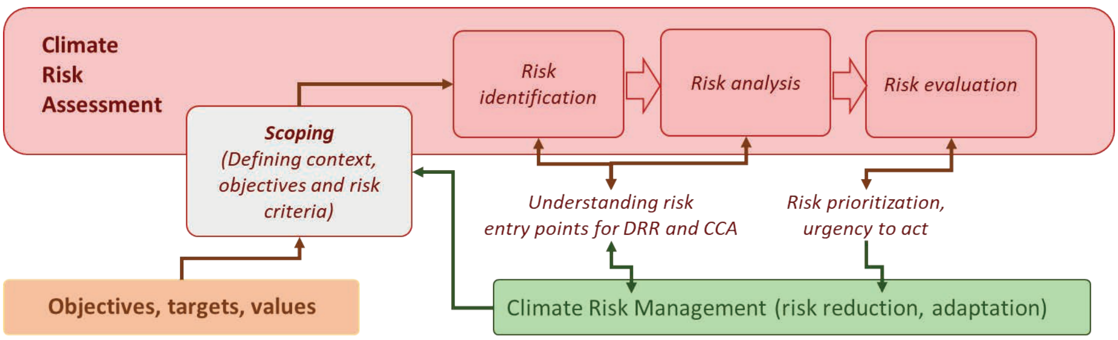
In a CRA, climate risks are typically described by key risks across systems and/or for specific exposed systems or functions (e.g. biodiversity, agriculture and food security, water security). Climate risks are assessed for different time periods including the current situation, the near and far future.

1.2.1. Phases of a CRA

With ISO 31000 on risk management (International Organization for Standardization, 2018) and its more specific guideline on risk assessment methods - ISO norm 31010 (International Organization for Standardization, 2019), a well-accepted generic standard workflow for risk assessment exists that is widely taken up in Disaster Risk and Climate Risk guidelines, studies and reports (Figure 7). The ISO 31000 workflow proposes the following phases of a risk assessment: scoping (to prepare the risk assessment), risk identification, risk analysis and risk evaluation.

Figure 7 : Phases of a risk assessment according to ISO 31000 and the relationship to risk-informed policymaking and planning

Scoping is preparing the risk assessment. The risk assessment itself is structured into Risk Identification, Risk Analysis and Risk Evaluation. (own illustration)



The risk assessment finally prepares the phase of risk management which refers to selecting and implementing options for addressing and reducing risk. Risk communication and consultation is conducted throughout the whole process. This also aligns with ISO 14091 (Adaptation to climate change - Guidelines on vulnerability, impacts and risk assessment) (International Organization for Standardization, 2021).

The objective of the four phases of a risk assessment can be described as followed.

- **Scoping** aims at designing a risk assessment to support CRM by taking into account existing objectives, goals and values and the existing policy and planning framework.
- **Risk Identification** aims to identify relevant hazards, impacts and risks starting from existing knowledge and expert input. It will also select key sectors and geographic regions of concern in which to conduct an in-depth analysis, develop an initial list of appropriate data sources, and identify potential future changes.
- **Risk Analysis** describes key risks more in-depth by analysing the risk components (hazards, exposure factors, vulnerabilities), understanding their interrelation as well as the resulting cascading impacts with the help of impact chains. Based on the risk description, the potential for and the magnitude and severity of adverse consequences for selected human or ecological systems are assessed for the current situation and specific future scenarios.
- **Risk Evaluation** means evaluating the severity of risk based on certain criteria and drawing conclusions from the risk assessment with respect to risk tolerance as well as the demand and urgency for risk reduction measures.

→ *More information on CRA in Module Risk identification + Risk Analysis can be found in the Expert Material chapter **E 1.2.** Moreover, there is information on the criteria for a risk assessment.*

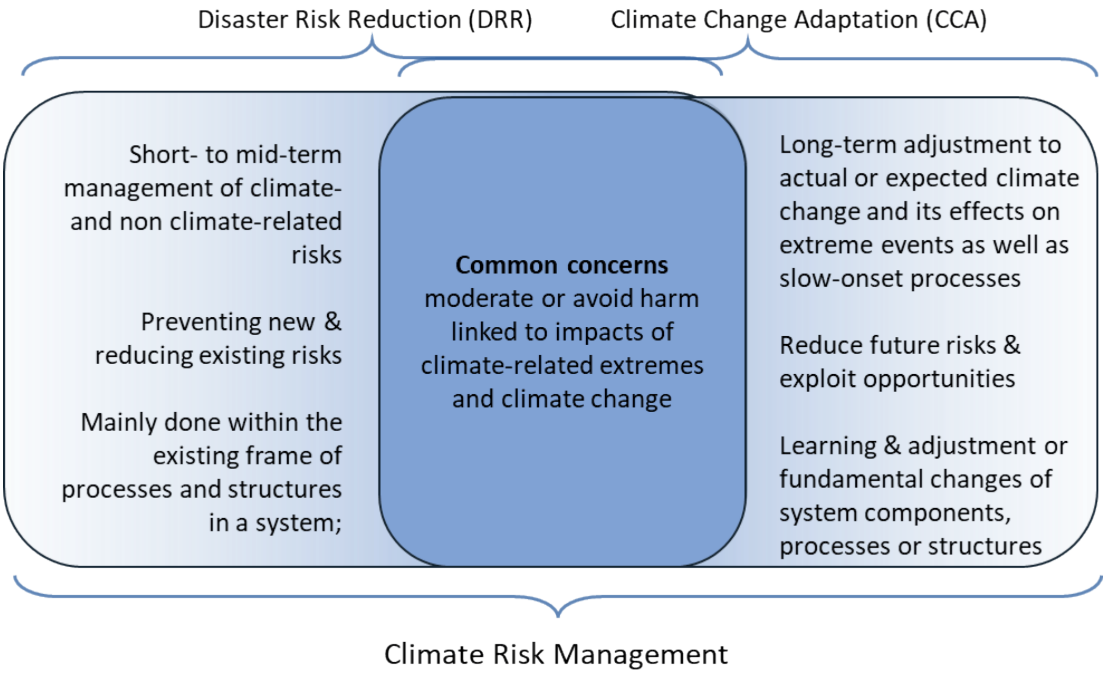
1.3. How CCA and CRM can reduce risks and contribute to climate-resilient development

A CRA´s main purpose is informing and supporting CRM through understanding climate risks, risk drivers (including those of exposure and vulnerabilities) and their underlying root causes, as well as identifying the demand and entry points for CCA. The overall goal of CRM is to support climate-resilient development (Schipper et al., 2022).

Resilience is the capacity of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganising in ways that maintain their essential function and identity. Resilience is based on maintaining and improving the capacity for CCA, learning and/or transformation. Climate-resilient development can be understood as integrating both CCA and mitigation decisions together, with the goal of achieving long-term sustainable development (Werners et al., 2021) (for more information see **Box I**).

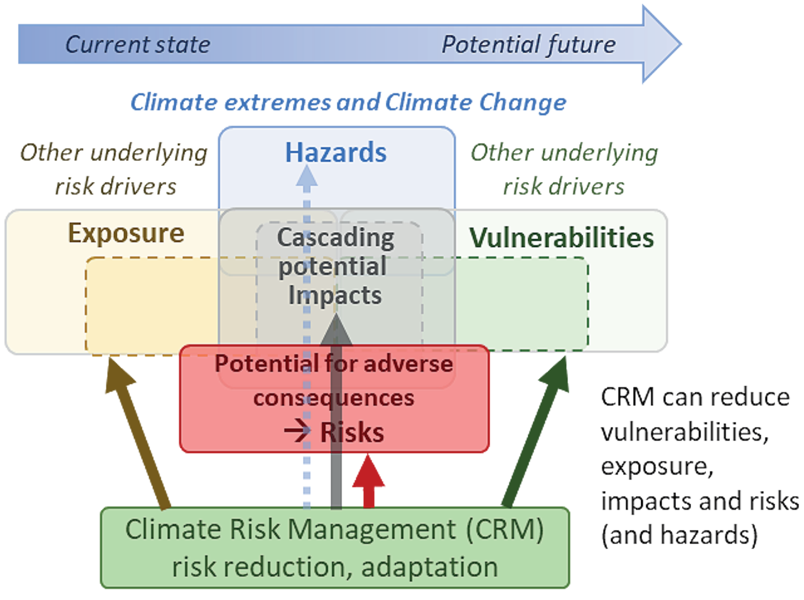
Appropriate CRM includes all mechanisms and measures (such as plans, actions, strategies or policies) to reduce current and future climate risks. The management of current risks to climate extremes is typically covered by the existing Disaster Risk Reduction (DRR) mechanisms. CCA involves the process of adapting current CRM practices to the actual or anticipated impacts of climate change in order to limit damage or take advantage of positive opportunities. This includes adapting to the increasing intensity and frequency of climate extremes, as well as slow-onset processes (such as sea-level rise) and emerging climate risks. Today, CCA and DRR are seen as integral components of successful CRM (Figure 8).

Figure 8 : Characteristics of DRR and CCA and their relation to CRM
(own illustration)



CRM aims to reduce climate-related risks mainly by lowering the vulnerabilities of exposed systems, by lowering the degree of exposure to climate-related hazards or by reducing cascading impacts (Figure 9).

Figure 9 : The role of CRM in reducing climate risks
CRM can reduce vulnerability, exposure, impacts and risk, and some climate-related hazards (such as flooding) (own illustration).



To ensure that a CRA is supporting CRM, we encourage the identification of possible climate risk reduction options (including DRR and CCA options) that can help to reduce climate risks in a specific context throughout the modules. See below for types of CCA options:

- structural (e.g. engineered/conventional infrastructure, for example a flood barrier);
- institutional (e.g. creating funds for small-scale on-farm CCA);
- behavioural (e.g. educating about climate-smart agricultural practices);
- Ecosystem-based Adaptation (EbA) (e.g. green or blue infrastructure, for example re-forestation or wetland restoration);
- early warning systems (e.g. installing a flood warning siren in a community);
- climate information services (e.g. developing or providing access to mobile apps that can provide farmers with weather projections).

CRM options can be targeted for specific challenges at different scales of vulnerability and exposure (see above). On the one hand, there are CRM options which reduce risk related to specific subsystems (e.g. protecting rainfed agriculture) or specific impacts on specific exposed elements (e.g. reducing loss of life from flooding). On the other hand, there are CRM options which aim to address generic vulnerability (e.g. support income or livelihood diversification). These are not mutually exclusive; CRM and CCA options can address all three impact scales at once if they are well-designed and implemented effectively.

Some actions that aim to strengthen adaptation to climate change can also introduce a series of new issues, and even increase, redistribute or create new risks and thus lead to maladaptation. Maladaptation occurs when CCA results in worse outcomes that are often unforeseen.

Additionally, CRM and CCA options are designed for specific geographical scales: local, sub-national and national scale. It is important to consider the specific impact and geographical scales at which CRM and CCA options are targeted and implemented, as decisions on all scales can influence risks even at the most local levels. For example, a national adaptation plan to address generic vulnerability (e.g. lack of housing) could have the potential to increase risks at the sub-national or local level (e.g. by encouraging urban development in flood plains), in a specific subsystem or for a specific impact.

Risk ownership should always be clearly assigned to enable efficient implementation of CRM and CCA options. A risk owner is a person or entity responsible for managing threats and vulnerabilities. Shared responsibility should be avoided. Assigning an individual risk owner is a particular challenge for climate-related risks. Given their complex systemic nature, it is difficult to clearly determine responsibility (e.g. for risks to intangibles). Moreover, it could be dynamic if we consider the possibility of cascading effects, where a risk can spread to different systems. Risk responsibility could be assigned to institutions, groups, and individuals as part of a whole-of-society, collaborative approach.

The limits of CCA are the point at which an actor's objectives (or system needs) cannot be secured from intolerable risks through adaptive actions. These can be hard limits, i.e. there are no possible adaptive actions that can be taken to avoid intolerable risks, or soft limits, i.e. adaptive actions that can be taken to avoid intolerable risks are currently unavailable.

While CRM and mitigation can reduce climate-related risks, it cannot completely eliminate risks. Residual risks are risks related to climate change impacts that remain following CCA and mitigation efforts and can lead to widespread losses and damages. Losses and damages can be both economic and/or non-economic.

CCA options can (intentionally or unintentionally) redistribute risk and impacts, with increased risk and impacts on some areas or populations, and decreased risk and impacts on others.

Effective CRM should also contribute to reducing other underlying drivers and root causes of risk, such as social inequity or poverty, even if these are often structural and out of the control of CRM at the local or regional level. However, this requires processes of transformational adaptation. Transformational adaption is CCA that changes the fundamental attributes of a socio-ecological system in anticipation of climate change and its impacts (IPCC, 2022b) and complements incremental adaptation, which is CCA that maintains the essence and integrity of a system or process at a given scale.

1.4. Stakeholder engagement

Importance of stakeholder engagement

Assessing and managing climate-related risk is a highly complex and cross-cutting process relevant to a diverse set of stakeholders. These can range from scientists, policy and decision-makers, practitioners, private sector representatives, NGO representatives, citizens, to, notably, groups in vulnerable situations.

Actions undertaken by one actor may limit (but might also widen) the room for manoeuvre, or actions expected, from other actors. This may inadvertently encourage inaction or 'free-riding' behaviour from certain actors. It is therefore important to identify relevant stakeholders and those ones who are affected by the climate-related risks and understand their respective interests, positions, and responsibilities at the beginning of the CRA process.

Continuing to engage relevant stakeholders in the different steps of the CRA encourages their buy-in and increases their trust in its outcomes. People, in general, are more willing to accept results if they have been part of the overall process, from the beginning to the end of the process by which these results were co-produced. Different stakeholders, including affected groups such as Indigenous Peoples, contribute important knowledge and skills that improve the quality of outcomes. The following list summarises important activities in preparing, implementing and postprocessing a successful stakeholder engagement process (based on Schinko and Bednar-Friedl, 2022).

Preparing a stakeholder engagement process

The first step towards preparing for stakeholder engagement is to identify and determine the individuals or groups who will be involved and to what extent. It is especially important to meaningfully involve marginalized individuals and groups who are affected by the climate-related risks. Further, it is necessary to consider the objectives of the engagement process as well as gender issues and differential vulnerabilities. This process requires creating a comprehensive stakeholder map that includes and considers all the interests that should be represented in the decision-making context. Before starting the participatory process, it is essential to establish clear roles for the stakeholders involved. Additionally, it is important to assess the available resources in terms of time, money, and experienced personnel. Furthermore, it is crucial to communicate in advance how the results of the process will be used in the CRA, underlining the valuable contributions of the stakeholders. Children and young persons are more vulnerable to climate and environmental shocks than adults for a number of reasons including physical and physiological vulnerability and an increased risk of death. In order to meaningfully engage children and young persons, please consult the checklist of the Nine Basic Requirements for meaningful and ethical children's participation (childrens-participation) (Save the Children, 2021), because the climate crisis is also a child crisis (UNICEF, 2021).

Implementing a stakeholder engagement process

To effectively implement a stakeholder engagement process, it is crucial to establish and clearly communicate rules and realistic expectations for the participatory process (e.g. neutral facilitation, equal rights for all participants, everyone should have their say, all input is taken equally seriously, confidentiality, etc.). Transparency helps build trust among stakeholders and fosters a collaborative and productive environment. Therefore, it is important to provide all participants with the same documentation and information, to promote transparency and equal access to information. This includes that documentation and information are provided in an accessible manner for everybody (e.g., in local languages or child- and youth-friendly language) (see also UN, 2023). It is important to keep in mind that cultural factors and beliefs significantly impact how stakeholders perceive the issues and potential solutions at hand. Link scientific knowledge at the global level, such as IPCC reports, to local knowledge as well as the local knowledge with the global level and provide stakeholders with an understandable 'translation' of terms and concepts. In addition, maintaining personnel continuity, especially in the working groups, is critical to the success of the stakeholder engagement process.

Postprocessing a stakeholder engagement process

For the postprocessing of the stakeholder engagement process, it is important to document all steps of the project (e.g., minutes, process reports and photos). Open, respectful, and proactive communication is essential when engaging stakeholders. It is important to thank stakeholders because participation deserves appreciation. Communicate the results and findings of the participatory process to the stakeholders involved and give them the opportunity to provide feedback with sufficient time. This process ensures transparency and empowers stakeholders by recognising their contributions and by taking them seriously and act upon them, or to explain why their views and suggestions have not been taken into account. In addition, their feedback plays a vital role in refining and developing participatory methods in the future, leading to more effective and meaningful participation processes. Further, it is important to provide stakeholders with feedback on the impact of their involvement and efforts.

→ *Find more background on why and how to engage stakeholders in a CRA in the Expert Material chapter* ***E 1.3.***

1.5. Gender, marginalised persons and groups as well as differential vulnerability

Populations and individuals are not homogenously vulnerable to climate change (Sillmann et al., 2022). Some social groups experience greater and more severe impacts from climate change than others that affect their livelihoods and cultural identity. This phenomenon is called differential vulnerability. Gender and differential vulnerabilities are cross-cutting topics of the CR-SB.

Women and marginalized groups, in all their diverse backgrounds, play a crucial role as agents of change and knowledge bearers in climate risk assessments. Their unique perspectives and experiences bring valuable insights to the table, enriching the understanding of climate impacts and vulnerabilities. By actively involving these groups in the assessment process, their expertise and local knowledge can inform more comprehensive and context-specific strategies to address climate risks. Their vulnerability stems from existing structural inequalities. Furthermore, it is crucial to acknowledge and explore the implications of climate-induced migration.

Vulnerabilities of people

People and population groups that are already disadvantaged, including women in all their diversity, children and youth, people living in poverty, Indigenous Peoples, LGBTIQ+ persons, persons with disabilities, migrants and refugees and the elderly, are particularly affected by the consequences of climate change.

Most aspects that influence vulnerability are deeply embedded in structural issues. Efforts were made to ensure the inclusion of all marginalized individuals and groups, extending beyond women and Indigenous Peoples. Such structural issues influence risk through differences between social groups in terms of power, agency and risk awareness, as well as access to knowledge, information and resources (Thomas et al., 2019). Additionally, differential vulnerability exists within communities and neighbourhoods in the same region, where vulnerability is associated with specific groups within a community. This increased vulnerability to climate risks is closely related to existing inequalities caused by the discrimination and exclusion of individuals or groups by a dominant group. They lead to differences in socioeconomic and political status, land ownership, housing conditions, exposure to violence and exploitation, and access to basic services such as education and health, among others.

Indigenous Peoples are disproportionally affected by climate change impacts. They are marginalized in society, as their rights, particularly their land rights, are often violated. They frequently experience political and social isolation, which is a cause and consequence of the denial of their right to self-determination, e.g. controlling their own development based on their own values, needs and priorities. Indigenous Peoples are not only disproportionately affected by climate change impacts but also serve as key agents of change, offering valuable insights in the development of solutions.

While no official definition of **Indigenous Peoples** exists, the term is broadly understood as referring to groups or communities who self-identify as indigenous and who have historical continuity with pre-colonial and/or pre-settler societies. Indigenous communities may have strong links to territories and surrounding natural resources, and have their own distinct social, economic and political systems, language, culture and beliefs (UNPFII, 2006).

An example is the unequal impact of water scarcity on different sections of exposed populations. In general, persons and groups in vulnerable situations are typically not connected to piped systems, suffer from inadequate access to safe drinking water as well as sanitation services and – in the case of agricultural systems – can unlikely rely on irrigation systems in the case of droughts (Grasham et al., 2019; Rao et al., 2019). Additionally, persons and groups in vulnerable situations lack political representation and decision-making power to influence where water infrastructure is built and maintained.

Sexual and gender minorities are people who identify as belonging to any of the groups represented by the acronym LGBTIQ+, which stands for lesbian, gay, bisexual, trans, intersex and queer persons (the + indicates our intention to also include other communities of gender and sexual minorities).

The combination of various individual factors, such as people's ethnicity, religion, gender, sexual orientation, age, caste, class as well as their physical or mental state may lead to exclusion and discrimination, thus contributing significantly to an individual's or group's vulnerability. Noteworthy for any type of CRA is the fact that refugees and internally displaced people (IDPs) are among the most disadvantaged groups, independent of the type of hazardous process or external pressures which occur, but there is no hierarchy in vulnerability among the groups. Given the significance that differential vulnerabilities play for a precise analysis of those population groups that are most likely to suffer losses and damages, any risk assessment should be carried out with the awareness that:

- disasters occur when humans are unable to prevent and prepare for, respond to and recover from climate-related extreme weather events or slow-onset processes. There is nothing natural about disasters, which are in fact, 'human disasters', since humans lack the adaptive and coping capacities to protect themselves from the impacts of climate-driven hazards.
- even small events can turn into human disasters when exposed population groups are particularly vulnerable, for example, those with limited informal support networks.
- the characteristics of populations leading to differential vulnerabilities and their identification is not straightforward; in most cases, these characteristics are non-tangible, and respective data/information is usually not easily available or quantifiable.

Designing a CRA which accounts for differential vulnerabilities

A CRA embracing differential vulnerabilities due to gender inequalities or other forms of discrimination should study the complexities and inequalities specific to the study area. The assessment should take into account the entrenched inequalities, power structures and the systems or institutions that perpetuate these (e.g. legal system, customs and norms, differential access to resources and services). These data should highlight the differences among various population groups, for example women/girls in all their diversity, men/boys in all their diversity, the elderly, the youth, people with disabilities, single-parent families, migrants and refugees, LGBTIQ+ persons and Indigenous Peoples and consider different climate risk impact areas (e.g. mortality, healthcare, WASH, livelihoods, education, housing, migration, etc.).

To design an inclusive CRA approach, differential vulnerabilities and gender aspects should be considered starting in the design phase. This process begins with the composition of the CRA team itself and means ensuring that people from vulnerable groups – and, where possible, experts from LGBTIQ+ groups – are part of the CRA team. Similarly, marginalised people and groups should be represented in any stakeholder group engaged in the CRA. This may involve tailoring data collection methods to allow these individuals and groups to actively participate and contribute data, where they may otherwise encounter barriers to their participation in the CRA. Examples include offering free childcare or changing the time and location of focus groups/interviews/surveys to allow parents to participate or offering gender-separated and ethnicity-separated focus groups that are facilitated by someone of the same gender or ethnicity. Further, offering spaces which are accessible for people with disabilities and save for children and young persons. Doing this has mutual benefits. It results in more effective gathering of data, as it can create a space in which participants feel they can share more openly. It can also make participants feel more at ease and relaxed in a situation that may be uncomfortable. Questions asked in data collection may be formulated differently to avoid any exclusion of specific ethnic or religious groups and to bring to the surface gender-differentiated experiences. The CRA can contribute to reducing inequity and marginalisation through the meaningful engagement of disadvantaged groups and women in all their diversity not only in data collection (i.e. as data providers) but by including them in the definition of CRA objectives, the data analysis and in identifying potential CCA options.

Following the do-no-harm approach, all relevant data used in a CRA should be disaggregated by gender and capture minority groups, such as LGBTIQ+ persons. Unfortunately, the reality is that many useful datasets are not even disaggregated by sex or binary gender. Aggregated data treats social groups as homogenous and ignores specific and multiple vulnerabilities of people within these groups, and therefore does not allow for conducting analyses scrutinising specific social groups or gender belonging. Risk could be reduced more effectively if disaggregated data were collected and were to inform more effective and transformative CRM and CCA. Especially when disaggregated quantitative data is limited, it is important to include qualitative data on these groups to make the differential vulnerabilities of women in all their diversity, LGBTIQ+ persons, children, people with disabilities and refugees visible.

Where disaggregated quantitative datasets are not available, qualitative data can provide insight into differential vulnerability. The collection of such data should proactively seek to uncover inequalities and identify what groups might be missing from other assessments or datasets. Qualitative data can be collected through surveys, focus groups or interviews. Informants may be workers from intermediary organisations (e.g. NGOs) with expertise in supporting women in all their diversity, LGBTIQ+ persons and Indigenous Peoples, or they may be individuals themselves who belong to one of these groups. In both instances, building trust between the assessment team and the informant is essential, as it is ensuring (and communicating) confidentiality and transparency.

A well-designed CRA, and subsequent CRM recommendations, can contribute to the reduction of structural inequalities, and the meaningful participation of marginalised persons groups in the CRA (see Save the children, 2021). Women in all their diversity and marginalized groups already are agents of change in many circumstances. The problem is rather that they are not able to participate meaningfully in (decision-making) processes.

→ *More material including a section on a gender-responsive approach is provided in the Expert Material chapter **E 1.4.***

1.6. Impact chains

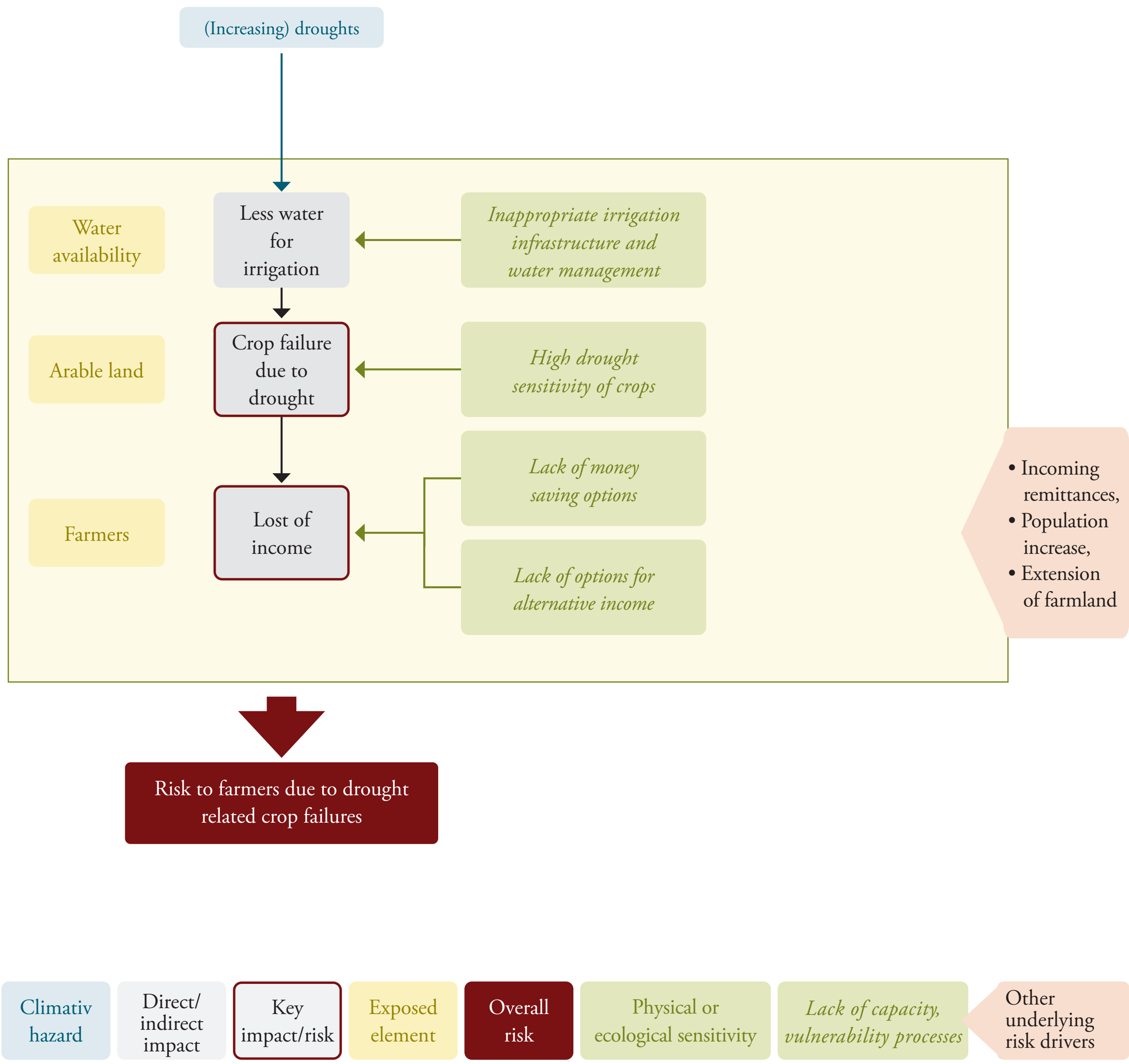
Impact chains are tailor-made conceptual models that represent and illustrate key risks and their drivers for a specific context. They are the backbone of the Risk Analysis within the CR-SB and are ideally developed in a participative approach involving experts and stakeholders. In any case, they should represent the best knowledge and evidence available for the specific context (specific risks in a specific region and a specific scale).

Impact chains provide a framework for understanding and visualising the causal relationships between changes in the climate and their impacts. These visual representations help to understand the cascading nature of impacts and enable stakeholders to better comprehend how changes in the climate propagate through a system with direct and indirect effects. Figure 10 gives an overview of the elements of an impact chain.

The elements of a simple impact chain address all components of risk drivers, such as:

- climate-related hazards (blue box) that have impacts and adverse consequences,
- a series of direct and indirect impacts (grey boxes) that are caused by a hazard(s),
- the exposed elements (yellow boxes), subsystems or functions that are affected by these impacts,
- factors that make exposed elements, subsystems, or functions vulnerable. This includes physical or environmental factors that result in sensitivity or vulnerability to specific impacts. It also includes factors that describe a lack of capacity to prepare, prevent, respond, cope, or adapt (green boxes).
- other underlying risk drivers that affect vulnerability or exposure (rose boxes).

Figure 10 : Example for an impact chain on crop farming with drought related risks
(own illustration)



Within these impact chains, key impacts can be identified that lead to key risks that have the potential for severe consequences. The analysis and assessment of key impacts and key risks is one of the main objectives of a CRA. Typically, key risks can be summarised to an overall climate risk for the system under review. Illustrations of impact chains can be found throughout the CR-SB ranging from simplified examples to more complex representations based on real-world cases.

The role of impact chains in a CRA

Within the CR-SB, impact chains serve to:

- co-develop a common knowledge and understanding between experts and stakeholders of key risks, their underlying drivers and interactions for the specific context and specific risks;
- structure the description and analysis of key risks and their risk drivers for the current situation and potential future situations making use of the best quantitative and qualitative knowledge and evidence available;
- develop indicators for certain sub-systems (optional: conduct a composite-indicator based risk assessment approach based on the factors and components of the impact chain as outlined in the → *Expert Material under **E 1.5.***
- identify key vulnerabilities, gaps in risk management and entry points for CCA.

Impact chains cannot capture all the information constituting the risks and risk drivers. Thus, a complementary description and detailed analysis of risk drivers in the specific context, including information about current and future risk, regional and local features, vulnerable groups or critical constellations are required.

Impact chains for multiple hazards and/or multiple subsystems and systems

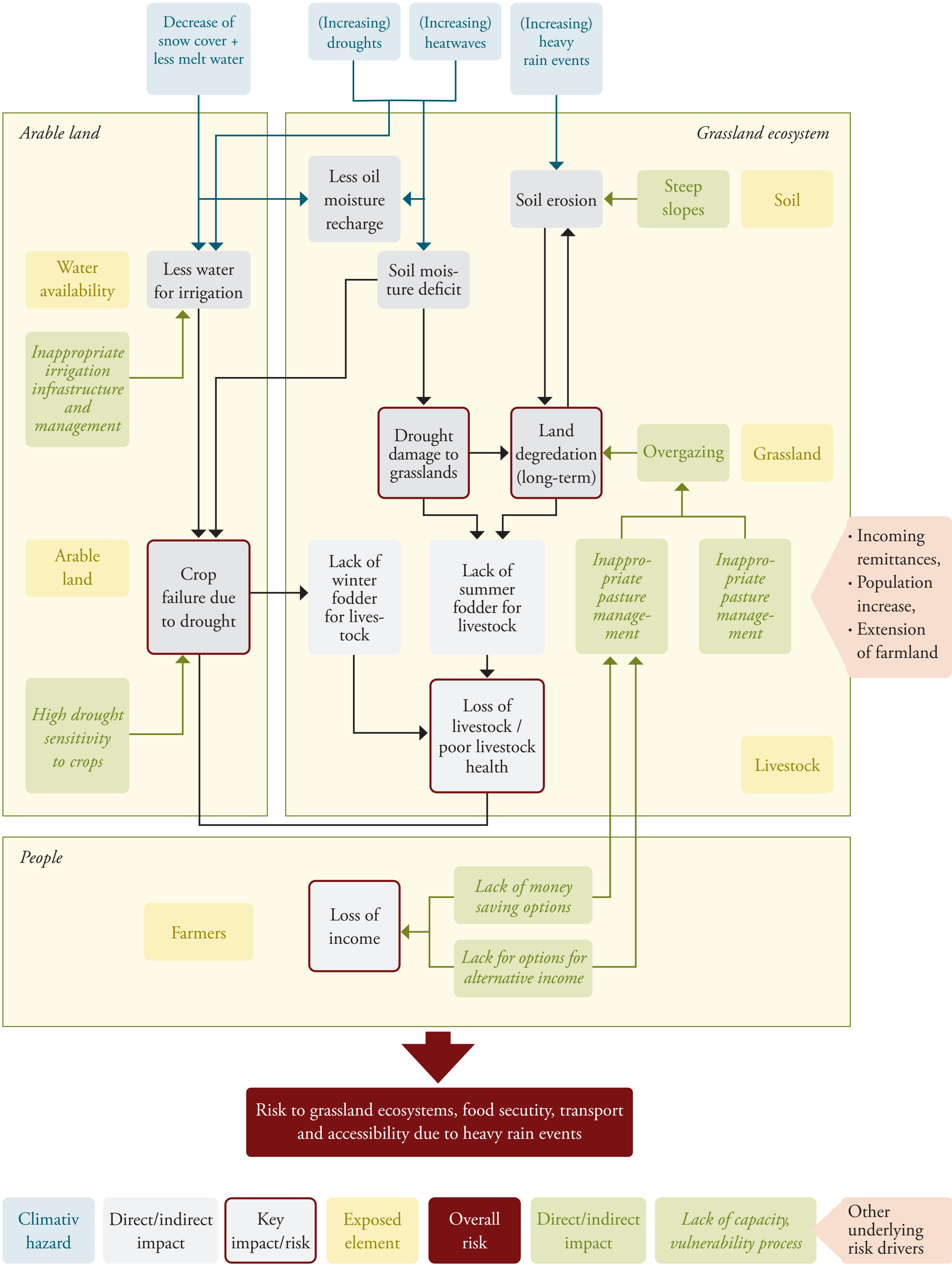
Impact chains are a useful tool to illustrate and systematise the effects and the interaction of multiple hazards and/or with multiple subsystems and systems (Figure 11).

Impact chains can be built for single systems or subsystems (e.g. biodiversity and ecosystems, food system and food security, water systems and water security), including multiple hazards and multiple key impacts. However, cascading impacts from one system into another system (e.g. from water to agriculture) should be considered in single system impact chains. See also Figure 15 as an example of risks that are affecting multiple systems.

→ *Find more material on impact chains and their elements in the Expert Material chapter **E 1.5.***

Figure 11: Impact chains with multiple hazards on multiple subsystems

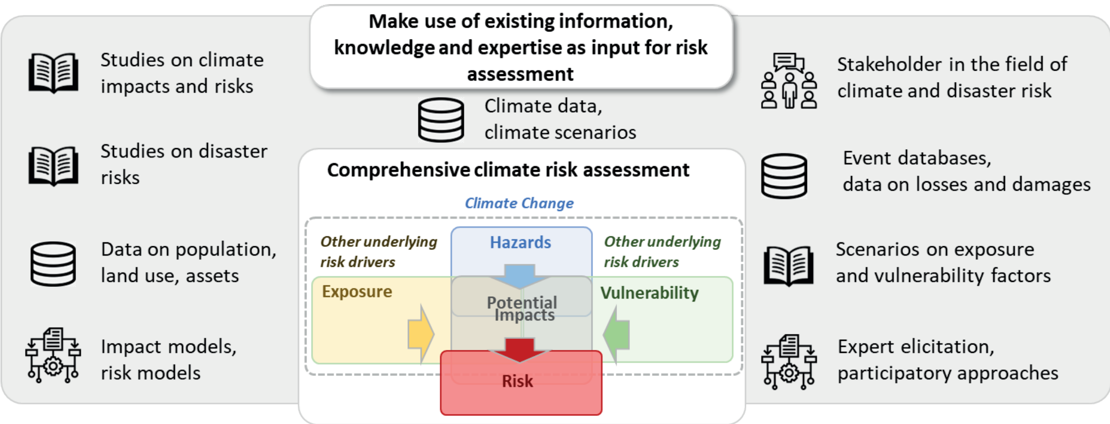
(own illustration)



1.7. Data, information, and knowledge sources – current situation and future scenarios

The quality of the results of a CRA depends to a great extent on the quality of the data, information and knowledge that informed it. A wide range of different types of information covering different components of a risk assessment is required to be collected, reviewed, analysed, combined, understood, visualised and discussed in stakeholder consultations. The information base needed consists of climate and hazard information, data on impacts, exposure and vulnerability for the presence and the future periods the assessment is covering. The knowledge is collated from observation data on climatic drivers as well as events and their impacts for the past and for the future, from studies such as the latest IPCC reports, national reports, national statistics, model results but also from stakeholders (including indigenous groups and local communities) and experts through workshops and consultations as well as earth information data from satellites and other geo-spatial information. Information and knowledge are comprised of quantitative as well as qualitative elements (Figure 12).

Figure 12 : Potential sources of data, information, and knowledge for the CRA
(own illustration)



In a CRA, climate risks are assessed for the current situation as well as for potential future situations. For most CRAs it makes sense to set a focus on the current situation as well as on a near-term future (e.g. 2021-2040) and eventually a mid-term future (e.g. 2041-2060), since current and quickly emerging risks need to be treated first with urgent CCA actions. However, for systems with a long planning and CCA horizon (e.g. forestry, large-scale infrastructure such as reservoirs) the consideration of a long-term future (e.g. 2081-2100) is also recommended.

While the assessment of current climate risk can be based on a larger body of quantitative and qualitative information including climate data, observation and experiences from recent climate impacts, an assessment of future climate risks needs to be based on scenarios.

Climate scenarios

To address future climate and climate-related hazards, climate scenarios are a well-established approach. Modelled climate scenarios in the context of IPCC exist for different emissions scenarios (Representative Concentration Pathway - RCP) (Figure 13). They range from low- to very high emissions scenarios, which result in very different warming levels, particularly for the long-term future. The emission scenarios reach from as low as +1.4°C global warming for a very low emissions scenario (RCP1.9) to +2.7°C under an intermediate emis-

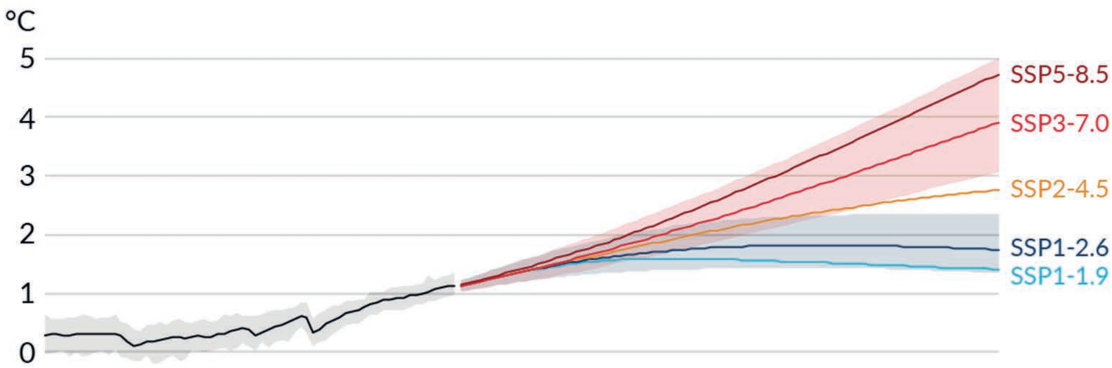
sions scenario (RCP4.5) to +4.4°C under a very high emissions scenario (RCP8.5). The intermediate emission RCP4.5 scenario is largely in-line with the implementation of current climate policies. RCP4.5, under a current perspective, is the most likely scenario and should therefore be included in any CRA. The high range of possible warming levels by the end of the century indicates the high potential and urgency of climate mitigation.

Variations in warming levels are much lower for the near-term future. We will likely exceed the 1.5°C global warming level within the next decades almost independently of the emissions scenarios. By the middle of the century, we are likely to reach global warming levels slightly below or near 2°C with respective adverse consequences for human and ecological systems.

Figure 13 : Global warming since 1950

Global warming since 1950 (grey line, 2022: +1.1°C) and for different emissions scenarios (coloured lines). While for the long-term future (2081-2100) warming levels are mainly determined by emissions scenarios, for the near-term future (up to 2040), warming levels are quite similar for different emissions scenarios and the spread due to model uncertainty is higher than the spread due to different emissions scenarios (IPCC, 2021b).

(a) Global surface temperature change relative to 1850-1900



Therefore, it might be sufficient for the near-term future to consider only one emissions scenario (e.g. RCP4.5) plus a range to address model uncertainty. For the mid-term and long-term future, it is beneficial to address two or even three scenarios. If the number of scenarios should be reduced, it would make more sense to not include the low-emissions scenario, since risk management prepares for plausible but harmful cases. If the number of future time periods is limited to two, it is recommended to consider the near- and mid-term future. See Table 2 for possible scenario combinations.

Table 2 : Possible combination of information and scenarios for climatic and non-climatic risk drivers

Climatic risk drivers address global warming levels with respective emissions scenarios (RCPs).

Temperature increases are global	Current Situation	Near-term future (e.g. 2021-2040)	Mid-term (2041-2060)	Long-term (2081-2100)
Climatic risk drivers	+1.1°C (current observations + past trends)	RCP4.5 +1.5°C (1.2°C – 1.8°C)	**Low emission (optional)** RCP2.6 (mid +1.7°C, long +1.8)	
			Intermediate emission RCP4.5 (mid +2°C, long +2.7°C)	
			High emission RCP7.0 or RCP8.5 (mid +2.1°C – +2.4°C, long +3.6°C – 4.4°C)	
Non-climatic risk drivers	Current situation + past trends	Explicit scenarios (quantitative) or extrapolation (business-as-usual – BAU) of past critical trends (narrative scenarios)	Only narrative assessment of potential development paths for BAU and Aspiration scenarios	
		Optional: Aspiration – Climateresilient development pathway		

Scenarios of non-climatic risk drivers

While climate scenarios are widely available at the global and regional scale, scenarios for non-climatic risk drivers (exposure and vulnerability) are rarely available and are typically limited to factors such as population growth.

At a minimum it is necessary to extrapolate existing critical trends that could modify and enhance exposure and vulnerability to climate impacts, and therefore increase climate risks in the near-term future. Such critical existing trends could be population growth, urbanisation, increasing degradation of natural ecosystems, increasing water demand, increasing demand for food, and increasing conflicts regarding water and other natural resources.

TIP

Just as important as climate change is the future evolution of exposure and vulnerability because it strongly influences climate risks. Therefore, developing at least narrative scenarios for the most relevant non-climatic risk drivers is highly recommended. A CRA that considers the future climate but neglects likely socio-economic trends is incomplete and does not lead to appropriate CCA measure recommendations (including transformative adaptation).

Socio-economic scenarios are in most cases only useful for the near future. The combination of climate scenarios and socioeconomic scenarios for the near future potentially leads to a future climate scenario in combination with one or two future socioeconomic scenarios. For the mid- and long-term future, it makes sense to produce two or three future climate scenarios without detailed assumptions on the socio-economic situation. Narrative scenarios are based on existing projections and are developed in workshops for the region and a specific context (e.g. a region with its exposed systems).

The future of socio-economic conditions and associated non-climatic risk factors will be shaped and influenced by respective climate resilience development policies. Therefore, it is advisable to at least discuss an Aspiration scenario following possible positive climate-resilient development pathways that could reduce climate exposure and vulnerability in the near future (Schipper et al., 2022).

→ *More information on data, information and knowledge collection and scenario building for climatic and non-climatic risk drivers is provided in chapter **E 2.3.** and in the Expert Material **E 2.1.3.***

Uncertainty and confidence

There are several sources of uncertainty in a CRA. Some of the most significant sources of uncertainty include:

- Climate data and models: climate observations might be sparse or incomplete. Climate models have high uncertainties specifically when it comes to precipitation related factors and climate extremes.
- Lack of understanding of processes related to adverse consequences: for complex impacts, knowledge of the mechanisms underlying climate risks may not be well understood.
- Socio-economic factors: CRAs also need to consider the potential impacts of socio-economic factors such as population growth, urbanisation, and land-use change that may influence vulnerability and exposure to climate risks.
- Lack of local knowledge: even if the evidence for certain climate risks may be high at the global level, a lack of data and knowledge at the regional to local level leads to large uncertainties.

It is essential to articulate the underlying causes of uncertainty pertaining to the available information across crucial levels and all factors influencing risks, including hazards, exposure, and vulnerability. Moreover, it is crucial to evaluate the level of confidence associated with this information for each significant risk. Confidence, according to the IPCC, is the robustness of a finding based on the type, amount, quality and consistency of evidence and on the degree of agreement across multiple lines of evidence and can be assessed qualitatively based on the schematic in Figure 14.

Figure 14 : Confidence scoring
(adapted from Mastrandrea et al., 2010)

Agreement	High	Medium	High	High
	Medium	Low	Medium	High
	Low	Low	Low	Medium
		Limited	Medium	Robust
		Evidence		

Box – B – Semi-fictive case study – an application example

The semi-fictive case study is adapted from a mission in 2018 where the methodology of the Vulnerability Sourcebook (Zebisch et al., 2017), the predecessor of the CR-SB, was applied in Central Asia. It serves as an example for an application of the CR-SB methodology and its outcome. In the CR-SB the case study is used as an example for instructions in the following modules. You will find this case study throughout the document.

Climate change is not only increasing the risk of droughts and mudflows in this mountainous district in Central Asia, but also threatening livelihoods and the infrastructure of local communities. A CRA was conducted over a duration of three months in order to understand the main climate impacts and the factors driving the risk in the past, presence and in the near future.

The area under review is sparsely populated in the more mountainous south with crop lands and large settlements in its flat and fertile north. The area has a subtropical arid climate with short and mild winters and warm to hot, dry summers with heavy rainfalls in early spring and summer. In the valleys, local communities rely on income from cultivating crops as well as light industry in and from rearing livestock in the mountains. A river runs through the district and is the main source of water for irrigation and drinking.

The assessment was conducted by international experts and local staff from GIZ. The scope was defined in the assignment's Terms of Reference (ToR). In the risk identification phase, a desktop study reviewed existing information for context. The data collection phase consisted of compiling information on the natural, ecological and socio-economic situation of the district as well as climate data and climate projections sourced from existing reports. For the risk analysis, workshops were held with regional and local experts to evaluate weather and climate-related hazards, risk management measures, climate change impacts and the availability of data and information. During the workshop, local knowledge and minority and gender issues were also taken into consideration.

Following the workshops, field visits took place with representatives from the resident community, experts from the district department and GIZ who explained the local context and the dynamics of exposure, vulnerabilities and risks present in the area. The following key risks to local communities were identified:

1. Risks due to mudflows generated by high-intensity rainfall events and upstream land degradation exacerbate the frequency and intensity of occurrences and result in increasing damage to infrastructure and livestock - especially if no appropriate early warning system is in place.
2. Risks due to droughts and high temperatures may result in water shortages and degraded soils that store less water. This could lead to reduced drinking water, fodder and crop yields. In addition, the inappropriate construction and maintenance of water management structures as well as a lack of water conservation technologies also exacerbates this risk.

Climate projections for the region show that between 2022 and 2050, the two main risks are expected to increase. Rising temperatures will also lead to reduced snow cover and early snow melt in the mountains as well as more rain in winter resulting in less water for irrigation.

The following vulnerabilities and risk drivers were identified:

- An 8% increase in population from 2000 to 2020 has augmented the demand for energy, food and water.
- General poor management practices in agriculture and a lack of maintenance of infrastructure and pastures.
- In addition, many of the local men work abroad resulting in the women having to undertake intensive jobs in agriculture and primary production on top of most domestic work and childcare. Due to a lack of other money saving opportunities, remittances are often invested in additional livestock which results in further degradation of the area's pastures.
- Lack of a transnational water management plan or transborder cooperation agreement and as such, water supply is not guaranteed.
- Rising water demand is, due to more livestock and agricultural fields in combination with degrading soils.

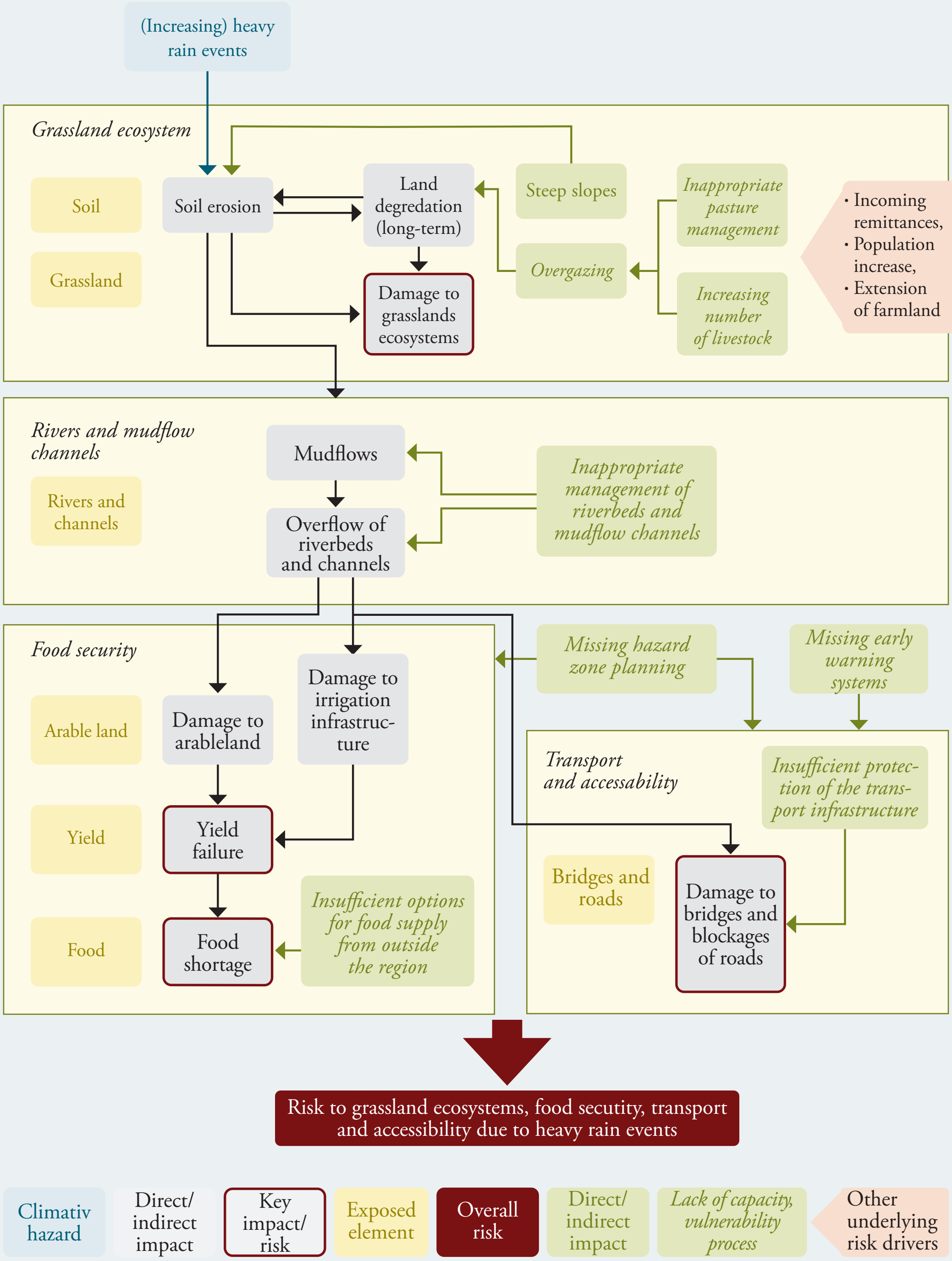
Many of the irrigation channels that exist are not maintained or are blocked and thus unusable. The large mudflow channel built during the 1960s is insufficiently maintained and is heavily damaged where it has been eroded by debris and water following mudflow events.

The suggested CCA measures concentrate on combatting land degradation due to overgrazing, renovating and upgrading water management systems for agriculture and drinking water as well as soil improvement and protection measures. Experts suggested ensuring better access to data on meteorology, climate, hazard impacts as well as on livestock density, and maintenance and exposure of infrastructure in risk zones.

All information gathered in the data analysis, literature review, the workshops and during the field trip was summarised in a descriptive report. For each key risk, impact chains were created, allowing an overall picture to be visualised schematically (Figure 16). For each element in the impact chain, indicators were analysed in a subsequent detailed CRA.

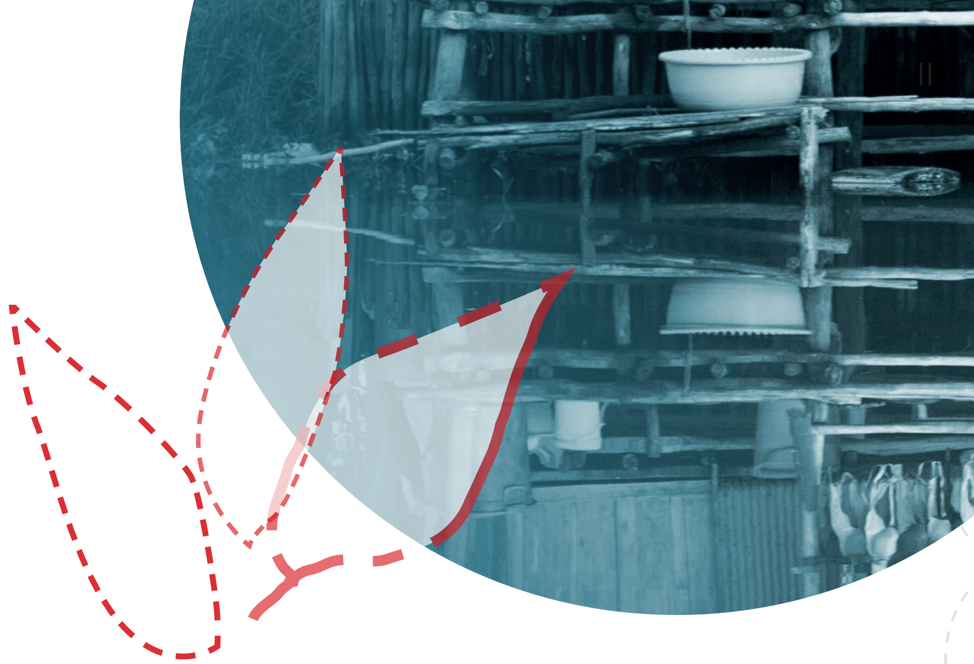
The analysis clearly shows how multiple risks can arise from the same social and environmental vulnerabilities and how risks can interact with and compound one another. Key risks are linked to soil degradation that leads to soil erosion which aggravates the impact of droughts. The impact of drought on pastures and agricultural fields also increases soil degradation and may as a consequence lead to a higher susceptibility to erosion and mudflow.

Figure 15: Impact chain for risks due to heavy rain and mudflows developed after the workshops (own illustration)



This case study is also a good example of how social vulnerabilities, such as acute population growth and lack of financial capacity and knowledge, can have severe environmental and economic consequences. After preparation, including data mining and planning workshops, two researchers spent 14 days on site and conducted the CRA. The report was completed three months after the trip.

II.



Modules for the CRA

The forthcoming chapters will introduce the distinct elements of a CRA in a modular form. Each module includes step-by-step instructions that are designed for a CRA of low to moderate complexity on a local to regional scale with low to moderate effort and resources. Ordinarily, such an evaluation can be carried out within eight months or less (see Table 3). For a more complex CRA, find comprehensive guidelines in the Expert Material. Links to each chapter in the Expert Material are given for every individual step in the modules.

Table 3 : CRA time planning

	CRA on sub-national to local scale/ CRA of project	CRA on national to local scale
Time required	4 – 8 months	8 months – 3 years
Sub-units for the analysis	5 or less sub-units (e.g. ecozones, districts)	6 or more sub-units
Systems and sectors	up to 5 systems	up to about 15 sectors

2.1. Overview, CRA workflow and cross-cutting topics

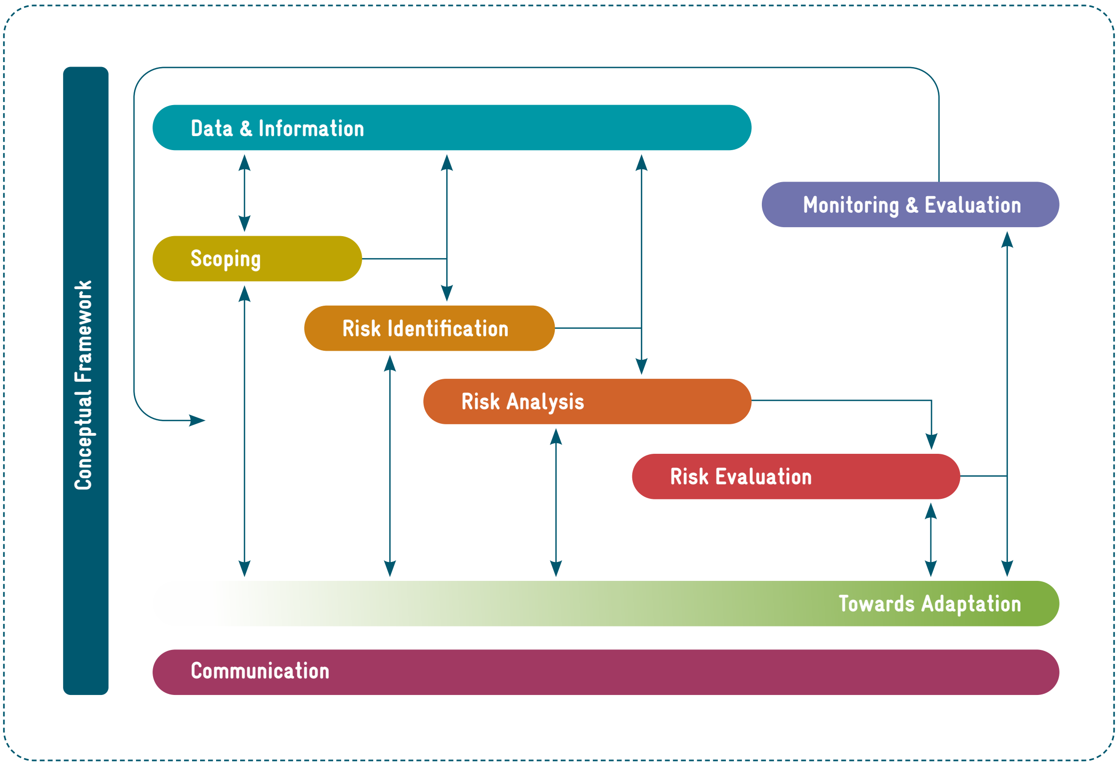
Figure 16 shows the structure of the CR-SB. The primary sequential steps of the CR-SB tackle the four modules of the CRA: ‘Scoping’, ‘Risk Identification’, ‘Risk Analysis’ and ‘Risk Evaluation’. These modules are structured with an inherent logic that builds upon one another. Moreover, four cross-cutting modules should be addressed throughout all modules:, ‘Data & Information’, 'Monitoring & Evaluation', ‘Towards Adaptation’ and ‘Communication’.

The cross-cutting module ‘Data & Information’ provides instructions and hints on how to gather information on climate, climate change, vulnerability and exposure as well as how to define scenarios for climatic and non-climatic risk drivers. Understanding data and information availability and collecting this information is important from the first step of the CRA. The cross-cutting module ‘Towards Adaptation’ deals with the process of moving from a risk assessment to planning for CCA. It offers clear and detailed instructions on how to make this transition. However, it is important to note that CCA is a fundamental theme that is interwoven throughout all the modules, appearing in different stages and contexts. The cross-cutting module 'Communication' provides guidance on how to ensure effective communication throughout the CRA process for clarity, collaboration, risk identification and mitigation, transparency, accountability, decision-making, and continuous improvement. A well-thought-out dissemination strategy is essential for targeted communication, ensuring clear and accessible communication, facilitating feedback and engagement, influencing opinions and actions, and fostering continuous learning and improvement. It ensures that valuable information reaches the right audience in a manner that encourages understanding and engagement, maximises the impact and ultimately drives positive outcomes.

The module 'Monitoring & Evaluation' represents a critical component of a climate risk assessment as they help to track and evaluate the effectiveness of interventions and assess the success of the CRA.

Figure 16 : Overview of the modules and their relationships

The length symbolizes length of time required to complete module. (own illustration)



In addition to the three cross-cutting modules, two cross-cutting topics that are key for a successful CRA process are addressed in a systematic way throughout the CR-SB: Stakeholder engagement and Gender & Differential vulnerability. Table 4 provides an overview of the cross-cutting topics of the CR-SB and how they are addressed in the different modules. We use symbols and colours throughout the CR-SB to indicate where aspects of one of these cross-cutting topics are addressed.

The outcome of a CRA will be a climate risk report. The process and the final result should be actively communicated to stakeholders. Even though the structure of the report heavily depends on the context and the scope of the specific CRA, certain sections could be directly informed by the single modules of the CR-SB (Figure 17).

Figure 17 : How the single modules of the CR-SB can contribute to a climate risk report as a final outcome (own illustration)

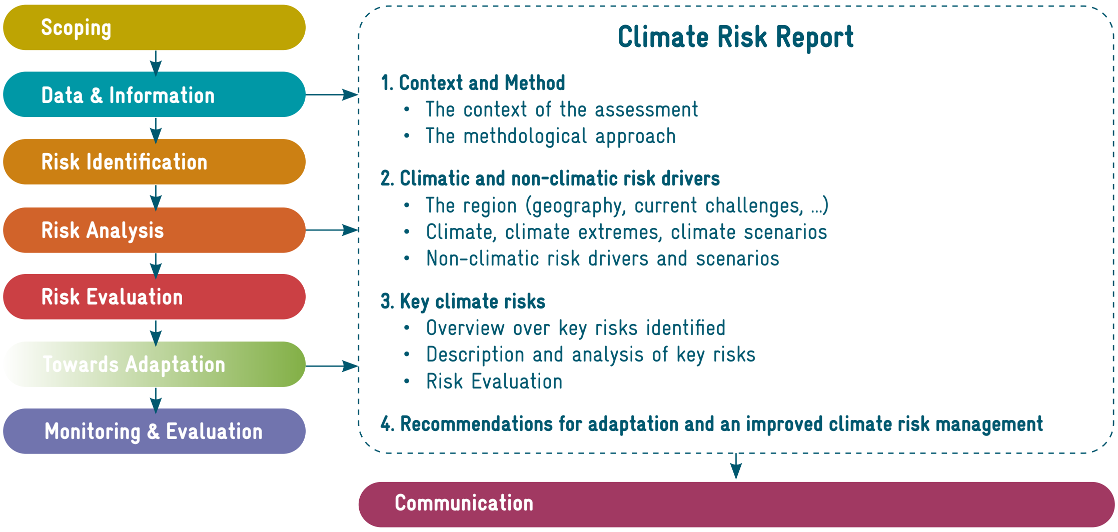


Table 4 : Cross-cutting modules and topics and how they are addressed in the different modules of the CR-SB

Module	Cross-cutting modules			Cross-cutting topics	
	Data & Information	Towards adaptation	Communication	Stakeholder engagement	Gender & Differential vulnerability
Scoping	Screen general availability of information on climate and climate impacts, as well as socio-economic data availability	Identify past and current CCA efforts and upcoming CCA plans, including what was and was not successful. Brainstorm on how your CRA can inform CCA planning	Communicate the aims of the study; identify your stakeholders and users; develop and agree on the main purpose of the assessment	Design partnerships with stakeholders such as environmental ministries and agencies, statistical offices, meteorological services, universities and research centres, NGOs and the private sector	Ensure women in all their diversity and minority groups are part of CRA technical team; develop a gender and social inclusion strategy; identify gender and differential vulnerability in your CRA area
Risk Identification	Investigate data and information; start collecting data based on the data-sharing agreements	Identify what climate risks have been targeted by past and current CRM and CCA plans	Engage with the relevant stakeholders and provide a summary of the methods and key findings to the wider user audience	Plan the assessment of each risk by the CRA team together with the expert and stakeholder group in a first stakeholder workshop	Consider how groups have been affected differently by past impacts
Risk Analysis	Collect and analyse data; produce outputs and results	Identify the drivers and root causes of vulnerability as well as climate-risks for the system and the subsystems, reflect on gaps and entry points for CCA options	Engage with the relevant stakeholders and provide a summary of the key findings to the wider user audience; communicate the applied methods	Co-develop preliminary impact chains with stakeholders in a workshop; lead a key risk identification workshop	Account for entrenched inequalities and external drivers' influence on the vulnerability of different stakeholders or social groups

Table 4 - Continuation : Cross-cutting modules and topics and how they are addressed in the different modules of the CR-SB

Modul	Cross-cutting modules			Cross-cutting topics	
	Data & Information	Towards adaptation	Communication	Stakeholder engagement	Gender & Differential vulnerability
Risk Evaluation	Use the analysed information and data	List key climate-risks; understand how key risks were developed with expert-based risk severity and community-based risk tolerance	Engage with the relevant stakeholders and provide a summary of the key findings to the wider user audience; communicate the applied methods	Define core stakeholders to assess the timing of and ability to respond to risk; engage in participatory processes for participatory risk layering	Ensure the inclusion of representatives from different gender and marginalised groups if you conduct a community-based risk evaluation
Towards Adaptation	Use the analysed information and data	Identify a list of CCA options; conduct an expert-driven and stakeholder led evaluation of the identified CCA options; identify co-benefits, trade-offs and limits to CCA	Engage with the relevant stakeholders, provide a summary of the key findings to the wider user audience and communicate the applied method	Find core stakeholders to identify potential CCA options; start a participatory process for potential CCA options including perspectives of those most vulnerable to the prioritised climate risks	Ensure the inclusion of representatives from different gender groups and marginalised groups when gathering community feedback
Monitoring & Evaluation	Use the analysed information and data	Define key considerations for establishing a monitoring, evaluation and learning plan for CRM and CCA	Engage with the relevant stakeholders, provide a summary of the key findings to the wider user audience and communicate the applied method	See 'Towards Adaptation'	Use gender-disaggre-gated data; consider the constraints for members of certain groups or genders to attend workshops or interviews and find solutions for this
Communication	Present information through maps, figures and storylines, provide access to results; co-develop the CRA with stakeholders	Communicate the CCA process, potential trade-offs for specific communities, groups and sectors as well as unforeseen maladaptive consequences	Develop a communication strategy and approach on how to communicate with relevant users and stakeholders	Co-develop the CRA with stakeholders	Consider the information channels and communication barriers experienced by different groups

Scoping

Scoping involves setting up a CRA in a way that it can support decision making and planning, by considering existing objectives, goals, values and policy and planning frameworks as well defining new ones.

Key steps you need to address in this module:

- Step 1: Define the context and purpose
- Step 2: Define the scope - risk screening versus in-depth risk assessment
- Step 3: Define the system, its subsystems and associated exposed elements
- Step 4: Review existing data, information, and knowledge sources
- Step 5: Define the temporal and spatial scope
- Step 6: Identify considerations for gender diversity and vulnerable groups
- Step 7: Design partnership and plan resources
- Step 8: Design a communication strategy
- Step 9: Write a project plan

What do you need to implement this module?

- A clear mandate to design the CRA
- A clear understanding of the context of the CRA
- A clear understanding of relevant stakeholders of the CRA
- An overview of existing data, knowledge, or studies on climate change and climate risk
- A clear overview of available/planned resources (budget, time, persons, competences)
- Coordination meetings with stakeholders/end-users

OUTCOMES OF THIS MODULE

A project plan defining the objectives and the methods of the CRA including allocation of responsibilities, resource planning, and project timeline.

Which (additional) tools and information does the CR-SB **website** provide?

https://www.adaptationcommunity.net/climate-risk-assessment-management/climate-risk-sourcebook/

- Example reports
- Publications: 'Guidance Note For Planning' and 'Contracting And Effective Backstopping Of A Climate Risk And Vulnerability Assessment (CRVA) (Zebisch and Renner, 2018)'. They give hints on how to conduct a good scoping and how to consider this in the ToRs of a potential tender.

A CRA can only support and improve CRM and CCA if it is tailor-made to the context of your region or project. Therefore, it is essential to co-design a CRA together with your stakeholders. Answering the questions below could lead to an introductory chapter of a CRA report and will help you to design the other modules to be as context specific as possible. Report the answers to these questions in a scoping report.

TIP

- 'Scoping' is typically already conducted by the contracting entity before a contract for CRA is issued.
- The result of 'Scoping' can lead to ToRs for a tender/contract and inform the first chapter of a climate risk report.
- For a complex and large-scale risk assessment covering various sectors at national level, you should conduct the module "risk identification" as a preliminary study before starting the full assessment and entering into contractual agreements.

Step 1 – Define context and purpose

This step provides an overview of the key aspects of your CRA. It outlines the different factors that must be considered, from the policy context and the contractors' expectations as well as the values and objectives that you want to achieve for providing a solid foundation for effective CRM.

What is the context and the purpose of your CRA?

The context and purpose of your CRA matters because it determines the scope and relevance of the research. Without a clear and well-defined goal, the study may lack direction or fail to address critical issues. The following questions help to define the CRA:

- What is the policy context (regulations and laws, existing studies, strategies, plans, obligations to report risks etc.)?
- Who contracted or will contract the CRA?
- What CRM and adaptation plans and strategies could be needed? How can the CRA best inform CRM and adaptation planning?

Which adverse consequences of climate extremes and climate impacts should you avoid?

By understanding the potential impacts of climate change on defined values and objectives, we can implement CRM and CCA measures to avoid or reduce the negative effects, thereby safeguarding our present and future wellbeing. It helps to ensure the sustainability of society, economy, and the ecosystems.

- Which other targets, frameworks, agreements and agendas (such as: Nationally Determined Contributions, Sustainable Development Goals, Sendai Framework for Disaster Risk Reduction, Paris Agreement) should be achieved together with climate risk reduction?
- How can prevention avoid economic and non-economic losses and damages?
- How might values, targets and objectives (e.g. becoming a climate-resilient city, fostering climate-resilient development, etc.) be adversely affected by climate impacts and risks?
- How could CRM and CCA potentially protect the defined values, targets, and objectives?

Step 2 - Define the scope – risk screening versus in-depth risk assessment

The context and the purpose of your CRA defines the scope and the general set-up of methods for your CRA. The effort that has to be invested in a CRA depends on several factors with the most important being the spatial scale (e.g. local, regional or national), the number of systems and sectors (e.g. agriculture, human health) and the number of spatial sub-units (e.g. districts) to be analysed (Table 5). Furthermore, it depends on the depth of the assessment. A rapid risk screening for a few sectors and subsystems on sub-national scale can be conducted in four to eight months, while an in-depth and data-driven assessment on national scale may even take up to three years. Stakeholder participation can lengthen the necessary time required (e.g. weak administration can impact the process).

Table 5 : Overview of different settings of a CRA and the related effort regarding time, data and expertise

	CRA on sub-national to local scale/CRA of projects.	CRA on national to local scale 5 or fewer units	CRA on national to local scale 6 or more units
Time required	4 – 8 months		8 months – 3 years
Sub-units for the analysis	5 or less sub-units (e.g. ecozones, districts)		6 or more sub-units
Systems and sectors	1-5	2 - 15	
Main objective	Quick overview on key risks, discussion on CCA demand and CCA options	In-depth CRA with a focus on understanding risk drivers, the demand and the entry points for CCA	In-depth CRA with a focus on a spatially explicit CRA for comparing sub-units and identifying spatial hotspots
Main assessment approach	Participatory (CRA Team + stakeholder based)	Participatory + experts (CRA Team + stakeholders + external experts)	Participatory + experts for impact chains; data-driven (composite indicators) for assessment aggregation
Demand for quantitative data	Low	Medium (not all information needs to be transformed into indicators)	High – working with composite indicators. Spatially explicit data needed
Demand for expert knowledge	Medium	High (requires participation of experts in assessment aggregation)	High (in particular for translating qualitative and semi-quantitative information into standardised indicators)
Demand for review and validation	Medium (review and validation recommended, but not obligatory)	High (review and validation process is highly recommended)	High (review and validation process is highly recommended)
CR-SB - Guideline needed	Sourcebook; Focus on risk screening module	Sourcebook + Expert Material	Sourcebook + Expert Material (chapter on composite indicator approach)

Linked to the scope is the general set-up of methods. While a risk screening will be mainly based on easily available material, qualitative information and participatory methods (e.g. through workshops), an in-depth risk assessment should be based on the best evidence available including quantitative information on climate, impacts, socio-economic data and climate scenarios. Quantitative information should be complemented by sound qualitative information from literature reviews and experts.

TIP

This Sourcebook covers all instructions required for a more rapid assessment, while material for a more in-depth assessment is in general provided in the → ***Expert Material***

Based on impact chains, the Vulnerability Sourcebook (Fritzsche et al., 2015) and its supplements were mainly proposing a composite indicator approach for data-driven assessments.

A composite indicator is a complex indicator, which contains several combined (and weighted) individual indicators. Composite indicators allow you to measure multi-dimensional concepts (e.g. vulnerability to climate change effects) which cannot be captured by a single indicator.

The feedback on this method revealed that data is often a bottleneck in CRAs and a more qualitative, but still in-depth description of climate risks and their risk drivers based on a variety of evidence (data, expert knowledge, stakeholder knowledge) is often more appropriate and applicable. This is the focus of the CR-SB and our preferred method for in-depth assessments with a small number of sub-regions. However, for an in-depth assessment with a focus on comparing and assessing risks in a spatially explicit manner with high spatial resolution and in regions, where data on risk drivers is abundant, the composite indicator approach is still a good option and is explained in detail → *in the Expert Material chapter **E 2.2.***

Step 3 – Define the system, its subsystems and its exposed elements

What are 'systems', 'subsystems', the exposed elements and their functions?

Systems are larger functional units or sectors (e.g. biodiversity, agriculture, etc.) that often refer to or are managed by corresponding institutional units (e.g. ministries, departments). In a CRA report, these systems could also be reflected in the chapter structure. Which systems are relevant for your CRA depends on its context and purpose. The systems in Table 6 follow a logic of cascading climate impacts, from system scale impacts down to functions for human wellbeing. Direct impacts often affect ecosystems, biodiversity, land and water, and subsequently systems such as agriculture or energy. We propose to always include systems which are directly affected as well as the subsequent systems.

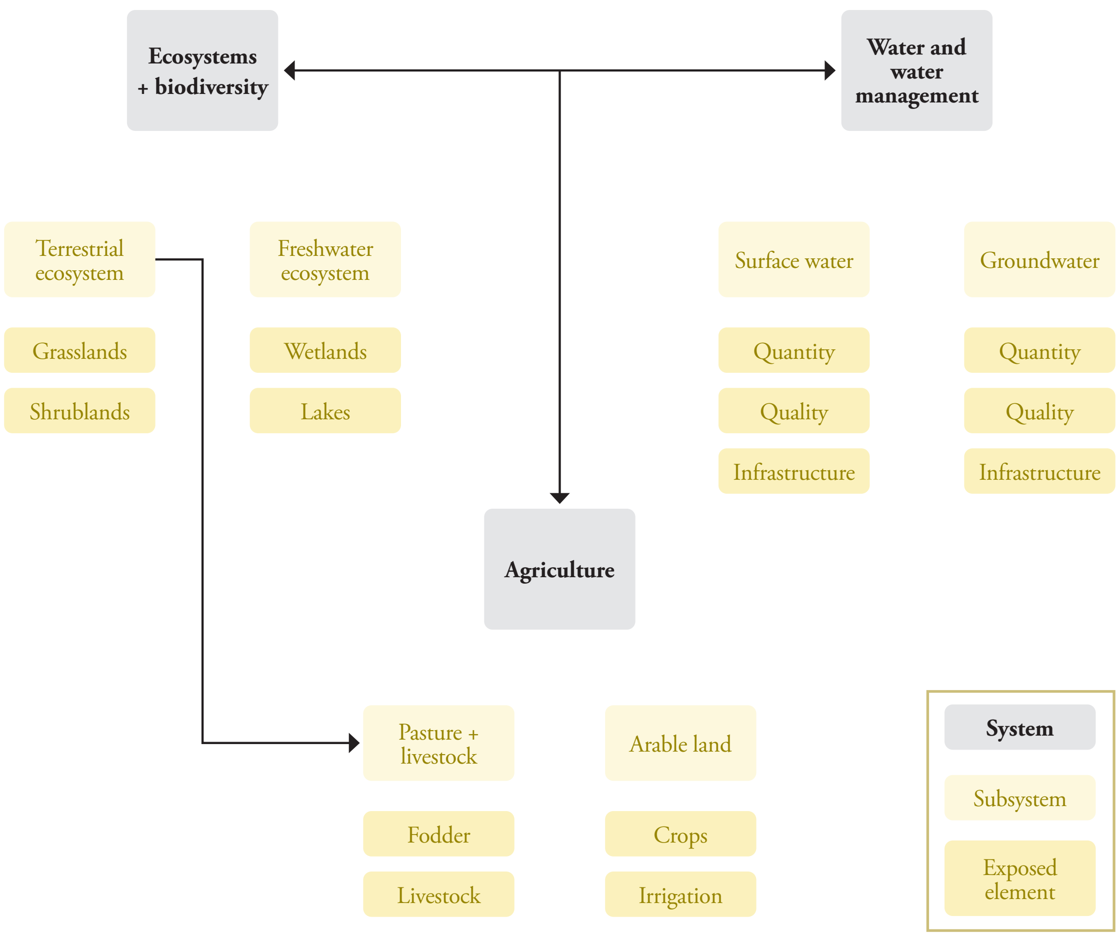
Subsystems can be defined according to your needs. For instance, for agriculture, it might make sense to distinguish between cropland and pastoral systems, if they show different mechanisms in their reaction to climate change. For water in a specific context, consider a distinction between groundwater and surface water. Exposed elements are the smallest units and typically refer to physical elements such as environmental or physical assets (e.g. wetlands, electric grid) or humans (e.g. farmers, women). Figure 18 gives an example of the graphic illustration of the interlinkages between systems, subsystems and exposed elements. Such an illustration supports the development of impact chains in the risk identification and risk analysis phase (modules 'Risk Analysis' and 'Risk Identification').

Table 6 : List of potential systems, subsystems, exposed elements and functions (examples)

Systems	Subsystems	Exposed elements	Functions for human wellbeing
Ecosystem and Biodiversity	Habitats, species or terrestrial ecosystem, freshwater ecosystem, etc.	Grasslands, shrubland, wetlands, desert, rivers, lakes, sea, ocean, high mountains	Various ecosystem services (erosion protection, water filtering, etc.)
Water and water management	Surface water, ground water	Water availability, water quality, water infrastruc-ture,	Drinking water, water for domestic uses, water for economic uses etc. (manufacturing, energy, etc.)
Agriculture and forestry	Cropland, pastoral systems, forestry, aquaculture	Livestock, food crops, cash crops, tree types	Food provision and security, healthy nutrition
Settlement, infrastructure and transport	Cities, villages, bridges, road-based transport, river-based transport	Private infrastructure, pub-lic infrastructure, transport infrastructure	Safe living, public spaces, supports service provision and transport of goods
People and society	Health, economic conditions	Social groups, ethnic groups, gender groups	Health, wellbeing, social cohesion
Energy	Power production, energy transmission and distribution	Hydropower, thermal power, solar energy, electric grid	Supply for domestic and economic uses
Economy	Industry, tourism, commerce	Production site, workers, touristic infrastructure	Labour, household financial security
Policy and governance	Different spatial or thematic levels of governance. Formal and informal governance	Social policies, sector policies	Education and wellbeing, service provision, land tenure/access

Figure 18 : Example of representing systems, subsystems, and exposed elements and their relationships in the scoping phase.

(own illustration)



TIP

Even if your CRA focuses on a specific sector or function, it is always recommended to include related systems or functions, particularly if climate impacts on those systems might trigger indirect climate impacts in your system of concern

'Functions' offer an alternative perspective when examining systems and subsystems, presenting a potentially more advantageous approach for describing the main aspects that require protection. By focusing on functions, rather than solely on the systems themselves, one can better understand the core objectives and essential operations that need safeguarding. To illustrate this point, consider the concept of 'food security' as a function that should be protected, instead of focusing solely on safeguarding the entire 'agriculture' sector. It is important to recognize that food security encompasses a broader scope, as certain aspects of the agriculture sector, such as cash crop farming, may not directly contribute to ensuring access to an adequate food supply. By understanding food security as a distinct function, one can shift the focus towards measures that specifically address the availability, access, and utilization of food resources, thereby directing efforts more effectively to protect and promote this critical aspect of the overall system.

Step 4 - Review existing data, information, and knowledge sources

What are potentially relevant data and knowledge sources for your CRA?

The amount and depth of data and information required depends on the scope you defined in ***Step 2 - Define the scope***. In any case, a CRA should be based on the best evidence available for the given scope.

Check the availability of:

- Data sets (climate data and climate scenarios, hazard event and impact/damage data); exposure data (population, infrastructure, ecosystems etc.); data on vulnerability factors (socio-economic data etc.)
- Reports on climate change, climate impacts, and other trends in your region as well as topic-related scientific literature
- Reports and projects on past and current CRM and CCA efforts, as well as any upcoming plans for CRM and CCA in sectors and for specific climate risks

> **TIP**
>
> **What about CCA?**
> CRA should always be done to inform CRM and CCA planning. The following questions should be identified in the scoping phase: what worked well in previous CCA plans? What did not go so well? Who was involved and importantly who was not involved, and why? See the module '**Towards Adaptation**'.

> **TIP**
>
> **Additional knowledge and expertise:**
> There will likely be no data available for many components of your risk assessment and thus these aspects will require additional expertise. For instance, the potential effects of climate extremes on crops will hardly be documented for your region, however, most likely there will be (tacit) expertise with the national/local authorities, universities, NGOs, or other international or local experts as well as scientific publications and reports. If there is no high-quality scientific literature for this region, scientific literature for comparable regions can be used.

Please find further information on collecting and processing data in the next module ***'Data & Information'***).

Step 5 - Define the temporal and spatial scope

What is the temporal scope?

The temporal scope of a climate risk assessment typically covers the current, the mid-term and the long-term future. We propose covering the following time periods in an assessment:

- Current situation
- Future situation
  - » Near-term future (e.g. up to 2040)
  - » Mid-term future (e.g. 2041 – 2060)
  - » Long-term future (e.g. 2081 – 2100)

For most CRAs it is reasonable to set a focus on the current situation as well as on a near-term future and eventually a mid-term future, since current and quickly emerging risks need to be addressed first with urgent CCA actions. However, for systems with a long planning and CCA horizon (e.g. forestry, large-scale infrastructure such as reservoirs) the consideration of a long-term future (e.g. 2081-2100) is also recommended.

When defining the 'current situation' from a climate perspective you would typically refer to a reference period such as 1990 to 2020. However, it is also important to report on the latest climate trends and observations of recent extreme events since with rapid climate change, a 20-year reference period no longer represents the current situation but already a past situation.

Since the future development of exposure and vulnerability might be as dynamic as climate change itself and has a strong impact on climate risks, we strongly recommend to develop at least narrative scenarios for the most relevant non-climatic risk drivers. This could include a 'business-as-usual' (BAU) scenario that considers known trends (e.g. on population, increasing water demand, more extensive land use) and an 'Aspiration' scenario, that is based on a positive plausible development pathway towards a more resilient and sustainable region. A CRA that considers a future climate but neglects likely trends in the socio-economic conditions would be incomplete and not lead to appropriate conclusions on the necessity for CCA (including transformative adaptation).

See more in chapter ***1.7.*** of the conceptual framework.

What is the spatial scope (in case of a risk assessment of a region)?

The assessment aims to determine the geographical scope it covers, whether it focuses on a particular municipality, valley, watershed, district, or even an entire country. Understanding the specific region of interest is crucial as it provides context for analysing climate risks and potential impacts. Furthermore, it is essential to examine how climate risks within the study area are influenced by developments and actions occurring at larger scales. This includes considering the interplay between local factors and broader contextual factors such as national policies, development plans, and regional initiatives.

Which are the spatial sub-units into which you want to structure your analysis?

If you are assessing the risks of an entire region or country, it is crucial to consider splitting the area into smaller parts, so-called sub-units. These sub-units could be based on the environment

TIP

- It is important to report interlinkages between sub-units and consider them within the risk assessment (e.g. mountain – lowland: water flowing from mountains to lowlands. Mountains and lowlands are distinct sub-units).
- Conduct a CRA for each sub-unit.

such as lowlands, mountains, or coastal areas, or based on administrative units like districts or municipalities. This will help you get a more comprehensive view of the risks and how they may differ within the region.

Try to answer the following questions:

- Is it possible to define sub-units?
- Can they be defined by ecological criteria (e.g. lowlands, mountains, coast) or as administrative units/districts?

Step 6 - Identify considerations for gender diversity and vulnerable groups

Are there vulnerable people within these groups?

Some people are more vulnerable than others and their vulnerabilities can affect their capacity to adapt to or manage climate risk. When thinking about the different groups affected by risk, consider the following:

- Are there minority ethnic groups in your system? Is there a history of conflict or oppression which means certain groups have difficulty accessing services (e.g. based on their religion)?
- Do women and girls in all their diversity have the same decision-making power as men, within their families or communities? Are they able to choose freely where/if they study, work or live?
- Are people with disabilities fully included in society?
- Are people belonging to LGBTIQ+ communities discriminated against or excluded from certain activities in society?
- What are some of the things included in activities for marginalized groups in relation to climate risk? This includes increasing their involvement in politics, making sure they have access to essential services from both government and non-government organizations, and supporting community-driven initiatives for adapting to and reducing the effects of climate change.

TIP

The conceptual framework provides more information on different types of vulnerability and why it is important to consider this in your CRA.

Inequalities in the way individuals or groups are treated by a society have a considerable impact on their vulnerability. If there are existing inequalities in your system, it is important to identify them early in your CRA so that they can be addressed throughout the CRA process.

Who is in your CRA expert team?

Addressing the topic of inequality also concerns the composition of your CRA team. As far as possible, ensure that there is a balance between genders on your team and that people from minority groups are represented.

Step 7 - Design partnership and resources

Who should be actively involved in the CRA?

Communication and interaction between the consultant and stakeholders are crucial for a successful CRA. Relevant stakeholders are for instance environmental ministries and agencies, line ministries and agencies, statistical offices, meteorological services, universities and research centres, NGOs, and the private sector. See also Table 7 and chapter ***1.4.*** how stakeholders are involved in the respective modules.

Table 7 : Overview of stakeholder involvement in single modules

Module	Stakeholder involvement
Scoping	• Design partnerships and resources
Risk Identification	• Assessment of each risk by the CRA team together with expert and stakeholder • group in a first stakeholder workshop
Risk Analysis	• Co-developing preliminary impact chains with stakeholders and experts in a workshop • Risk identification workshop to define the key risks in the region
Risk Evaluation	• The group of core stakeholders assess the timing of and ability to respond to risk • Participatory processes with a representative group of relevant stakeholders (recruited from the extended stakeholder network) for participatory risk layering
Towards Adaptation	• The group of core expert stakeholders to support the identification of potential CCA options (including sectoral experts) • Participatory processes with a representative group of relevant stakeholders (recruited from the extended stakeholder network) for participatory feedback on potential CCA options (incl. perspectives of those most vulnerable to the prioritised climate risks)
Data & Information	• Stakeholder consultations can offset the lack of high-quality data on past observations and future projections, especially for a local-scale assessment, where the data available is too crude and/or of poor quality • Stakeholder workshops and expert consultations can help you to gather information on the occurrence of extreme events which are not covered by the measured and modelled data set
Monitoring & Evaluation	• Stakeholders must be included in monitoring and evaluation in assessing the effects of the CCA actions on the stakeholders themselves, sectors and systems. Accounting for the perspectives and experiences of all stakeholders through inclusive monitoring and evaluation should be a key requirement
Communication	• Engage stakeholders in the co-development of the CRA

Step 8 - Design communication strategy

Communication and interaction between the consultant and the stakeholders should be bi-directional throughout the entire process, employ participatory methods and tools, and take into account gender and other equity aspects. It is important to draw on a wide involvement of stakeholders and decision makers already in the planning phase before designing the ToRs. A good communication and engagement strategy provides access to useful data and information in a user-friendly format and ultimately helps stakeholders to engage with the CRM and CCA process.

Find more information on how to develop a communication strategy in the module ***'Communication'***.

Step 9 - Write a project plan

Once all the pertinent information to the objective of the CRA has been gathered, it is advisable to develop a thorough work plan that includes well-defined work packages and a practical timeline. Additionally, it is important to document all potential partners involved in the assessment and consider their potential roles and contributions.


Iglesia Católica
Salón Comunal
Auxiliatura

Data & Information

Collecting and processing of data, information and knowledge means preparing the information base that will allow you to conduct the risk assessment with the best available data and information for the area under review. This includes information on climate and climate change (current situation, climate scenarios), information on climate impacts as well as information to describe the current and the potential future situation of exposed systems, subsystem and elements and their vulnerability to climate impacts.

This module is a cross-cutting module that should be considered throughout other modules and steps.

The effort that is required for collecting data, information and knowledge heavily depends on the scope of the CRA (scale, complexity, method).

Key steps and topics you need to address in this module:

- **Step 1: Identify your data and information needs**
- **Step 2: Gathering of data and information, data quality check and data management**
  - Data and information gathering
  - Data and information quality check
  - Data and information management
  - Climate data and climate scenarios
  - Scenarios for non-climatic drivers
- **Step 3: Summarise the information in a chapter on climatic and non-climatic risk drivers**
- **Optional Step: Develop composite indicators**

What do you need to implement in this module?

- Review of existing data and knowledge
- Data and information requirements gathered from ‘Scoping’, ‘Risk Identification’ and ‘Risk Analysis’
- Knowledge of the available resources (time, staff, skills)

OUTCOMES OF THIS MODULE

- A curated collection of data and information to be used for analysis in the CRA
- A chapter on climatic and non-climatic risk drivers for your risk report

Which (additional) tools and information does the **website** provide?

https://www.adaptationcommunity.net/climate-risk-assessment-management/climate-risk-sourcebook/

- A list of data platforms, existing tools and other resources,
- references of example CRAs using a quantitative indicator approach,
- additional guidance and literature (e.g. Joint Research Centre (JRC) composite indicator tools).

TIP

- The 'Data & Information' module is supporting the 'Scoping', 'Risk Identification' and 'Risk Analysis' modules.
- Collection, preparation and interpretation of data and information are time-intensive and require technical skills. It is recommended to have one person dedicated to data and information management.

In this chapter, we provide an introduction on the single steps required to collect and process the necessary information.

→ *Most of the more technical information on data management and processing can be found in the Expert Material chapter* ***E 2.1.***

Step 1 - Identify your data and information needs

- In the 'Scoping' module screen the general availability of information on climate and climate impacts, as well as the availability of socio-economic data.
- In the 'Risk Identification' module analyse data and information availability for the identified key impacts and risk.
- In the 'Risk Analysis' module scrutinise the availability of data information for each element (hazard, impacts, exposure, vulnerability) of each key risk for the current as well as for the future situation.

The data and information requirements strongly depend on the depth of your assessment (from a quick screening to in-depth assessment) and the spatial resolution of your assessment (e.g. from a few spatial sub-units to a fully-fledged spatial assessment using spatial indicators in a GIS environment). Always consider quantitative information (data) as well as qualitative information (e.g. reports, scientific papers, expert knowledge, local knowledge). It is important to have a good understanding of the information available and its quality. When good quality quantitative data is not available the recommendation is to collect qualitative data according to the information needs, i.e. climatic hazards, exposure, impacts and vulnerability for the past and future trends. Qualitative data can be collected in expert consultations or workshops. Always use the best information available. The chapter in the CRA report describing climate and other risk drivers subsequently is a combination of both information originating from measurements, computer models as well as literature reviews and expert consultations.

In addition, you need to collect at least some baseline geographic data such as information on elevation, administrative boundaries, settlements and river networks. Topographic maps are useful to address spatial features in workshops, reports etc. Spatial data to create topographic maps if not available from local or national source can be gathered from global data sources available online (see the ***CR-SB website*** for a list of data portals). ***https://www.adaptationcommunity.net/climate-risk-assessment-management/climate-risk-sourcebook/***

We recommend noting your data and information needs and data availability in a table that is structured along the risk components (see Table 8 for an example). If you are assessing different systems (e.g. agriculture, water Example of representing systems, subsystems, and exposed elements and their relationships in the scoping phase., energy) include sections for each of the systems in the table.

Table 8 : Data and information needs table for assessment at district level

First check for data availability in the country and in a second step consult publicly available global data.

Component	Data theme	Spatial resolution	Temporal resolution	Potential data provider*
Background Reports	National Adaptation Plan/Strategy	National	--	National/Regional Government – Ministry of Environment
	Nationally Determined Contributions	National	--	National/Regional Government – Ministry of Environment
	Climate Risk Assessments	National	--	National/Regional Government
	Sector strategic plans and policies	National	--	Line ministries
	National Disaster Management Policy	National	--	Civil protection agencies
Climate/Hazard	Historic climate observations	Gridded or station data	Minimum 20-year time series	National/Regional Hydromet office/IPCC
	Climate model simulations	5km Grid	2020 – 2050; 2070 - 2100	National/Regional Hydromet office
	Hazard events, e.g. drought, flooding, storms, landslides	Location/extent	Date of occurrence	National/Regional Hydromet office Stakeholder workshops, local knowledge
Impacts	Observations of water scarcity, loss in yield, economic damage, loss of lifes	Location/extent	Date of occurrence	National databases Stakeholder workshops
	Modelled impacts e.g. on water availability or crop yield.	Location/extent	Time series e.g. 2000 – 2100 or time slices (2020-50)	Climate impact studies, literature (IPCC, ...)

Table 8 - Continuation : Data and information needs table for assessment at district level

Component	Data theme	Spatial resolution	Temporal resolution	Potential data provider*
Vulnerability	Soil erosion	Data or expert knowledge	Current	Ministry of Environment
	Land degradation	Maps/expert knowledge	Current	Ministry of Environment
	GDP per capita	Lowest admin level	Current	Ministry for Economy
External risk drivers	Poverty structure	Regional	Current	National authorities + stakeholder workshop
	Increasing prices for fertilizer	Global/National	Timeseries	FAO
Scenarios on Exposure, Vulner-ability, external risk drivers	Potential future situation of key non-climatic risk drivers (e.g. popula-tion, poverty, land use, etc)	Regional	Scenario for near future (up to 2050)	Result of dedicate scenario workshops
Baseline data	Elevation	30m	N/A	Ministry of Environment
	Land use land cover	30m	Most recent	Ministry of Environment
	Administrative boundaries	100m	Most recent	Ministry of Environment

Step 2 - Gather your data and information, data quality check and data management

Data and information gathering

Obtaining the data needed for your assessment can be as easy as downloading available census data or GIS files from publicly available websites. However, it can also be complicated, particularly when you need a lot of data for conducting an expert workshop or for processing large datasets, such as climate data. Data acquisition depends on the following closely related key questions:

- What kind of data do you need for the risk analysis?

- Does the data already exist?
- If it is not available, what can you commit in terms of time and other resources to generate this data?

*See chapter **E 2.1.1.** in the Expert Material for guidance on different types of data (measured data, data from surveys, data from models, information from expert consultations), how to prepare data collection, an overview of providers of freely available global datasets and how to plan resources for generating data.*

Data and information quality check

Data and information are vital to any CRA and the quality of the results depends to a great extent on the quality of the data (summarised in the saying: 'garbage in, garbage out'). Once you have gathered your data you will need to conduct a quality check. Ideally, you keep the quality criteria below in mind while collecting data. In practice, however, you may first gather the data and then choose the most appropriate data set.

*For that purpose, use the questions in the Expert Material chapter **E 2.1.1.** under 'Data & Information'*

Data and information management

Once data and information are collected and checked for quality, they should be stored in a common database to avoid the risk of redundancy and data loss. Documents (e.g. reports, scientific papers) could be stored in a reference management software. Data (spatial data, point data) and processed data (e.g. maps) should be managed in a consistent way including proper metadata management.

*Find more information on data management, processing of data and map production in the Expert Material chapter **E 2.1.1.** under 'data and information management'.*

Climate data and climate scenarios

Information on past trends and future climate projections are core pieces of the needed information for any CRA. The data gathering differs depending on the spatial extent of the area under review, the resources available, the methodology applied and the data available. For a local-scale (small area) assessment the available information on past observations and future projections may not be fully representative (e.g. if the data available is too crude and/or of poor quality), and thus the information gathering should consist of expert and stakeholder consultations. In stakeholder consultations, you should present climate change trends for the larger area. You can use this information to add to the existing or generated quantitative data with the climate change perceived by local stakeholders. Stakeholder workshops and expert consultations help you to gather information on the occurrence of extreme events which are not covered by the measured and modelled data set.

As a first step screen the information available in relevant national reports, IPCC data portals such as the ***https://interactive-atlas.ipcc.ch/*** or ***https://climateinformation.org/*** *see **Table 29** in the Expert Material,* contact partner/academic institutions in the country or your region and enquire about climate data availability. Enquire at the national level with meteorological and hydrological departments (Hydromet) about past climate data and which future projections are available.

*See the **Expert Material** on how to use all the information you gather through a literature review, data analysis, model outputs and expert consultations as a foundation for risk identification and screening (see also **Risk Identification**). For more guidance on datasets for future climate projections see chapter **E 2.1.2.** section 'Review existing climate information', 'Collection and processing of future climate projections' and 'Climate indices and extremes'.*

Data and scenarios on impact, exposure, vulnerability and external drivers

Note that data and information on impact, exposure, vulnerability and external drivers for the past and future are just as important to gather and analyse as climate data (see also chapter ***1.7.***). In fact, vulnerability is usually the risk component that contributes most to intermediate impacts and risks.

→ *Find detailed step-by-step instructions on how to develop narrative scenarios in a participatory manner in the Expert Material chapter* ***E 2.1.3.***

Step 3 - Summarise information on climatic and non-climatic risk drivers

The data and information collected for the CRA will be mainly used in the 'Risk Analysis' module. However, we recommend writing a dedicated chapter on 'climatic and non-climatic risk drivers' for your risk report in which you set the scene for the following risk identification, analysis and evaluation.

- **General overview:** provide a general geographic description of your region and the subregions that are considered in the risk assessment (e.g. the tropical south, the dry central plains, the cold and wet north). Make use of the baseline data (e.g. land-use, elevation) you collected. Include physical characteristics (e.g. terrain, vegetation) as well as socio-economic aspects (e.g. population, infrastructure).
- **Climate and climate change:** Describe the current climate of your region including maps and graphs. Report current observed slow-onset processes (e.g. temperature increase, desertification), and climate extremes (e.g. heat, heavy rain). Present the results of the climate change scenarios that you collected or processed. What is known about climate change impacts for your region for the near-term, mid-term and long-term future? When possible, cite reports and literature as references.
- **Non-climatic risk drivers:** Report on current trends in exposure and vulnerability that are potentially aggravating climate risk such as poverty, population increase, land degradation or conflicts. Report about potential trends of these risk drivers in the near-term future (BAU scenario). Optional: develop an 'Aspiration' scenario for the near-term future that describes a climate-resilient development pathway.

Optional Step - Quantitative assessment based on composite indicators

For an in-depth and data-driven assessment with a focus on a larger number of sub-units or a spatially explicit analysis an assessment with composite indicators is possible (see Fritzsche et al., 2015). Find more advice on when this approach is suitable in the module ***'Risk Analysis'***. Be aware that quantitative CRAs have a high demand on data availability. In case of data scarcity, the qualitative approaches that are described above might be more appropriate. An intermediate approach would be to mix quantitative and qualitative approaches.

→ *In the Expert Material you find a dedicated chapter* ***E 2.2.*** *on how to assess risks with composite indicators and includes guidance on how to normalise and aggregate data to composite indicators.*

Risk Identification

Risk Identification aims to identify relevant risks starting from existing knowledge, (local) expert input and stakeholder input (using participatory methods). In addition, the affected sectors and geographic regions for in-depth analysis are selected, an initial list of suitable data sources is developed, and potential future changes are identified.

Key steps that you need to address in this module:

- Step 1: Current and future climate impacts and risks
- Step 2: Decision on relevant risks for an in-depth analysis
- Step 3: Writing and sharing the risk screening report
- Optional step: Prepare preliminary impact chains for risks within and across systems/sectors, including major CCA gaps (options) (including participatory approaches)

TIP

The risk identification module is one step in a regular CRA. It might also be used to do a quick risk screening for smaller projects or as part of the scoping of a more complex risk assessment.

What do you need to implement this module?

- You should have a good understanding of the significant climate impacts in your region, both now and in the future.
- You should understand which systems and sub-systems in your region are affected.
- You should know about the current CRM practises in your region.

OUTCOMES OF THIS MODULE

A risk screening report with all relevant risks (key risks) pertinent for your context that will be treated in a more in-depth risk analysis.

Which (additional) tools and information does the **Climate Risk Sourcebook Website** provide?

https://www.adaptationcommunity.net/climate-risk-assessment-management/climate-risk-sourcebook/

- Catalogue of standard hazards (IPCC, UNDRR)
- Catalogue of key risks (from IPCC)
- Catalogue of exposed systems
- Catalogue of vulnerability factors

Table 9: Example of how hazards, impacts and risks could be described for each subsystem in a tabular way

Results could be gathered during a workshop and further refined and validated by the CRA team and external experts.

Studies on disaster risks — Event databases Data on losses and damages — Studies on climate impact and risks — Expert and stakeholder input (workshops, interviews, questionnaires)

(1) Exposed systems, subsystem, elements, functions	(2) Natural hazards (current climate change relation, trends?)	(3) Impacts (direct impact -> indirect impacts)	(4) Where? Spatial hotspot (map)?	(5) Which future trends in hazards and impacts are expected? When?	(6) How efficient is the current CRM? Are adaptation options in place or planned?	(7) Data availability (hazard, impacts): current and future, confidence	(8) Risk to who/ exposed system] related/ due to hazard/ impact]	(9) Current / future: relevance for the region (low, moderate, high, very high)
Agriculture / food security	Heavy rainfall events (increasing intensity and frequency)	Erosion -> yield losses -> loss of income for farmers. Current consequences are moderate.	Steep slopes at medium altitudes (600 – 1400 m).	Not clear – consequences may get high (critical).	Local protection (fences) for grazing on steep slopes.	Heavy rain: HydroMet Impacts: agriculture surveys (incomplete). High confidence Future: none	Risk to the agricultural sector due to extreme precipitation events.	Moderate / High
	Heat and drought (increasing intensity and frequency)	No water for irrigation -> yield losses -> loss of income for farmers -> famine. Currently already high consequences.	Southern part of district (lowlands)	Increasing intensity and frequency of events with increasing impacts on agriculture. Extension to full region. Consequences might get very high (catastrophic).	A few small reservoirs	Drought and heat: HydroMet service Impacts: agriculture surveys (incomplete) – high confidence. Future: National climate change report – medium confidence.	Risk to the agricultural sector due to heat and drought impacts.	High / Very high
Roads, transportation	Heavy rainfall events (increasing intensity and frequency)	Roads flooded -> fatalities, road infrastructure damaged, region inaccessible.	Roads close to rivers, river crossings.	Not clear Consequences might get high.	Hazard information panels. No early warning system.	Heavy rain: HydroMet Impact on roads: Civil protection – medium confidence Future: none	Risk to transportation and road users due to heavy rain events and flooding.	Moderate / High

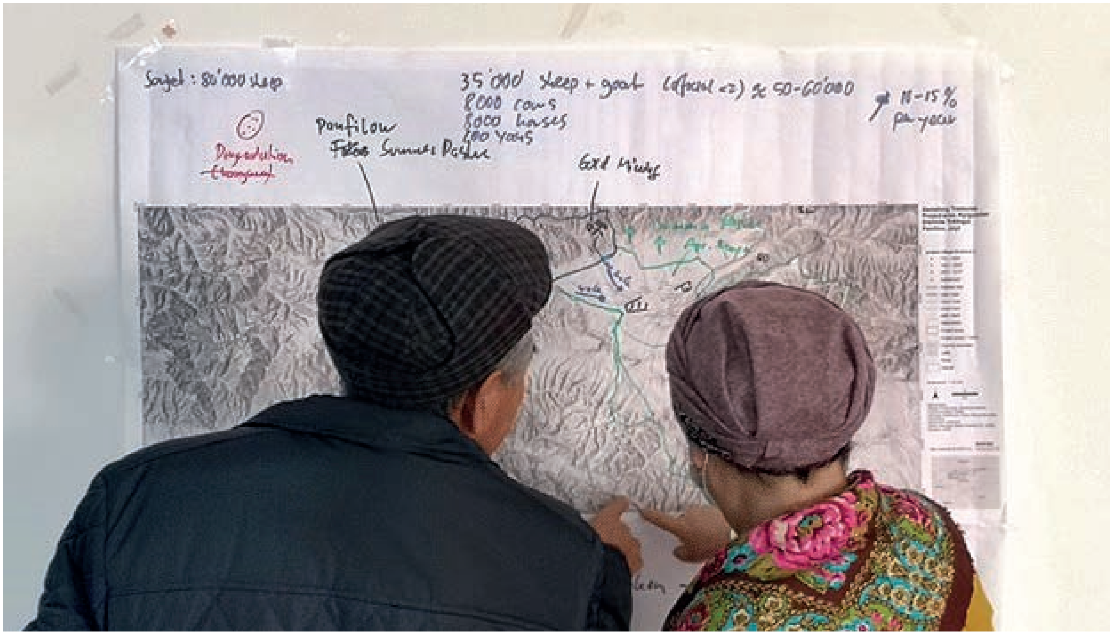
Risk identification can be seen as a filter process that starts with creating a 'long list' of impacts and risks that are potentially affecting your region. From this 'long list', a 'short list' of prioritised risks is compiled based on their relevance for your region. The 'short list' contains your key risks for the assessment. It is important at this phase to already base the identification as much as possible on evidence about climate hazards and impacts.

The following steps can help you to identify current and future impacts and can be initially raised during a workshop with the stakeholders identified in the scoping phase. Table 9 can be used as a template to report the answers of the risk identification phase.

Besides the table, maps help the participants to discuss the spatial aspect of risks and point to local hotspots (Figure 19). The workshop findings should later be analysed and confirmed by experts, taking into account existing data and evidence, and be reported in a short risk identification report.

Figure 19 : Example reporting about the status and activity within a municipality on a map during a workshop – livestock, villages and water infrastructure

(Picture: M. Zebisch)



Step 1 – Gather your data and information, data quality check and data management

Which climate-related hazards, impacts and risks are relevant for your context?

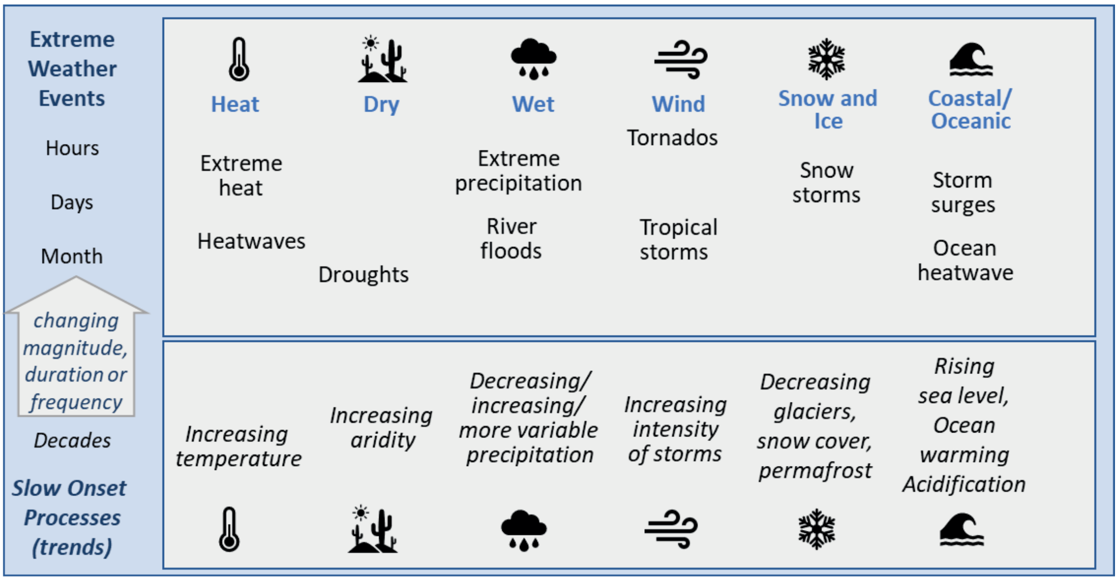
- Which climate-related hazards, impacts and risks could potentially harm the selected systems, subsystems, or functions? Focus on impacts that potentially lead to adverse and severe consequences.
    - » What is the current situation? --> based on observation, expert knowledge, and local knowledge.
    - » What are potential future situations until the middle of the century? --> based on available information collected during the scoping phase.
    - » Cluster impacts and risks by subsystem (identified in *'Scoping'*).

- Where is the hazard occurring? Are there spatial hotspots?
- Which data or knowledge do you have on these hazards, impacts and risks?
- Where were past and current CRM and adaptation plans targeted? For what climate risks?

In order to assess each risk comprehensively, it is recommended that the CRA team organizes an initial stakeholder workshop involving experts and relevant stakeholders. It is crucial to consider groups that have been differentially affected by past impacts when selecting the stakeholders to be included.

To have an overview of relevant hazards you can take inspiration from Figure 20. To pinpoint future hazards and impacts, it is recommended to start identifying existing hazards and impacts that can be used as a baseline. Do not forget to also consider new hazards and impacts that have not yet occurred in your region. It might be helpful to additionally take into account hazards and impacts that occur in neighbouring regions (or have been identified in CRAs of neighbouring regions). For the future, also consider narratives of plausible extreme scenarios that could happen but are not well covered in standard climate scenarios (e.g. high-intensity rain events, subsequent droughts over several years, compound events such as heavy rain after a drought). To discuss impacts and risks you might also consult the list of key risks as well as standard impact chains on the ***CR-SB website*** and check the ones that might be relevant for your region.

Figure 20 : Climate-related hazards



Step 2 - Decision on relevant risks for an in-depth analysis

Once the 'long list' of risks is compiled, the relevance of each risk has to be assessed by the CRA team together with the expert and stakeholder group. This could be done during the first stakeholder workshop in a 'voting session', for instance with 'sticky dots' on a board.

What is the relevance of every single risk?

A relevant risk ('key risk') is a risk that has the potential to lead to severe consequences for your region (or your project, your value chain, etc.). We propose the following criteria, inspired by the IPCC AR6 criteria for assessing key risks:

- The magnitude of the hazards and the (potential) consequences (if you have knowledge of this) including aspects such as the degree of consequences, the size or extent of consequences, the pervasiveness of consequences across the system (geographically or in terms of affected population), the irreversibility of consequences, the potential for impact thresholds or local tipping points, and the potential for cascading effects beyond system borders.
- The likelihood of severe consequences.
- The possibilities and limits for risk reduction (CRM and CCA).
- The importance of the system.
- The timing of the risk (e.g. quickly emerging or unfolding slowly).

These risk criteria will be used throughout the CR-SB for assessing risks.

→ *Find more information on the risk criteria of the IPCC in chapter **E 1.2.1.** in the Expert Material.*

Depending on the level of knowledge on impacts and risks and your specific context, you can decide to assess some of the criteria explicitly, or to directly assess the relevance of each risk (implicitly considering these criteria). We propose excluding 'negligible' risks from analysis in the next module 'Risk Analysis' phase and classifying the relevance into four classes, separated for the current situation and a potential future situation (until mid-century). The criteria and the classes of Table 10 will be used in similar form through the risk assessment process.

Table 10 : Classes for assessing the relevance of risk

Class	Criteria
4 very high	Frequent, very likely and major damages and losses within important systems. Loss of system functionality, irreversibility of consequences, large extent, very high pervasiveness, high potential for impact thresholds or tipping points, cascading effects beyond system boundaries, systemic risk. Low ability to respond or adapt to the risk.
3 high	Likely significant damages and losses, disturbance of system functionality, long-term effects, large extent and high pervasiveness, potential for impact thresholds or tipping points, cascading effects beyond system boundaries and systemic risk. Moderate ability to respond or adapt.
2 moderate	Likely moderate losses and damages, moderate disturbance of system functionality, effects are temporary or unfolding slowly with a moderate extend / pervasiveness. Moderate to high ability to respond or adapt.
1 low	none to low losses and damages. No or rare disturbance of functionality, high ability to respond or adapt.

What is the data, information and knowledge availability and demand for relevant risks?

In this phase you should already make a record of the availability and demand for data, information and knowledge for each relevant risk in order to start collecting information as early as possible (see also module ***'Data & Information'***).

Step 3 - Write and share the risk screening report

The risk screening report should document the process of the risk identification result, the table with impacts and risk as well as the selection of relevance and additional information on relevant risk in text form.

Engage with the relevant stakeholders and provide a summary of the methods and key findings to the wider user audience. Share the risk screening report with your stakeholders or let it even be reviewed by external experts that did not participate in the risk screening phase. This may help to validate and sharpen your findings. A particular focus could be on the question of whether complex risks that cascade through the system and the potential for new emerging risks have been addressed sufficiently.

> **TIP**
>
> During the risk identification phase, it is possible to gather information from stakeholders and conduct desktop research simultaneously. However, it is important to note that onsite workshops and field visits should remain the primary sources of local knowledge.

Optional Step - Prepare preliminary impact chains for risks within and across systems/sectors, including major CCA gaps (options) (including participatory approaches)

This step could be part of 'Risk Identification' for a more extensive CRA or if you are working on more complex, cascading impacts. Impact chains can be developed for a reduced selection of hazards, impacts and risks (e.g. the ones with medium or high relevance). See chapter ***1.6.*** on how to build impact chains.

Risk Analysis

Risk Analysis is about analysing the risk components (hazard, exposure, vulnerability), understanding their interrelation and the resulting direct and cascading impacts. Impact chains are the central tool for the risk analysis. A focus of the risk analysis phase should be to understand the drivers of risks (including external risk drivers), identify hotspot regions, critical constellations and a set of key risks. The risk analysis phase also addresses adaptation gaps and missing capacities. Risk analysis includes an assessment of the magnitude of consequences of risk (current, future) and a selection of key risks.

Uncertainties must always be addressed (including a final confidence assessment). The approach and the effort of the risk analysis phase strongly depends on the scope of the climate risk assessment. It can extend from a mainly descriptive analysis based on existing knowledge and expert and stakeholder elicitation to a more in-depth risk analysis that is (as far as possible) driven by data and evidence. For spatially explicit assessments a composite indicator approach is recommended. In any case, the risk analysis will synthesise heterogenous information sources on risk drivers and draw conclusions on the potential for adverse consequences.

Key steps you need to address in this module:

- **Step 1: Develop impact chains for relevant risks within each subsystem**
- **Step 2: Consider interlinkages between subsystems**
- **Step 3: Reflect on gaps and potential entry points for CCA options in the impact chains**
- **Step 4: Collect data and indicators for components and factors of impact chains**
- **Step 5: Describe and analyse impacts and risks along the impact chains – risk report**
- **Step 6: Aggregate assessment of risk drivers and potential for severe consequences**
- **Step 7: Compile a risk analysis report**

What do you need to implement this module?

- Good understanding of climate-related hazards and their impacts
- Good understanding of other external risk drivers and their effects on vulnerability and climate-related risks, including an understanding of current trends and potential evolutions of external risk drivers

- Access to external expertise for support and validation
- Good knowledge of the region and good cooperation with local stakeholders and experts
- Good understanding of vulnerable groups

OUTCOMES OF THIS MODULE

A risk analysis report with an assessment for relevant risks including vulnerabilities, adaptation gaps and missing capacities, hotspots, and assessment of their magnitude at the current as well as potential future situation.

Which (additional) tools and information does the Climate Risk Sourcebook **website** provide?

https://www.adaptationcommunity.net/climate-risk-assessment-management /climate-risk-sourcebook

- Catalogue with standard hazards (IPCC, UNDRR)
- Catalogue with key risks (from IPCC)
- Catalogue with exposed systems
- Catalogue for vulnerability factors
- Impact chains for key risks
- Data, knowledge and information sources

Risk per system or compound risks across systems and sectors

In this module, you should include all risks that have been classified with at least 'moderate' relevance for your context in the risk identification phase.

Risk analysis can be performed:

- a) separately for single systems (e.g. agriculture, energy, health) and/or
- b) along compound risks across systems and sectors (e.g. risks related to enduring drought and heat-waves).

In any case, most risks have linkages across systems. Therefore, you should still consider linkages and design your assessment in a way that includes systems with direct impacts (e.g. water) to be able to address indirect impacts on other systems (e.g. missing water for irrigation in system 'agriculture'). See also ***Step 3 - Define the system ...*** in 'Scoping' on how to structure your risk assessment into systems and subsystems. Remember to focus on the impacts and risks that can lead to serious consequences for your system (key risks).

Typical set-up of the risk analysis phase

The 'Risk Analysis' module is typically the phase to which you will have to dedicate the most effort. We recommend using a good mix of participative activities (workshops) and desktop phases complemented by consultations with external domain experts for single systems (e.g. agriculture, water management). If you have several systems, it might even be a good idea to create teams for each of the systems.

A possible workflow could be:

- 1st workshop (Step 1-3): Based on the 'Risk Identification' and the first collection of data, information and knowledge
  - » Present the current state of knowledge on climate change and climate impacts for each system in your region.
  - » Develop impact chains for each system (and optional impact chains for compound risks) together with stakeholders and experts. You may want to have separate sessions or break-out groups for each system.
  - » Address gaps and potential entry points for CCA options in the impact chains.
- Desktop phase (Steps 4 and 5):
  - » Review, clean and improve impact chains with your team. You might also want to consult external experts for validation.
  - » Collect data and indicators for components and factors of impact chains.
  - » Describe and analyse impacts and risks along the impact chains. Depending on the scope of your CRA, this might even include data processing, modelling, or the calculation of composite indicators.
  - » Assess the current level of CCA and identify CCA gaps.
  - » Develop a first order draft of a risk report and share it with stakeholders and external experts.
- 2nd workshop on presenting results of the 'Risk Analysis':
  - » Present the results of the 'Risk Analysis' to stakeholders and experts and ask for feedback.
- For more complex assessments you could organise a dedicated review process after the workshop.
- Aggregate the assessment of risk drivers and potential for severe consequences (Step 6). In a final step summarise and classify the potential for adverse consequences for each key risk. Depending on the scope of the CRA, this could be part of the 2nd workshop, or you can organise a 3rd workshop with experts and stakeholders which focuses only on a structured risk assessment and 'Risk Evaluation'.

Step 1 – Develop impact chains for relevant risks within each system

Impact chains are tailor-made conceptual models of risks and its drivers and are the backbone of the 'Risk Analysis' within the CR-SB. The 'Risk Analysis'- be it qualitative, hybrid or quantitative - is conducted following the logic of these impact chains (Figure 21).

The development of impact chains is best initiated by co-developing preliminary impact chains with stakeholders and experts in a workshop back-to-back with, or as part of, a risk-identification workshop. Remember to consider entrenched inequalities and the influence of external drivers on the vulnerability of different stakeholders or social groups when organising workshops and developing impact chains.

You will find example impact chains for various systems on the ***Climate Risk website https://www.adaptationcommunity.net/climate-risk-assessment-management/climate-risk-sourcebook***

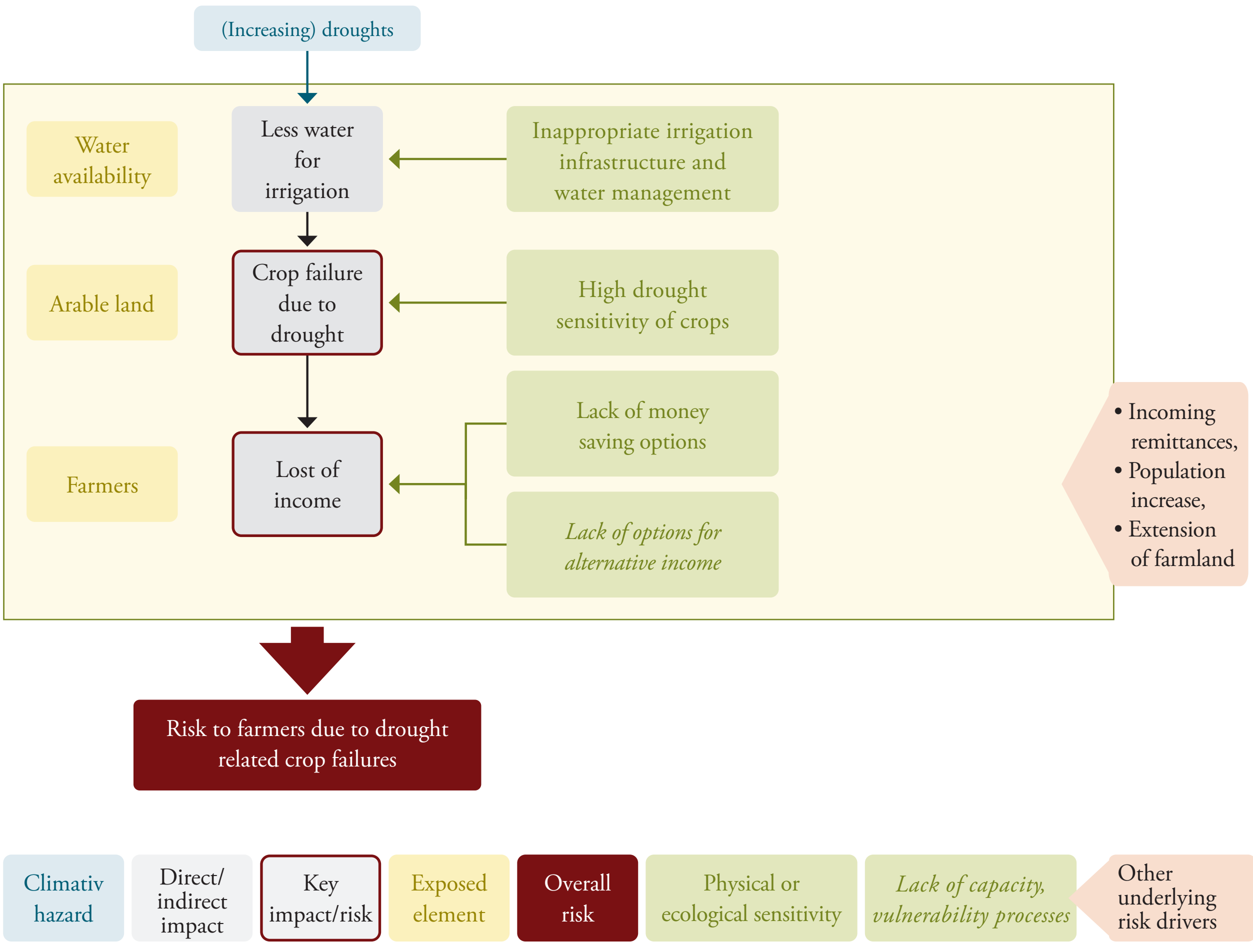
Impact chains should be based on the knowledge gathered during the risk identification phase.
After this co-development, impact chains should be refined, improved and cleaned by the CRA team. Further consultations with experts and stakeholders could also help to improve the impact chains. The final impact chains should focus on key risks for subsystems that have the potential to lead to severe consequences (see also ***'Risk Identification'***).

Identify the drivers and root causes of vulnerability as well as climate-risks for the system and the subsystem and reflect on gaps and entry points for CCA options.

*You will find more detailed information on impact chains in the conceptual framework chapter **1.6.** 'Impact chains' and in the Expert Material chapter **E 1.5.** 'Impact Chains'*

Figure 21 : Impact chain for the system 'agriculture' with risks to farmers due to drought related crop failures

(own illustration)



Key questions when developing impact chains are:

- Which direct impacts are relevant for your subsystem?
- Who or what is affected (what are the exposed elements)?
- Which climate-related hazards are triggering these impacts? Consider climate-related events (such as droughts) as well as slow-onset processes (such as decreasing precipitation or sea-level rise). Address the climate change effect (e.g. increasing intensity and duration of droughts).
- Which other, more indirect impacts are triggered by the direct impact? Who or what is affected (exposed elements)? How do impacts cascade through the system?

- Which factors make exposed elements vulnerable to direct or indirect impacts? Vulnerability factors could be high physical or ecological sensitivity or susceptibility towards a hazard, high socio-economic vulnerability, or the lack of capacity to prevent, cope, respond or adapt to a hazard. The lack of capacity could include:
  - » Lack of (specific) knowledge
  - » Lack of (specific) technology or a lack of access to technology
  - » Lack of financial resources
  - » Lack of (specific) institutional structures and resources
  - » Lack of (specific) legal frameworks, regulations or strategies.
- Which external risk drivers are contributing to risks (such as increasing poverty, economic crisis, demographic change, or conflicts)? External risk drivers might increase vulnerability (e.g. poverty increases vulnerability of people), exposure (e.g. increasing population in cities increases exposure) or directly increase impacts (e.g. increasing energy demand due to higher living standards)
- Where can you identify entry points for CRM and CCA options?

The easiest way to develop impact chains is to follow the order of the key questions above. However, you can start at any point of an impact chain. Impact chains should be developed for each subsystem that has been identified in the risk identification phase.

It is also important to note that impact- and risk-cascades often start with impacts on ecosystems and their services. For that reason, we recommend explicitly to include 'ecosystems and their services' as a system in any CRA. Understanding the role of ecosystems in risk cascades is a pre-requisite to recognise the high potential of Nature-based Solutions (NbS), and specifically Ecosystem-based Adaptation (EbA) in DRR and CCA.
For further information, the ***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 modular Vulnerability Sourcebook methodology (GIZ, EURAC & UNU-EHS, 2018).

What to consider when conceptualising complex risks with impact chains

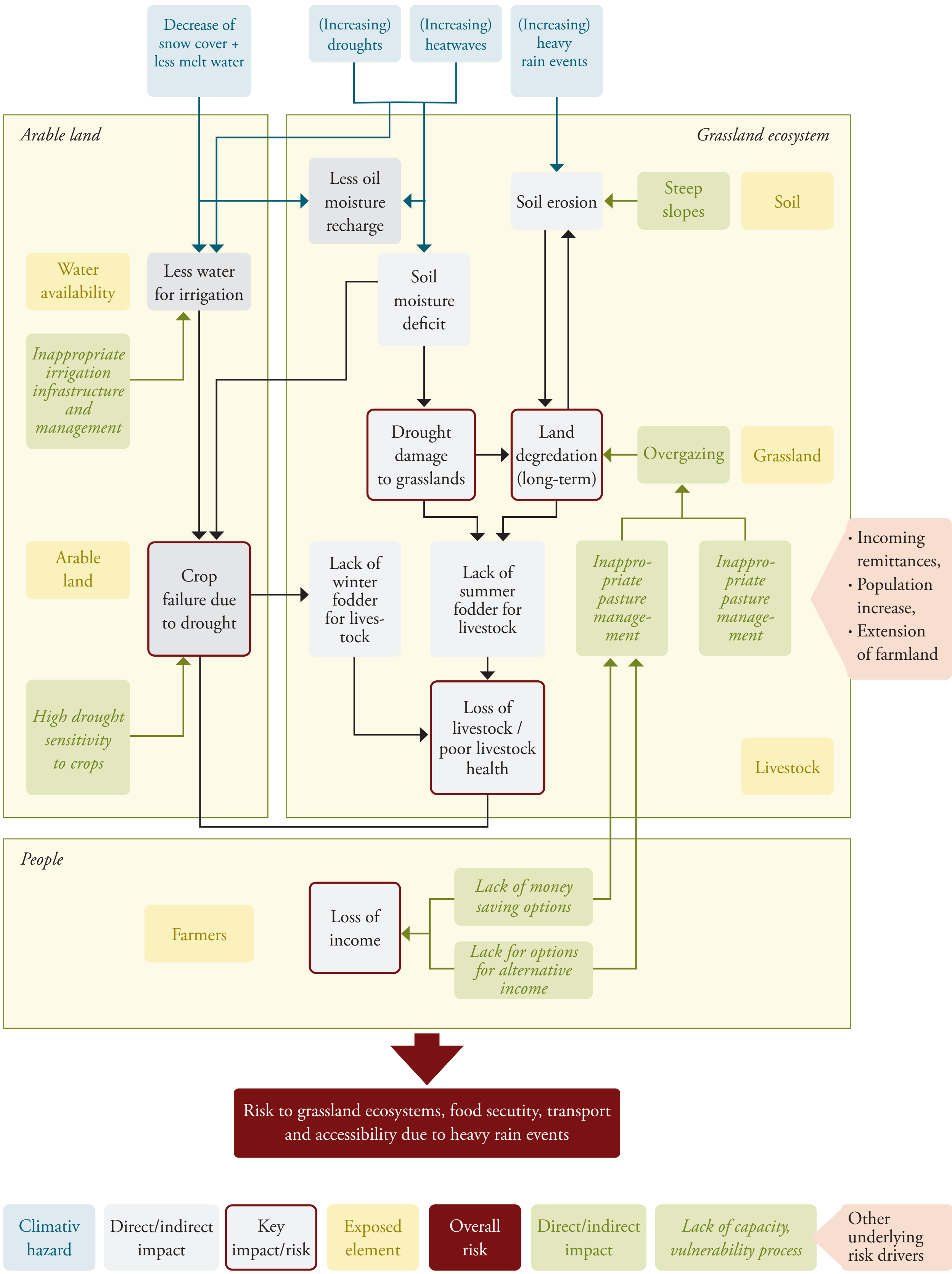
- The key question when formulating risk factors is 'what leads to the risk?' (see Figure 21). Starting from hazards (e.g. droughts) that drive impacts (e.g. crop failures, loss of income) on exposed elements (e.g. arable land, farmers) to the vulnerability of these elements (e.g. high drought sensitivity of crops, lack of options of alternative income). Elements should be formulated as precisely as possible (e.g. 'droughts' and not 'missing precipitation'). Vulnerability elements relating to a lack of capacity should be identified as a 'lack of...' (e.g. 'lack of knowledge of drought management').
- If specific social groups are more vulnerable than others, they should be treated as explicit exposed elements. If specific groups are exposed in very different ways, a specific impact chain for each group should be considered.

Step 2 – Consider interlinkages between systems

When developing impact chains, it is important to conceptualise cascades through the system. Often, climate-related hazards have direct impacts on the environment (e.g. the amount of water) that then indirectly affect human systems (e.g. agricultural sector). Conceptualising these cascades is important to allow the identification of risk reduction and CCA options that can interrupt these cascading effects. Such cascades through systems could be conceptualised, for instance, for specific (compound) hazards. See Figure 22 for an example of cascading impacts of enduring drought and heatwave on water security and agriculture.

Figure 22 : Example of a complex impact chain for three interconnected systems

Arable land, grassland ecosystem, people (own illustration)

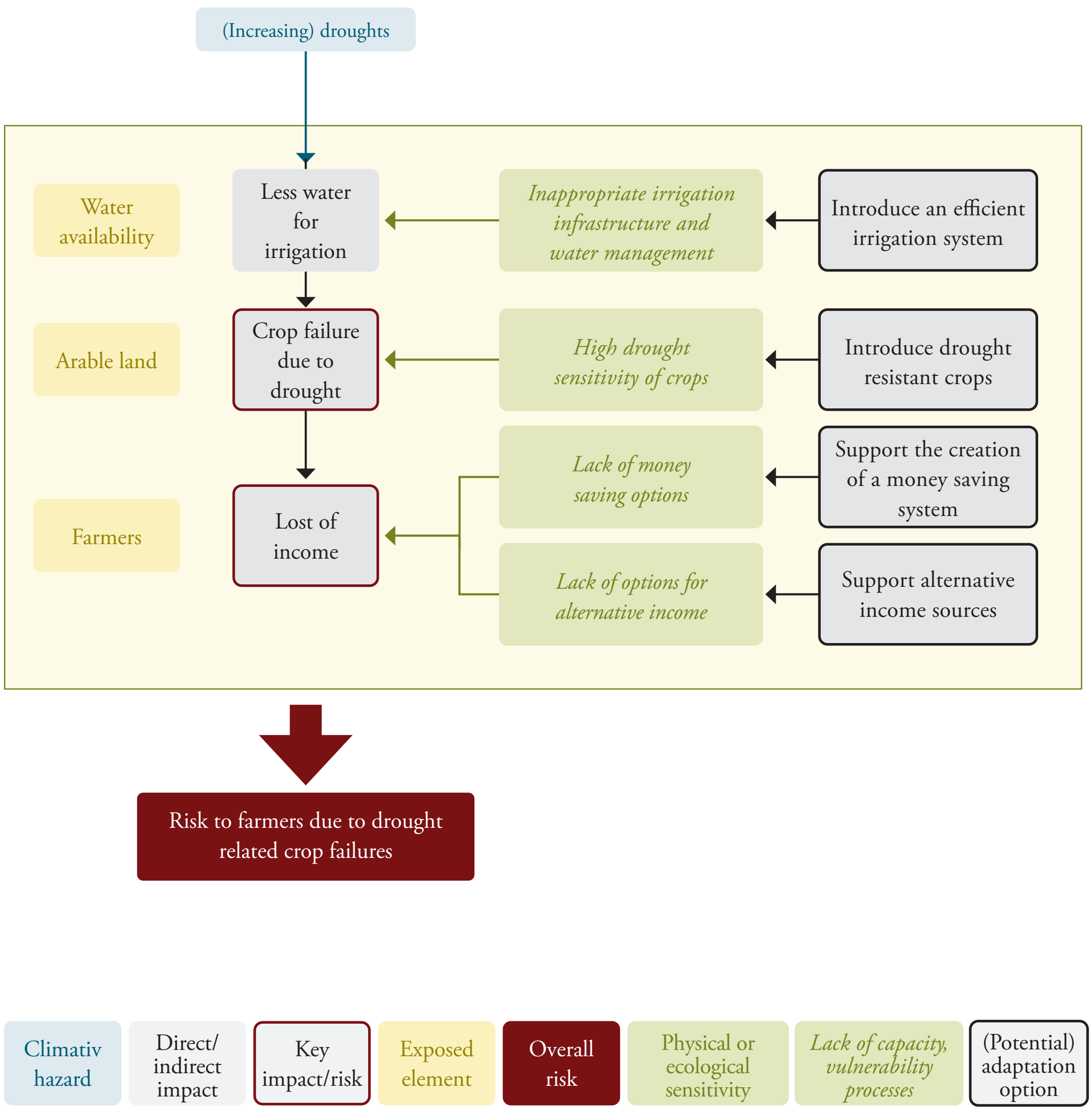


Step 3 - Reflect on gaps and entry points for potential CCA options in the impact chains

Impact chains provide an immediate impression about highly exposed elements, vulnerabilities, and the lack of capacities. Understanding these critical constellations is key to identifying appropriate CCA measures that can reduce vulnerability, exposure, hazards and impacts.

When co-developing impact chains in a workshop, you can already begin a discussion on CCA gaps and potential options that should be initiated. Typically, CCA responds to generic vulnerabilities (Figure 23): First ideas about potential CCA options but can be impact-specific or subsystem specific (see chapter ***1.1.3.***). Even exposure can be reduced by CCA, for instance, by re-locating people that are living in floodplains or along a coast to higher regions.

Figure 23 : First ideas about potential CCA options
Turquoise boxes (own illustration)



Once impact chains have been developed, a preliminary reflection with stakeholders on potential entry points for CCA options is useful. By 'entry points' we mean places in the impact chain where a targeted CCA option could 'break', 're-direct', or 'minimise' risk creation. For details, see module ***'Towards Adaptation'***. In this step it is useful to bring in the knowledge from the scoping on past and current CCA efforts, future CCA plans, as well as knowledge on what worked well and what did not in the past.

Options for 'Risk Analysis': risk screening, in-depth descriptive approach, and composite indicator approach

The next steps depend on the scope of your CRA (see ***Step 5 - Define the temporal and spatial scope*** in 'Scoping'). In all cases, the impact chains built in the previous steps are the backbone of the 'Risk Analysis'. The options introduced below are not exclusive but offer some different approaches that can be applied in conjunction in a real CRA.

Risk screening on sub-national to local scale

For a risk screening on sub-national to local scale, you will work with your team on describing the risks for the current and future situations along the impact chains based on the knowledge you have identified and collected during the scoping and risk identification phase.

You might still want to deepen certain aspects where knowledge is missing with expert consultations, targeted stakeholder workshops or field visits focused on specific aspects (e.g. water availability for irrigation). You should ultimately work with the best evidence available for all risk components, even for a risk screening.

Particularly for the local scale, participatory methods for collecting information and knowledge for the final assessment and the evaluation of risks are recommended to achieve a common understanding of risks. In addition, participatory methods provide a perception of ownership for the stakeholders, which is helpful in the process of CCA.

However, participatory methods may be biased due to a lack of knowledge and understanding of the complex effects of climate change or due to individual stakeholder perspectives regarding what is needed. Therefore, it is always recommended to let the impact chains and the risk description be validated by independent experts.

This is the typical setting for an in-depth risk assessment on national to local scale that focuses on understanding risks and identifying CCA options.

For a thorough understanding, you should collect the best evidence possible for all risk drivers and the mechanisms leading to risk. This will include methods such as literature review, data processing, impact modelling, stakeholder workshops and expert consultations and will naturally result in a heterogenous pool of knowledge. We recommend building teams for every system of concern (e.g. biodiversity, agriculture/food security, water, …), conducting workshops for each system and identifying independent experts that could review and validate the results.

The main methodology to aggregate and summarise the knowledge collected on impacts, risk drivers and risk is a descriptive approach. The description is organised along the impact chains. Identifying and understanding critical constellations that have the potential for severe consequences should be a focus in the description.

In a descriptive analysis, aspects such as vulnerable groups, CCA gaps or the importance of other underlying risk drivers and structural vulnerabilities should be considered.

For larger and more heterogeneous regions or for a national scale assessment, it is recommended to consider spatial sub-units. These would typically be ecozones with similar climates, ecosystems and land uses (e.g. the tropical south, the dry central plains, the cold and wet north) or watersheds, but could also be administrative units (e.g. districts), if they have relatively homogenous climatic and environmental conditions. Examples for further units that might be specifically addressed are cities, riparian zones or mountain areas.

Spatial data plays an important role for an in-depth risk assessment. Information should always be addressed as spatially explicit as possible and illustrated with maps, for instance on climate change, and exposed elements (e.g. ecosystems, infrastructure). Spatial hotspots should be highlighted. This could be locations with high- or multiple hazards, but also with high exposure or vulnerability or a constellation of all three. Where appropriate, working with indicators is recommended (e.g. for climate-related hazards). Single indicators could also be aggregated into composite indicators where appropriate.

*Find more information on data collection and processing including working with composite indicators in the Expert Material chapter **E 2.1.** 'Data & Information'*

In-depth risk assessment with a spatially-explicit composite indicator approach

This option is recommended if your focus is on a spatially explicit risk assessment with a focus on risk maps for the various risk drivers (hazards, exposure and vulnerability) that are aggregated to an overall risk map.

This approach is useful if you want to compare risk across regions or if you want to identify risk hotspots. It depends on the availability of high-quality spatially explicit data for all relevant aspects and expertise in spatial data processing and visualisation.

TIP

When data is not available, this approach requires working with proxy data (e.g. meteorological forest fire risks index) or converting qualitative information into semi-quantitative spatially explicit information (e.g. capacity of early warning systems classified for each sub-region in classes from 1 to 5).

Composite indicators are the primary methodology for aggregating information on single risk drivers. All available information, be it quantitative or qualitative, is converted into a normalised scheme (e.g. from 0 to 1) or classified into a standardised classification scheme (e.g. from 1=low to 5=high) and aggregated with methodologies (e.g. weighted arithmetic mean).

This approach was recommended in the first Vulnerability Sourcebook and its Risk Supplement (Fritzsche et al., 2015; Zebisch et al., 2017). It is still a valid approach for a spatial risk assessment. It is more suited for the spatial comparison of certain aspects of risks, but less suited to generate a deeper understanding of risk drivers and identifying CCA options. However, working with composite indicators should not exclude a more descriptive in-depth assessment and can be combined when appropriate.

*Find an own module on how to work with the composite indicator approach in the Expert Material chapter **E 2.2.** 'Optional – Quantitative assessment based on composite indicators'*

Step 4 - Collect data and indicators for components and factors of impact chains

In this step you will identify the potential data and knowledge sources for each risk component.

This step is mainly required for an in-depth risk assessment. Indicators need to be defined for a risk assessment that uses composite indicators, or for selected key impacts in a more qualitative, expert-based assessment. However, since a risk screening should always be based on evidence and may even lead to a more in-depth assessment, it makes sense to create an overview of factors and potential data and knowledge sources and to identify gaps in knowledge. These gaps may be filled by gathering the missing knowledge, for instance by conducting structured interviews with experts and stakeholders or conducting household surveys.

Table 11 : Example for indicators and potential data sources for factors of an impact chain (example)

Component	Element	Potential data and knowledge source	Indicator (for key figures and for a composite indicator approach)
Hazard			
Hazard	Enduring Drought	Weather stations, ERA5 data, IPCC climate scenarios	Standard Precipitation Index
	Heatwave		Number of days with T-max > 35°C
Subsystem Crops			
Exposure	Crops	National or district statistics, stakeholder knowledge	Crop type, % area covered by crop types
Vulnerability	Drought sensitivity of crops	Expert + stakeholder knowledge	Semi-quantitative assessment per crop type (high, medium, low)
	Lack of irrigation system	Expert + stakeholder knowledge, surveys	% of arable areas under efficient irrigation
Impact	Drought damage to crops	Agricultural statistics, expert + stakeholder knowledge	% of yield losses due to droughts
Subsystem Farmers			
Exposure	Farmers	Agricultural statistics, expert + stakeholder knowledge	Number of farmers, % of the population depending on farming
Vulnerability	Lack of drought insurance	Expert + stakeholder knowledge	Availability of drought insurance, % of farmers with drought insurance
	Lack of alternative income sources	Regional statistics, expert + stakeholder knowledge	% of farmers´ income from non-farming activities
Impact	Loss of income for farmers	Economic statistics, expert + stakeholder knowledge	% of loss of income of farmers

Step 5 - Describe and analyse impacts and risks along the impact chains – risk report

Once the impact chains are developed, impacts and risks for each system should be described in more detail based on the knowledge you gathered during risk identification, the impact chain development (Step 1) and the data collection (Step 4). This could be done in the form of short reports or factsheets or even in dedicated sub-reports with in-depth information (depending on your available resources). These reports will become part of the risk analysis report. More in-depth and data-driven risk analyses will be time intensive and will take several months or even more than a year. For risk analyses that are data-driven, consider the use of composite indicators → *see chapter **E 2.2.** in the Expert Material*

Base your description as much as possible on evidence and reference this evidence (e.g. IPCC reports, national reports, scientific papers). For a report, where possible and appropriate, provide data in tables or figures as well as maps collected in Step 4. Reports and photographs from field visits with examples of current climate impacts are also helpful. The focus of the risk report should always be on the hazards (extreme events as well as slow-onset processes), impacts and risks that could lead to severe consequences (key risks). Do not try to cover all potential impacts you discussed during the development of impact chains. Provide a summary of the key findings to the wider user audience and communicate the methods applied.

Risk report per system

The report or factsheets could be structured for each system as follows (example for system 'ecosystems'):

1. Ecosystems and climate impacts

- General description of how extreme weather events and slow-onset processes affect the system.
- Figure of the impact chain and description of risk drivers.

2. Past and current situation

- Tell the 'story' of past and current impacts along the impact chains.
- Subsystems or relevant impacts could be a useful substructure.
- Describe past and current impacts (adverse consequences) and their magnitude (with as much evidence as possible) and explain how the risk driver hazard, exposure and vulnerability as well as other underlying risk drivers contributed to these impacts.
- Which constellations were particularly critical and led to severe adverse consequences? Why? Where? Are there spatial hotspots?
- Consider differential vulnerability (existing inequalities, particularly vulnerable groups).
- What is the current status of risk management and CCA concerning this specific system?
- To what extent did gaps in risk management and CCA contribute to the adverse consequences?

3. Future situation: potential for severe consequences

- What is the potential future dynamic of risk drivers (hazard, exposure, vulnerability, other underlying risk drivers) that have the potential to lead to severe consequences? What evidence do you have on this? Be explicit for selected time horizons (near-term, mid-term, long-term) and the specific scenarios for climatic and non-climatic drivers (see ***'Scoping'***).

- Follow the structure of cascading impacts through exposed subsystems along the impact chain.
- How could already occurring risks aggravate and/or extend in time and space?
- Which new severe consequences could emerge because of new dynamics in risk drivers, including unexpected impacts and risks (=‘black-swan’ or ‘wildcard’ event)?
- Which constellations might become particularly critical and might lead to severe adverse consequences? Why? Where? Are there spatial hotspots?
- What is the potential and what are the limitations for CCA for the future situation? To which extent could CCA reduce risks for the specific systems? To what extent could CCA reduce risks for the specific systems? Under which constellations does adaptation reach its limits?

4. Confidence and uncertainty

- Report on sources of uncertainty and confidence in your risk description. The assessment of uncertainty will qualitatively address the sources of uncertainty such as missing data, a lack of process understanding, a lack of understanding of cascading effects, a lack of understanding of the external risks, uncertainty in future developments of risk drivers, and uncertainty of experts in assessing the consequences of impacts.
- The IPCC´s concept of confidence as a function of agreement and number of evidence may be used.

Repeat this process for every system identified for your CRA and report the links between systems. If you have divided your region into subregions (e.g. mountains and lowlands), risks should be reported separately for each subregion.

In your argumentation, when possible, use the criteria for key risks that were used in the risk identification phase qualitatively. These criteria will also be used for the aggregated assessment in the next step. You may also use standardised terms to describe the magnitude and respective likelihoods of hazards and impacts.

Risk report – cascading impacts and risks across subsystems

Report on cascading impacts and risks across subsystems in a separate chapter. You might have developed a few impact chains across subsystems that you may want to further explain in this chapter. Which of these risks across subsystems have the potential for severe or even systemic consequences? These risks should be described as 'key compound risks' with impact chains and follow the same logic and structure as the one for key risks within single subsystems.

Step 6 – Aggregate assessment of risk drivers and potential for severe consequences

The purpose of the aggregated assessment is to summarise, assess and classify the magnitude of the risk drivers and the potential for severe consequences in a structured and standardised way. This process informs and supports the ***'Risk Evaluation'*** in a transparent way. The results will be added to the risk analysis report.

There are two ways of conducting this process:

1. As a purely expert-based assessment approach, ideally with a panel of experts and stakeholders. This approach could be combined with the risk evaluation phase ('Risk Evaluation').
2. As a composite-indicator based approach (for assessments that require the comparison of a larger number of spatial sub-units or in data-rich situations).

The composite-indicator approach is covered in the → *Expert Material chapter **E 2.2.*** Here we focus on the expert-based approach, which is suitable for most cases, including assessments with fewer resources. We propose working with an expert and stakeholder panel in a dedicated risk assessment workshop on the aggregated risk assessment or through a risk assessment survey. All participating experts and stakeholders should have read the risk report from Step 6 before conducting the aggregated assessment.

The granularity of the risk assessment depends on the available knowledge and resources. The maximum range of criteria that could be assessed for each key risk within each subsystem and for each key compound risk across subsystems are the following (according to IPCC AR6):

- Magnitude of the risk drivers: hazard, exposure, vulnerability, other underlying risk drivers
- Magnitude of the (potential) consequences, taking into account:
  - » the degree of consequences,
  - » the size or extent of the consequences,
  - » the pervasiveness of the consequences across the system (geographically or in terms of affected population),
  - » the irreversibility of consequences,
  - » the potential for impact thresholds or local tipping points,
  - » the potential for cascading effects beyond system borders.
- The likelihood of (severe) consequences

Risk should be assessed and evaluated by the experts for all time periods that have been identified within the scoping phase (e.g. current, near-term, mid-term) and be explicit for different scenarios on non-climatic drivers (e.g. 'BAU' vs. 'Aspiration') and for different emissions scenarios/warming levels for the future period. Furthermore, you could assess spatial sub-units (e.g. ecozones, districts) separately. We propose limiting the number of factors to a pragmatic level and applying a simplified summary table as shown in Table 12.

Table 12 : Example of a summary table of an aggregated assessment for single risks

This assessment should be conducted for each key risk within each subsystem as well as for key compound risks across subsystems.

Risk Drivers	Key risk 1 – risk to farmers due to drought - lowlands		
	Current	Near-term (2021 - 2040) Intermediate emissions -> +1.5°C BAU = Business-as-usual Asp. = Aspiration	Mid-term 2041 – 2060 High emissions -> + 2.4 °C Moderate emissions -> +2°C
Hazards (magnitude and likelihood) that could lead to severe consequences	Moderate: critical droughts happen occasionally (in 2022) moderate droughts occurred frequently in the last 15 years. Combination with heatwaves critical	High: critical droughts could become frequent	Very high: potential for occasional catastrophic droughts (particularly under high emissions)
Exposure (or degree of exposure) that could lead to severe consequences	Moderate: increasing area of arable land (conversion from grassland)	High: if arable land extends further into drought-prone areas (BAU)	High: frequent critical droughts
		Moderate: if further conversion of grassland is halted (Asp.)	Moderate: if further conversion of grassland is halted (Asp.)
Vulnerability that could lead to severe consequences	High: vulnerability of arable land due to insufficient irrigation. High vulnerability of farmers due to poverty and lack of insurance	High (BAU)	Very high (BAU)
		Moderate: if new water-saving efficient irritation and a water storage system are introduced (Asp.)	Moderate: water is used efficiently (Asp.)
Other relevant underlying risk drivers that could contribute to severe consequences	Moderate: increasing water demand for irrigation, increasing economic crisis	High: with further increasing water demand (BAU)	Very high: if water demand increases further and economic situation deteriorates (BAU)
		Moderate: if a sustainable development path is chosen (water saving, economic stabilisation) (Asp.)	Moderate: if a sustainable development path is chosen (water saving, economic stabilisation) (Asp.)
Potential for severe consequences (magni-tude and likelihood of adverse consequences)	Moderate: only occasional critical consequences	High: critical consequences may become likely, particularly if exposure and vulnerability further increase (BAU)	Very high: under high warming levels and without massive CCA and transformation (BAU)
		Moderate: if exposure and vulnerability can be lowered through CCA (Asp.)	High: potential for severe consequences if exposure and vulnerability further increase even under moderate emissions (Asp.)

We propose conducting such an assessment in a tabular form for each key risk within each subsystem and for each subregion. For the color code and standard description for classes for magnitude see Table 13 and for frequency/likelihood see Table 14.
A pragmatic approach to fill this table is for the CRA-team to conduct this assessment first within the team and then present the results to the expert and stakeholder panel for revision and validation. More advanced methods such as the Delphi-method can be applied in complex assessments (e.g. on the national scale) if time and resources allow for such an approach.

The analysis of severe consequences and their likelihood is the key aspect of the assessment. It should be informed by the assessment of the risk drivers, hazard, exposure, vulnerability and other underlying risk drivers. No specific fixed aggregation rule is proposed. However, we propose that if the hazard is rated as severe (critical or catastrophic) and the vulnerability is moderate or worse, the consequence should also be rated as 'severe'.

Table 13 : Classes for assessing the magnitude of risk and its elements

	Class	Criteria: potential for consequences with the following magnitude/severity
Severe consequences	4 very high	Major losses and damages, loss of system functionality, irreversibility of consequences, large extent, very high pervasiveness, high potential for impact thresholds or local tipping points, cascading effects beyond system boundaries, systemic risk.
	3 high	Significant losses and damages, disturbance of system functionality, long-term effects, large extent and high pervasiveness, the potential for impact thresholds or local tipping points, cascading effects beyond system boundaries and systemic risk.
	2 moderate	Moderate losses and damages, moderate disturbance of system functionality, effects are temporary or unfolding slowly with a moderate extent/pervasiveness.
	1 low	None or minor losses and damages. No disturbance of functionality.

Table 14 : Likelihood classes for hazards and consequences of the event type or the slow-onset process

	Hazardous event		Slow-onset process	
4	Frequent	Likely to occur often in a lifetime (every 0 – 10 years)	Very likely	Very likely (90%-100%) to occur in the next ten years
3	Probable	Likely to occur several times in a lifetime. (every 0 – 25 years)	Likely	Likely (66% - 100%) to occur in the next 10 years
2	Occasional	Likely to occur sometime in a lifetime. (every 0 – 50 years)	As likely as not	As likely as not (33% to 60%) to occur in the next 10 years
1	Remote	Unlikely but still possible to occur in a lifetime (0 – 100 years)	Unlikely	Unlikely (0% - 33%) to occur in the next 10 years

For assessments with fewer resources, you might even reduce this table further or do the assessment on the level of subsystems (and not single key risks within subsystems).

*Find more information on risk criteria of the IPCC in chapter **E 1.2.1.** in the Expert Material*

Step 7 - Compile a risk analysis report

Compile the analysis and the risk description (Step 5) in the aggregated assessment (Step 6) into a risk analysis report. Ideally it should be reviewed and validated by stakeholders and, if possible, also by external experts to ensure quality and validity. It will serve as the basis for the risk evaluation in the next phase and should be shared with all stakeholders and experts that are participating in this phase.

Risk Evaluation

This module aims to evaluate climate-related risks in terms of their severity and subjective risk tolerance to inform CRM and CCA decisions where action on key risks is urgent.

Key steps you need to address in this module

- **Step 1:** Assess the severity of key risks
- **Step 2:** Understand the (subjective) risk preference/tolerance with risk layering
- **Step 3:** Identify the urgency to manage key risks

What do you need to implement this module?

- A list of key risks identified in the 'Risk Identification' and 'Risk Analysis';
- A quantitative (modelling) and/or qualitative (expert elicitation) estimate of specific climate-related risks' potential for adverse consequences from the 'Risk Analysis';
- An estimate of the current CCA capacity and/or deficit in managing these key risks, and knowledge of potential CCA constraints and how these could translate into CCA limits (see ***Step 3 - Preliminary evaluation ...*** in 'Towards Adaptation').

OUTCOMES OF THIS MODULE

- A list and visualization of key risks that are considered severe by experts
- A visualization of (subjective) risk tolerance levels based on participatory risk layering leading to a list of key risks that are considered intolerable by the affected community
- A synthesis report answering the guiding question, 'Where is action on key risks urgent?' that will form the basis for the next module 'Towards Adaptation'

Stakeholder engagement needed:

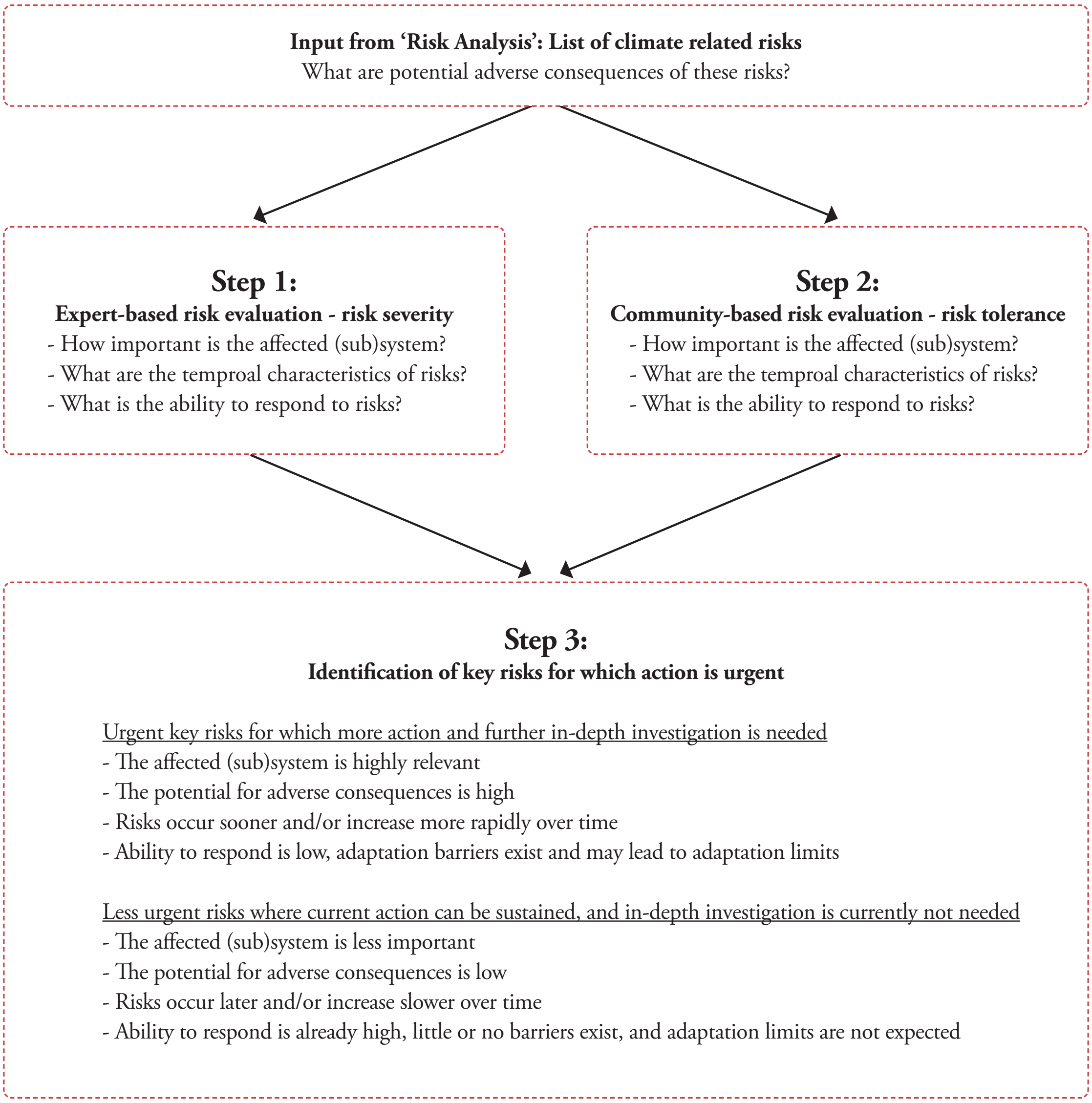
- The group of core stakeholders assessing the timing of and ability to respond to a risk.
- Participatory processes with a representative group of relevant stakeholders (recruited from the extended stakeholder network) for participatory risk layering.

General approach

Risk evaluation takes up the results from 'Risk Analysis'. 'Risk Evaluation' is combining an expert based and a community-based evaluation of key risks with the aim to integrate potentially different perspectives and values of the communities. The main aim is to identify priorities for action (Figure 24).

'Risk Evaluation' could be organised together with the last step of 'Risk Analysis' ***(Step 6 - Aggregate assessment of risk drivers ...)*** in a specific workshop.

Figure 24 : Workflow for the risk evaluation phase
(own illustration)



Step 1 - Assess the severity of key risks

How to translate the 'potential of risks causing adverse consequences' into 'risk severity'?

The module 'Risk Analysis' provided guidance on assessing the potential magnitude of consequences of (current and future) risk and how to select key risks. In addition to hazard, exposure and vulnerability, the importance of risks is determined by values. Values are highly context-specific and vary across individuals, communities, and cultures. The authors of Chapter 16 in the IPCC AR6 WGII Report (O'Neill et al., 2022a) identified and evaluated 127 key risks (across all sectoral and regional chapters) based on four other criteria that may be used to objectively determine the severity of each key risk. While two of these four criteria, the potential of adverse consequences and the likelihood thereof, have been assessed in the previous module ('Risk Identification'), this current step adds the temporal characteristics of the risk and the ability to respond to the risk:

- Temporal characteristics' of the risk. Risks that occur sooner, or that increase more rapidly over time, present greater challenges to natural and societal CCA. A persistent risk (due to the persistence of the hazard, exposure and vulnerability) may also pose a higher threat than a temporary risk due, for example, to a short-term increase in the vulnerability of a population (e.g. due to conflict or an economic downturn).
- Ability to respond to the risk. Risks are more severe if the affected ecosystems or societies have limited ability to reduce hazards (e.g. for human systems, through mitigation, ecosystem management) to reduce exposure or vulnerability through various human or ecological CCA options; or to cope with or respond to the consequences, should they occur (IPCC, 2022b). The ability to respond to the risk should be informed by the analysis of CCA options as described in 'Towards Adaptation'.
- Importance of the system at risk. Essential systems and functions such as food security or human health may be perceived as more important than certain economic sectors, such as tourism or mining. The importance of a system may also be related to the number of questions of how many other systems which depend on this specific system. For instance, ecosystems or water are the basis for many other systems and functions such as agriculture or health.

Expert users of the CR-SB can rely on these criteria to identify key risks that could potentially become severe according to the timing of changes in the associated hazards, the assessed systems' exposure and/or vulnerability, and the ability to respond to risks as well as evaluated the severity of these risks. This step is conducted through expert elicitation and is based on quantitative and qualitative data regarding risks' potential for adverse consequences from 'Risk Analysis', and knowledge on current CCA capacities and deficits from 'Towards Adaptation'. For more information → *see chapter* ***E 1.2.1.***

The output of this step can be a list and/or a different visualisation synthesising the key risks and sets of conditions—defined by levels of warming, exposure/vulnerability and CCA—that lead to severe risks by the end of the 21st century with a certain level of confidence.

The results could be reported as in Table 15 that expands on the list of 'Risk Analysis' (Table 12).

Table 15 : Results of a risk evaluation process

This table expands on the table on risk assessment from 'Risk Analysis' (rows from risk analysis in italic).

	Key risk 1 – risk to farmers due to drought - lowlands		
From Risk Analysis	**Current (2001 – 2020)**	**Near-term (2021 - 2040)** Intermediate emissions -> +1.5°C BAU = Business-as-usual Asp. = Aspiration	**Mid-term 2041 – 2060** High emissions -> + 2.4 °C Moderate emissions -> +2°C
Potential for severe consequences	Moderate: only occasional critical consequences	High: the critical consequences may become likely (BAU)	Very high: under high warming levels (BAU)
		Moderate: if exposure and vulnerability lowered through CCA (Asp.)	High: potential for severe consequences (Asp.)
Critical constellations or locations	High: small-scale farmers in remote areas in the north are highly vulnerable towards climate change	High: the situation in vulnerable regions for vulnerable groups might aggravate	Very high: in highly vulnerable regions and for highly vulnerable groups if no CCA measures are taken
Temporal characteristics of the risk	High: droughts are already posing a risk under current conditions, but persistence is low. Persistent droughts (over several years) might become more frequent already in near future, which requires urgent action.		
Ability to respond to the risk	The ability to respond to current droughts is high. Land degradation can be stopped, and irrigation systems can be made efficient and water saving	High: low ability to respond, if CCA is not started now (BAU)	Very high: Very low ability to respond in high emissions scenario. For some farms, limits of CCA may be reached (BAU)
		Moderate: if CCA has been started today and land is managed in a sustainable manner (Asp.)	Low to moderate: ability to respond even in a moderate emissions scenario; it is important to start CCA now and practice in order to move towards sustainable land-management(Asp.)
Importance of the system at risk	Very high importance of agriculture for food security and as the main source of income		
Severity of risk	Moderate	High (BAU)	Very high (BAU)
		Moderate (Asp.)	High (Asp.)
Confidence and uncertainty of the assessment	High, good data on current drought impacts as well as on the economic situation and farmland distribution	Moderate, climate model data available, but no model on future drought impacts. Aspiration scenarios are highly uncertain	High uncertainty, particularly on exposure, vulnerability and underlying risk drivers

Step 2 - Understand the (subjective) risk preference/ tolerance with the help of risk layering

How to understand subjective risk tolerance using risk layering?

While the previous step supports risk experts in assessing the severity of risks in the study region, based on quantitative and qualitative data on potential adverse impacts of risks gathered in the previous modules, this current step addresses the fact that public risk perception varies substantially on temporal as well as spatial scales. Risk perception is strongly determined by economic capacities, social norms and culture, as well as individual characteristics, and often requires joint subjective and expert judgment (Klinke and Renn, 2002). It is therefore extra important to include representatives from different gender and marginalised groups if you conduct a community-based risk evaluation.

Hence, in this step, we propose to use participatory methods to answer the same questions as in Step 1. This will involve a representative group of stakeholders from the study region to assess the risk tolerance of the respective community to certain key risks that may lead to severe impacts. It is advised that participatory methods are carefully selected according to context-specific capacities and social and cultural backgrounds of participants, and are led by trusted facilitators. For example, role play simulations may be a highly effective participatory format in one sociocultural context while not being accepted by participants in another.

We recommend implementing this participatory risk layering exercise complementarily to Step 1, again informed by expert and data-driven knowledge collected in 'Risk Identification' and building on participatory vulnerability analysis (PVA) tools and lessons learned from applying those in different spatial and sociocultural contexts. In the end, this step can result in a visualisation of the risk tolerance. It shows the identified risks placed along a spectrum ranging from acceptable to tolerable to intolerable risk. This assessment considers both present and future time horizons, as well as different levels of global warming. Additionally, the visualisation highlights the need for further CRM interventions, as depicted in Figure 25. Ultimately, this process leads to the creation of a bottom-up list of key risks.

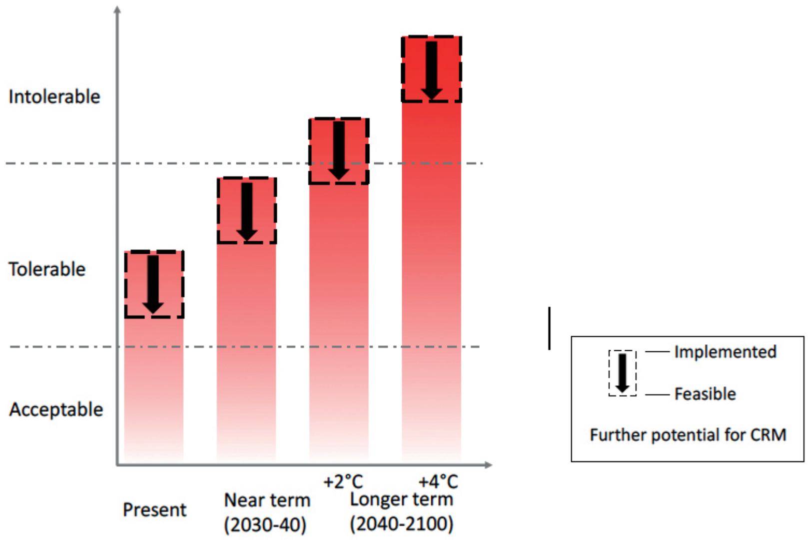
Acceptable climate-related risks are those where the group of stakeholders does not ask for additional CRM measures and the community in the study region is thus satisfied with the status quo.

Next comes the transition zone of tolerable risks, where stakeholders do see a need for additional action but not at any price – here costs and other constraints shall be weighed against the potential benefits of additional CRM measures.

Recognising CCA limits (see module 'Towards Adaptation' ***Step 3 - Preliminary evaluation ...***) as socially constructed stresses the importance of ethics, knowledge, risk and culture in understanding where CCA limits may arise (Adger and Barnett, 2009). Finally, intolerable risks are those which "exceed a socially negotiated norm (e.g. the availability of clean drinking water) or value (e.g. continuity of a way of life) despite [current] adaptive action" (Dow et al., 2013). Values refer to what is considered important by a group or society. Together with societal norms, they shape how rules and institutions are developed, and which actions are taken. For key climate-related risks that qualify as intolerable, stakeholders will ask for urgent additional CRM measures despite high costs or other constraints.

Figure 25 : Risk tolerance, layering climate-related risks on the spectrum from acceptable, tolerable, to intolerable risk

(based on Mechler, R., Schinko, T., 2016)



Step 3 - Identify the urgency to manage key risks

Where is action on key risks urgent?

The final Step 3 of the 'Risk Evaluation' module synthesises the results of steps 1 and 2 in order to identify those key climate-related risks where policy- and decision makers are advised to urgently take additional CRM action and/or to initiate a further in-depth investigation. Urgent key climate-related risks will comprise those selected risks from 'Risk Analysis' which expert elicitation in Step 1 classifies as severe (because of the temporal characteristics of the risk and the ability to respond to the risk, which is based on CCA barriers and limits) and a representative group of stakeholders in Step 2 perceive as intolerable for their community (again based on importance, timing, and ability to respond to the risk). The final outcome of Step 3 also reflects the final outcome of this module, namely a synthesis report with a final list of urgent climate-related key risks for the study region.

This report will serve as an important input for 'Towards Adaptation', as it indicates where current levels of CCA are not sufficient to tackle urgent key risks and thus highlights where additional – potentially transformational – CRM measures will be needed in order to sustain the functioning of a (sub)system.

Towards Adaptation

CRM includes both DRR and CCA. CCA is the process of adjustment to actual or expected climate change and its effects, in order to moderate harm or exploit beneficial opportunities. This module provides guidance on moving from CRA and evaluation to informing and supporting decision making towards CRM (including CCA) which reduces hazards, exposure and vulnerability, enhances adaptive capacity and strengthens resilience to climate risks.

Key steps you need to address in this module:

- **Step 1: Revisit underlying objectives, targets and values with stakeholders**
- **Step 2: Review existing CCA options, identify entry points and develop lists of potential CCA options**
- **Step 3: Conduct a preliminary evaluation of CCA options**
- **Step 4: Collect stakeholder feedback on potential CCA options**

What do you need to implement in this module?

- The impact chains and the report from 'Risk Analysis' with the identified key risks and their underlying risk drivers (hazard, vulnerabilities, exposure, and underlying risk drivers).
- A list of key climate risks for which CRM and CCA action is urgent, developed from 'Risk Evaluation', and an understanding of how these key risks were developed with expert-based risk severity and community-based risk tolerance steps.
- An understanding of the drivers and root causes of climate risks in the subsystems for which CRM and CCA action is urgent.

OUTCOMES OF THIS MODULE

- A list of potential CCA options that could be implemented to reduce climate risks
- Identified potential benefits, co-benefits, trade-offs and soft and hard limits to CCA of CCA options for different sectors and groups of people
- Feedback from stakeholders on important evaluation criteria for CCA

Stakeholder Engagement needed

You need a group of knowledgeable key stakeholders to help you identify potential CCA options (e.g. research experts, government, private sector, sectoral experts). In addition, for participatory feedback on potential CCA options, including the perspectives of those most affected by priority climate risks (marginalized and excluded groups), you will need a group of representative and relevant stakeholders recruited from the broader stakeholder network.

Box — C — What 'Towards Adaptation' cannot provide

This module is an effective starting point for engaging with the process of CRM and CCA in the context of your CRA. However, the outcomes of this module are not sufficient to design and implement a CCA plan (incl. the prioritisation of measures) and should not be viewed as the only steps needed to do so.

Depending on the scale of the risk assessment, in-depth, spatially explicit analysis and quantitative modelling may be needed to identify where options (and which combination of options) should be implemented to produce maximum CCA benefits. Tools such as Multi-Criteria Analysis (MCA), Cost-Benefit Analysis (CBA), and Cost-Effectiveness Analysis (CEA) offer possibilities to assess CCA options and CCA packages. Here we point to a number of additional resources that are useful to guide adaptation planning and implementation:

https://unfccc.int/topics/adaptation-and-resilience/resources/guidelines-for-national-adaptation-plans-naps
https://unece.org/environment-policy/publications/guidance-water-and-adaptation-climate-change
https://climate-adapt.eea.europa.eu/en/knowledge/tools/adaptation-support-tool/step-5-0

Introduction – How this module should be approached

For effective and efficient CRM and CCA planning, you should build on the knowledge you have gained during the CRA (from 'Risk Identification', 'Risk Analysis' and 'Risk Evaluation'), specifically on key risks, their potential severe consequences and risk drivers (hazard, exposure, vulnerability, underlying risk drivers).

All steps in this module should be conducted iteratively, with increasing levels of detail and additional information as well as a filtering process to identify and appraise potential CCA options relevant for the context of your assessment. This will be done through a process of:

- Desktop-based research, gathering of information from the outcomes of previous modules, previous CCA studies/projects, and explorative and informal talks with local experts or stakeholders (in person or online);
- A minimum of one workshop for the collection of local knowledge and insights on the potential CCA process in the context of your assessment. Depending on the time available, two workshops are preferential at different administrative and sectoral levels, with a diverse and dedicated representation of expert stakeholders to support identifying potential CCA options through expert consultation. It is important to reflect on who is at the table, and why, to ensure a fair, relevant and impartial representation. These stakeholder engagements could be done at the same time as others during the CRA process, for example when conducting the expert-based risk severity and community-based risk tolerance steps in 'Risk Evaluation';
- Consultations with domain experts (e.g. water management/agricultural experts);
- Desktop refinement of the potential CCA options.

Step 1 - Revisit underlying objectives, targets and values with stakeholders

Revisit the outcomes of 'Scoping' of the CRA (Step 9). Have any new challenges been detected since undertaking the previous modules in the CR-SB? Responses to the below questions will re-confirm important system components, functions and stakeholders that should be prioritised for CCA (e.g. a specific sector, ecosystem, or community that is at risk of climate extremes).

What do you value? What do you want to protect?

- What has been the main purpose of the CRA?
  - E.g. to inform national CCA plans, a project in climate-proof agriculture, a value-chain project in tourism, achievement of protection targets, etc.
  - Has the purpose changed since its inception in 'Scoping'?
- Which underlying objectives, targets, and values were defined and by whom?
  - E.g. what impacts are to be avoided? For example, loss of lives, damage to infrastructure/cultural heritage, diminished food/water security, loss of ecosystems and ecosystem services, etc.
  - Have underlying objectives, targets and values changed since their inception 'Scoping'?
  - Who was involved in defining these objectives, was anyone (e.g. a specific group) left out? Why were they left out?
- What development goals are at risk from climate change?
  - Were specific Sustainable Development Goals (SDGs) or locally defined development goals specified? E.g. 'double the agricultural productivity and incomes of small-scale food producers, in particular women, in all their diversity, Indigenous Peoples, family farmers, pastoralists and fishers.'
  - Have new risks to development goals been identified since the first identification in 'Scoping'?
- What are the development goals and aspirations of the stakeholders?
  - E.g. How do different stakeholders want the region to develop? Do these aspirations differ between groups, particularly between community-based and policy-making levels?

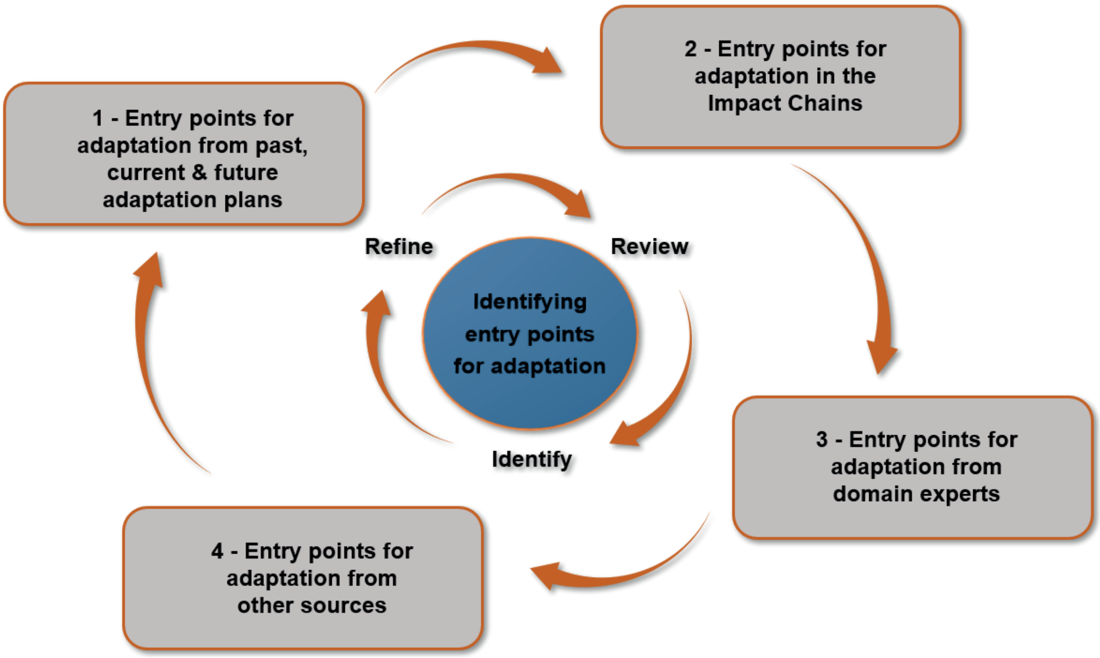
The responses to these questions are important to understand which CCA options could be implemented, who should be involved in their design and implementation, and how coordination between stakeholders could be organised.

Step 2 - Review existing CCA options, identify entry points and develop lists of potential CCA options

In this step, you will compile lists and ideas for potential CCA options and strategies (including through the review of previous and current CCA efforts) that could be effective for addressing the list of key risks for which action is urgent (see output of ***'Risk Evaluation'***). You will also identify entry points for CCA options; this should be an iterative process. Each list of potential CCA options should be reviewed and refined several times based on the outcomes of the following sets of guiding questions (see after Figure 26).

During the previous modules, you will have already engaged with elements of CRM and CCA. The potential CCA options identified in earlier modules can be reintroduced here and further refined. Figure 26 illustrates the iterative process that should be taken for identifying past, current and potential CCA options and their entry points, which follows the four sub-steps detailed below.

Figure 26 : Iterative process of identifying entry points for CCA
(adapted from Adaptation Committee (Schipper, 2022; UNFCCC. Adaptation Committee (AC), 2022)



Which CCA options could be considered? Develop your output for this step

While following the four sub-steps in Figure 26, write down lists of potential CCA options that you foresee could be useful in the context of addressing climate risks in your assessment. Pay attention to the list of key risks for which action is urgent, to the subsystems in which their impacts occur and to the risk drivers that could be lowered by CCA (vulnerability, exposure and intermediate impacts). As highlighted in the Conceptual Framework (section *1.3.*), it can be useful to categorise CCA options as the following:

TIP

Be exhaustive when compiling lists of CCA options. In the following steps in this module you will refine this list, with the aim of making it more targeted to your assessment.

- Structural (e.g. engineered/conventional infrastructure, for example, a flood barrier)
- Institutional (e.g. creating funds for small-scale on-farm CCA)
- Behavioural (e.g. educating about climate-smart agricultural practices)
- Ecosystem-based Adaptation (EbA) (e.g. green or blue infrastructure, for example, re-forestation or wetland restoration) (see ***Box D: Ecosystem-based Adaptation*** for definition)
- Early warning systems (e.g. installing a flood warning siren in a community)
- Climate information services (e.g. developing or providing access to mobile apps that can provide farmers with weather projections)

We encourage you to think about packages of a combination of integrated CCA options, that will increase diversity, sustainability and effectiveness of CCA options. These can include both incremental and transformative CCA. Additionally, think about the three impact scales and geographical scales of CCA, and how different CCA options can be effective for impact-specific, subsystem-specific and generic vulnerability at local, sub-national and national scales. Well-designed and effective CCA options can address risks and impacts across multiple scales at the same time. However, they can also create or increase risks or impacts across different scales, or result in maladaptation (see ***Box E***) if they are not planned and implemented with sufficient consideration of potential cascading effects (see chapter ***1.3.***). Table 16 provides an overview of selected examples of CCA options.

Table 16 : Selected examples of CCA options for generic climate risks
(adapted from IPCC, 2022b)

Generic Climate Risk	Category	CCA Option	Example	Scale (impact/geographic)
Risk to coastal socio-ecological systems	Structural	Seawalls	Seawalls can reduce exposure to low-lying coastal areas from sea level rise and inundation	Impact specific/local scale
Risk to living standards and equity	Institutional	Government-funded insurance for small-scale agriculture	Insurance can allow profitable agricultural investments because people are less vulnerable to losing income for a season	Generic vulnerability/ National scale
Risk to water security	Behavioural	Reducing water use in the agriculture sector	Adjusting irrigation patterns during a drought to limit water use for less important needs	Subsystem specific/ sub-national or national scale
Risk to critical infrastructure	EbA	Planting green infrastructure in a city	Green infrastructure can cool urban areas and reduce overheating of transport networks during a heat wave	Impact specific/local scale
Risk to human health	Early warning systems	Governmental implementation of flood and storm warning sirens	Early warnings enable evacuation from/preparations for storms	Impact specific/National scale
Risk to food security	Climate information services	Mobile phone applications with seasonal weather projections	Providing farmers with access to applications that allow them to better plan for the season, improving crop yields	Subsystem specific/national scale

Where do you see entry points for CCA when you look at past and current CCA plans or strategies?

Reviewing existing CCA plans and strategies can have several benefits. Existing options can serve as inspiration for CCA in your CRA, and synergies can be developed between past, current and future CCA activities. These synergies can be 'low hanging fruit' which avoids duplication of work and build on other successful CCA efforts; this can strengthen CRM and the CCA process. Additionally, you gain an understanding of what has worked (e.g. successful CCA) and what hasn't worked (e.g. CCA options leading to maladaptation) in the past. This includes stakeholders' perceptions of different types of strategies, as well as past and current CCA plans to address key risks for which action is urgent, or future plans to address key risks.

- Revisit the ***'Scoping'*** module – what relevant past and current CCA efforts have been made?
  - » What climate risks were targeted by these CCA efforts? For which subsystems and sectors? Were there any efforts targeted towards key risks that require urgent action?
  - » Are there any locally developed CCA strategies in place or planned by local governments or institutions? What about the private sector? What about informal CCA?
- What went well and what did not go so well concerning these past and current CCA efforts?
  - » E.g. did one group of stakeholders strongly favour or oppose a certain category of option (e.g. ecosystem-based adaptation or structural options)?
  - » Were there any unintended negative consequences of these CCA efforts for groups or areas, either locally or further afield (i.e. maladaptive consequences)?
- Have any future CCA plans/strategies been developed in the sectoral areas or subsystems that are the focus of your CRA? Have any plans been developed to address key risks that require urgent action?
  - » E.g. has the country where your assessment takes place submitted National Adaptation Plans (NAPs) or Sectoral Adaptation Plans (SAPs)? Are NAPs or SAPs developed for comparable countries or regions with similar topographies, climate risks and incomes?
  - » Has the country where your assessment takes place submitted any Nationally Determined Contributions (NDCs) that include an adaptation component (See the TAAN – Tool for Assessing Adaptation in the NDCs: https://taan-adaptationdata.org/)?
  - » Can you identify any plans or strategies for key risks in other countries or regions which could provide valuable lessons for your context?
- Are stakeholders already implementing CCA strategies?
  - » E.g. are there any large-scale government-funded adaptation projects? Are the implementation of NAPs already taking place?

Box – D – Ecosystem-based Adaptation

Ecosystem-based Adaptation (EbA) is a type of Nature-based Solutions (NbS) that harnesses biodiversity and ecosystem services to build the resilience of human communities and societies to the impacts of climate change (FEBA, 2022). Often, NbS and EbA are used interchangeably, given the two concepts are closely linked. In the CR-SB, we use the term EbA. Other terms you may come across include, e.g. green infrastructure, blue infrastructure, ecosystem-based approach, building with nature, working with nature, Ecosystem-based Disaster Risk Reduction (EcoDRR).

EbA strategies can be considered 'low-regret' solutions since they are often more cost-effective than structural (i.e. conventional engineered) CCA interventions and can generate additional social, economic or cultural/recreational co-benefits that go beyond the direct CCA benefits. Examples of potential co-benefits include, but are not limited to, positive effects on health and wellbeing (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. It is important to keep in mind that EbA often generates not only co-benefits for the related social, economic or cultural/recreational systems, but may also entail trade-offs and unintended consequences. Additionally, ecosystems providing the adaptation measures might themselves be affected by the impacts of climate change. This potentially limits their adaptation capacity. Such potential consequences should be considered during the identification, evaluation, design and implementation of EbA measures. Impact chains are a useful tool for the identification of trade-offs, synergies and unintended consequences (see Step 3 below).

Identifying EbA options should be done in parallel with identifying other types of CCA options. You should identify what ecosystems and related ecosystem services are affected by key risks identified from 'Risk Evaluation', and ask questions such as how they are affected and if the damage can lead to cascading effects (e.g. if regulating or provisioning services are affected (Walz et al., 2021)). Next, you need to understand how ecosystems are managed, by whom and for the benefit of whom. This should include the identification of key ecosystem services that are provided (e.g. water regulation, flood prevention, erosion control, food provision), by whom they are used and how they could contribute to risk reduction. It is important to be aware that the spatial areas where ecosystem services are provided may differ from the spatial areas that benefit from these services, or areas may provide benefits both locally and remotely. For example, a forest upstream in a catchment reduces erosion levels locally and provides a buffer for floods, and by doing so also protects downstream areas.

Table 17 : Examples of the ecosystem services provided by a mountain forest
(Adapted from Haines-Young and Potschin, 2018)

Ecosystem type	Ecosystem service provided	Type of service	Spatial benefits
Mountain forest	Provides timber	Provisioning	Locally
	Stops landslides/avalanches harming people	Regulation & maintenance	Locally
	Provides habitat for animals that are useful to humans	Regulation & maintenance	Locally
	Regulates water flow	Regulation & maintenance	Locally & remotely
	Reduces soil erosion	Regulation & maintenance	Locally & remotely
	Buffers floods	Regulation & maintenance	Locally & remotely
	Sequesters carbon	Regulation & maintenance	Locally & remotely
	Provides space for sport/recreation	Cultural	Locally
	Provides items of spiritual or cultural importance to humans	Cultural	Locally & remotely

   » Are there any small-scale adaptation projects taking place? E.g. farmers who are already implementing local level strategies for changing precipitation patterns.
   » What about informal CCA that is occurring without institutional guidance, financing and support?
- Where can you see synergies and 'low-hanging fruit' for CCA?
   » E.g. are CCAs currently underway (due to climatic or other drivers) that could be up-scaled or out-scaled to support CCA in the context of your assessment?
- Have any past or current CCA efforts effectively addressed drivers and root causes of risk?

Where can you see entry points for CCA options in the impact chains?

Impact chains can serve as a useful tool to identify entry points for CCA. In Step 3 of 'Risk Analysis', there is a first critical reflection on gaps and entry points for potential CCA options in the impact chains. Here we elaborate on this step. By 'entry points' we mean places in the impact chain where a targeted CCA option could 'break', 're-direct', or 'minimise' risk creation (see Table 18 and Figure 27 below for an example).

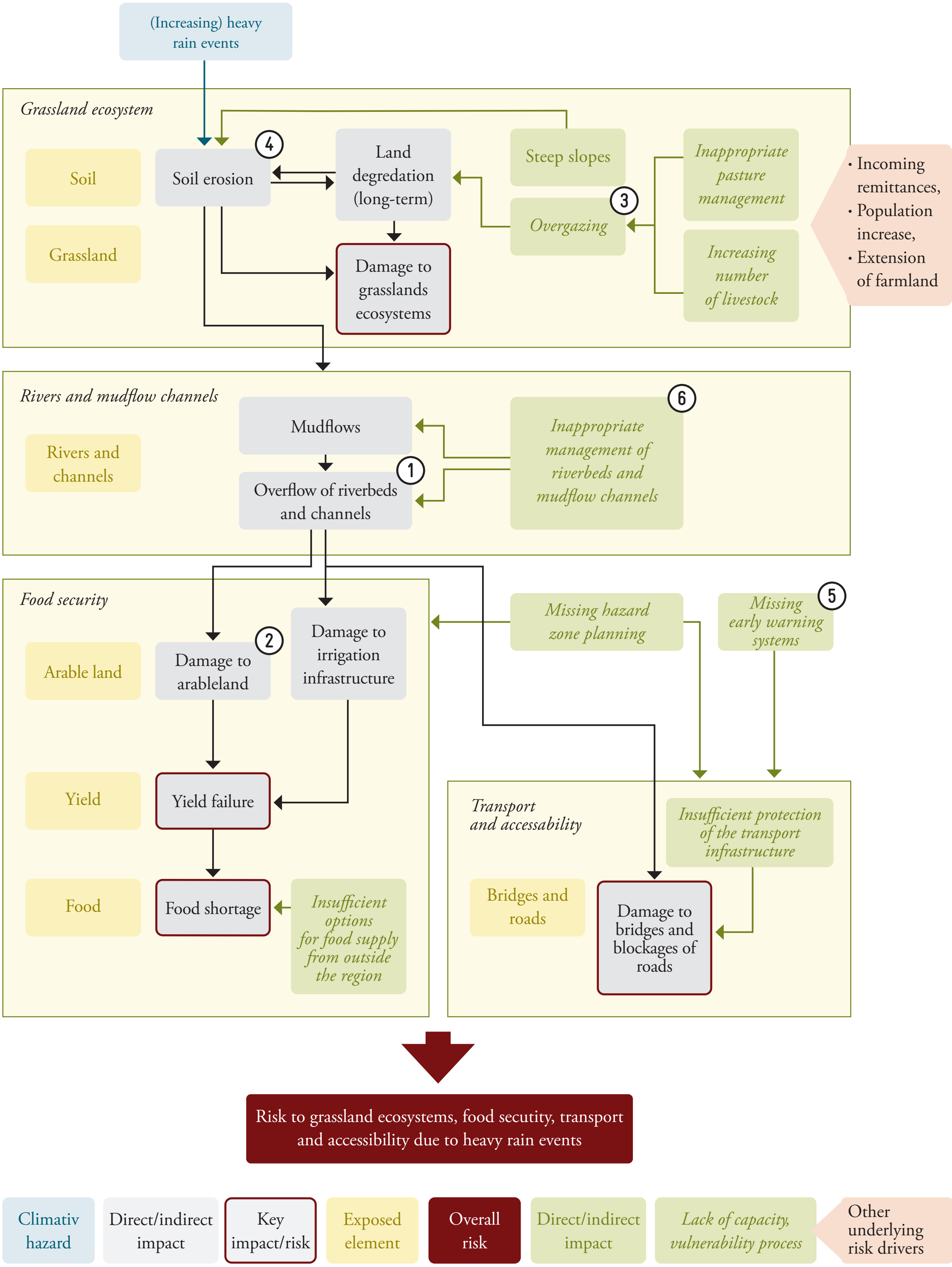
- In the 'hazard', 'exposure', 'vulnerability' and 'intermediate impacts' sections of the impact chains, where can you see entry points for CCA?
   » E.g. to avoid a specific sectoral impact or negative effects for a certain group/community, or a negative effect for a specific SDG.
   » E.g. what strategies or measures could work and are feasible (with the resources available)? What types of measures are these (e.g. structural, institutional etc.; see Table 18)?
- When developing your impact chains, did you identify specific elements that you think should be prioritised for CRM more so than others?
   » E.g. because the information generated from the CRA suggests they are more vulnerable or provide an important critical service or function. This could be an impact on a sector or ecosystem, or a certain group/community who are more exposed than others.
- Are there any leverage points that can address multiple risks at the same time?
- Which risk factors and underlying drivers/root causes do you want to address?
- Do the entry points you have identified align with what you want to protect? Do they address key risks which require urgent action?

Table 18 : CCA options in the impact chain illustrated in Figure 27

No.	CCA option	Category
1	Construct dykes along the river channels	Structural
2	Government-funded insurance for damage to arable land	Institutional
3	Farmers diversify grazing patterns & locations for their livestock	Behavioural
4	Afforestation/reforestation on slopes	EbA
5	Developing & implement early warning systems	Early warning systems
6	Seasonal forecasting apps for farmers to improve pasture management	Climate information services

Figure 27 : Using impact chains to identify entry points for CCA

(own illustration)



OUTPUT

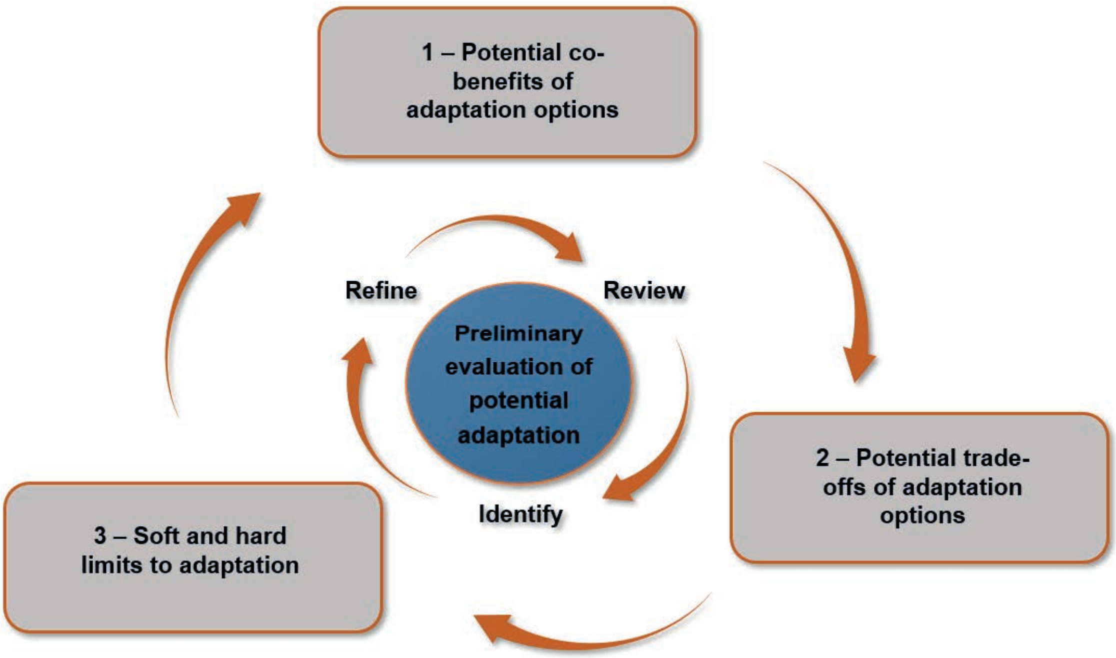
Preliminary lists of potential CCA options

After completing Step 2, you should have produced extensive lists of different potential CCA options and their possible entry points. The CCA options lists may be organised according to the type of option, the relevant stakeholders/beneficiaries or the impact/geographic scales.

Step 3 - Preliminary evaluation of potential CCA options and packages

This step involves a first evaluation of the identified CCA options, with the aim to narrow down the more extensive lists developed in Step 2. It is important to identify criteria against which existing, planned and possible new CCA measures should be evaluated. While cost-benefit is a commonly used criteria, it is recommended to consider additional criteria such as social acceptance of measures, possible co-benefits, and trade-offs as well as CCA limits and barriers. While the CR-SB does not offer in-depth guidance on how to evaluate measures in detail (see ***Box C***), this step is nonetheless useful to preliminarily engage in the evaluation of CCA options. The results of this step can serve as the basis for a CRM and CCA workshop with stakeholders (see Step 4), or they can be used as an input for another workshop during the implementation of the CRA. Following the suggested iterative process of identifying CCA options and packages in Step 2, we recommend the same in Step 3 (Figure 28).

Figure 28 : Iterative process of evaluating potential CCA options and packages.
Adapted from Adaptation Committee (Schipper, 2022; UNFCCC. Adaptation Committee (AC), 2022)



Sub-Step 3.1 - Potential co-benefits of CCA options

Certain CCA options can go beyond the direct CCA benefit (i.e. the main purpose or objective of the CCA option). When this occurs, the CCA option does not only address the CCA need, but it also results in additional positive outcomes. We call this 'co-benefits' of CCA. This could be, for example, a CCA option that not only protects a vulnerable community from flooding, but also provides ecological benefits to surrounding flora and fauna. Co-benefits can be social, economic, cultural, recreational, or ecological (Choi et al., 2021).

- Of the identified CCA options, which would be effective for reducing hazard exposure and/or vulnerabilities for multiple climate risks identified in the impact chains?
  - » E.g. would a CCA option be effective for both flood and windstorm risk? Would it reduce cascading impacts across more than one sector/system?
- Of the identified CCA options, which would be effective for addressing multiple key climate risks identified in 'Risk Evaluation'?
  - » Would any be effective for addressing drivers and root causes of vulnerability?
- Of the identified CCA options, which have other social, economic, cultural, recreational or ecological co-benefits beyond the direct effects on hazard, exposure and vulnerability?
  - » E.g. does it have positive effects on wellbeing, biodiversity, or does it provide ecosystem services that benefit a community?
- Who and what might be positively affected and how?
  - » E.g. which stakeholder groups, sectors, subsystems, ecosystems, businesses?

Sub-Step 3.2 - Identifying potential trade-offs of CCA options

Along with co-benefits, some CCA options may address CCA needs in one context (e.g. for a specific sector, system, group or asset), but result in negative outcomes elsewhere, for example, by transferring the risk to another sector, community, ecosystem or individual. This negative/positive spillover effect is also called 'trade-offs of CCA'. This could be, for example, a CCA option that protects an upstream community from flood risk by diverting water away from their town, but this diversion pushes more water downstream, increasing flood risk for a downstream community.

- Of the identified CCA options, what negative outcomes can you think of?
  - » E.g. does the CCA reduce flood exposure to one community, but increase exposure to another? Is the CCA effective for reducing risk to a specific sector such as agriculture, but it is damaging for a wetland ecosystem close by?
  - » Do any of the potential CCA options increase exposure for another sector, community, system, or individual to key climate risks that require urgent action?
- Of the identified CCA options, what social, economic, cultural, recreational, or ecological trade-offs can you see?
- Who and what might be negatively affected?
  - » E.g. which stakeholder groups, sectors, ecosystems, businesses
- How might these negative outcomes specifically affect individuals, groups and communities that are already vulnerable or marginalised?
- What trade-offs can you identify specifically for women in all their diversity?

Sub-Step 3.3 - Where can you see soft and hard limits to CCA?

Constraints make CCA processes more difficult and are unevenly distributed across regions and groups. The IPCC distinguishes between physical, biological, economic, financial, human resource, social and cultural, as well as governance and institutional constraints (Klein et al., 2014). Constraints to CCA may lead to CCA limits, defined as "conditions or factors that render CCA ineffective as a response to climate change and are largely insurmountable" (Adger et al., 2007) or "the point at which an actor's objectives (or system needs) cannot be secured from intolerable risks through adaptive actions" (IPCC, 2019).

CCA limits can be qualified as 'soft' when they can be shifted, for example, once adaptative measures become available, and as 'hard' when no adaptive action is possible (Klein et al. 2014). Soft CCA limits are also referred to as barriers, which can in principle be overcome (Dow et al. 2013) either with concerted effort, changes in thinking, or shifts in resources (Barnett et al., 2015; Moser and Ekstrom, 2010).

Limits to CCA can also occur when the adaptive capacity of a human system is exceeded (Adger and Vincent, 2005). Barriers that may lead to CCA limits are context-specific and vary according to sectoral, spatial and temporal scales (Biesbroek et al., 2013), while adaptive capacity depends on a combination of physical and intangible assets (Brown and Westaway, 2011) as well as political and social power relations (Birkmann, 2011). The actual feasibility of adaptative measures depends on available resources and measures, their appropriate and culturally acceptable use, as well as other external constraints or barriers (Brown and Westaway, 2011; Füssel, 2007).

We suggest employing the categorisation of constraints that may lead to soft and hard CCA limits proposed by (Thomas et al., 2021) because it is based on a comprehensive, systematic literature review and summarises recent insights on limits to CCA across the world. This list of constraints comprises the following eight categories:

1. economic: existing livelihoods, economic structures, and economic mobility;
2. social/cultural: social norms, identity, place attachment, beliefs, worldviews, values, awareness, education, social justice, and social support;
3. human capacity: individual, organisational, and societal capabilities to set and achieve CCA objectives over time including training, education, and skill development;
4. governance, institutions and policy: existing laws, regulations, procedural requirements, governance scope, effectiveness, institutional arrangements, adaptive capacity, and absorption capacity;
5. financial: lack of financial resources or corruption;
6. information/awareness/technology: lack of awareness or access to information or technology;
7. physical: presence of physical barriers;
8. biological/climatic: temperature, precipitation, salinity, acidity, and intensity and frequency of extreme events including storms, drought, and wind.

Building on existing literature as well as the outputs from 'Risk Analysis' and 'Risk Evaluation', risk experts may set out to identify key constraints for the potential CCA options and packages identified in this module according to the eight categories listed above. Additionally, experts can identify potential interactions between constraints that may lead to soft and hard limits to CCA. The final output of this step is a list of key constraints associated with potential soft and hard limits to CCA for the key risks identified in 'Risk Evaluation'.

- Soft and hard limits to CCA
  - » Which CCA options are not available now, but may be available in the future with social, institutional, or technological innovations?

  - » Where will CCA options not avoid intolerable risks?
- Risk urgency for CCA
  - » Which CCA options could be effective to address more urgent risks?
  - » Do the CCA options help to reduce risks identified by stakeholders as more urgent?
  - » Which CCA options would be targeted to reduce risks identified as less urgent?

Box — E — Avoiding Maladaptive Actions

Some actions that aim to strengthen CCA to climate change can also introduce a host of new issues, and even increase, redistribute, or create new risks. We call this maladaptation. Maladaptation is different from trade-offs. Trade-offs are the negative effects of CCA options that are identified and assessed in relation to the direct CCA benefit and co-benefits. Trade-offs are inherent in the CCA process and will always arise. This is why identifying them is important, so they can be evaluated and managed. Maladaptation, on the other hand, is when the CCA option results in overall worse outcomes than before and is often not foreseen. Maladaptive actions are defined by the IPCC (2021a) as 'actions that may lead to increased risk of adverse climate-related outcomes, including via increased GHG emissions, increased vulnerability to climate change, or diminished welfare, now or in the future. Maladaptation is usually an unintended consequence.'

Maladaptation is most often identified after it has happened, i.e. when the negative effects of the 'CCA option' emerge, and it is too late to do something about it. However, to avoid taking actions that are maladaptive, it is important to try and anticipate these negative effects early on. In this box we point to five important structural challenges that contribute to maladaptation (Bertana et al., 2022).

1. Not understanding the root causes of vulnerability and risk to climate change
2. Implementing CCA options that lack flexibility
3. Not clearly distinguishing the difference between CCA and development actions (where climate risks are not the focus and development undermines efforts to reduce risk)
4. Not attempting to mainstream CCA into planning processes, thereby marginalising CCA with respect to other issues at hand
5. Ineffective monitoring, evaluation and learning processes that do not accurately reflect the reality of the situation

When planning CCA in the context of your assessment, it is important to remember that not all responses to climate risks are 'good' (Eriksen et al., 2011), and engaging with these five structural challenges can support the identification of CCA options that do not lead to maladaptation.

Step 4 - Stakeholder feedback on potential CCA options

Engaging with stakeholders (e.g. communities, sectoral experts, policymakers, the private sector, academia, consultants) is critical in the CCA process to understand how they perceive the effectiveness and fairness of CRM and CCA options and if they agree or disagree with implementation strategies. Engaging stakeholders can help reveal blind spots regarding possible co-benefits, trade-offs and CCA limits. It is crucial to incorporate diverse perspectives from vulnerable, marginalized, or otherwise excluded groups, specifically including a gendered perspective. This inclusion allows for a comprehensive understanding of the potential impacts of climate change adaptation (CCA) options on different communities, as well as how these communities might be affected.

> **TIP**
>
> **The importance of power dynamics**
>
> - Which stakeholders have been selected for feedback and why?
> - Are stakeholders with more influence and voice dominating the decision-making or discussion space?
> - May marginalised stakeholders feel uncomfortable speaking up and giving their opinions to others in the room?
> - Do women in all their diversity feel they cannot express themselves openly and transparently?
>
> If the answer to any of the last three questions is possibly 'yes', you need to consider redesigning your feedback process to allow everyone to have an equal say.

Stakeholder feedback of potential CCA options

- Of the potential CCA options you have identified in this module, what feedback do stakeholders have?
  - Do they strongly oppose or favour a particular option, or do they have a preference for a certain category of CCA? (e.g. structural, institutional, ecological, or behavioural)
- Do CCA options address risks they perceive as more tolerable or less tolerable? (See outcomes of ***Step 2 - Understand the (subjective) risk preference ...*** in 'Risk Evaluation'.)
- What criteria are important for stakeholders to evaluate different and competing options?
  - E.g. cost-benefit, social acceptance, co-benefits, level of 'protection', capacity building
- How do the identified CCA options complement or conflict with CCAs that stakeholders are already implementing?
  - E.g. do the identified potential options complement past/current CCA plans, do they conflict with past/current CCA plans
- What new insights do they have on existing CCA strategies and 'low-hanging fruit'?
- What new insights do they have on potential co-benefits and trade-offs?
- What new insights do they have on soft and hard limits to CCA?

Perspectives of vulnerable and marginalised groups

The views and opinions of groups who are often excluded from the decision-making space need to be accounted for to understand how they perceive potential CCA options. Often, it are those who are already vulnerable that feel the negative effects of trade-offs, which exacerbates inequality in a community. By engaging with the perspectives of the vulnerable and marginalised, more equitable CCA decisions can be made, and CCA can be targeted specifically to improve conditions for those groups.

- Of the potential CCA options you have identified in this module, what feedback do vulnerable, and marginalised groups have?
- What criteria are important for vulnerable, marginalised and excluded groups to evaluate different and competing options?

   » E.g. to reduce exposure? To provide livelihood and development opportunities? To protect cultural values and beliefs?

- What new insights do they have on existing CCA strategies and 'low-hanging fruit'?
   » Often those who are vulnerable are already adapting because they are forced to, so it is useful to include their local expert knowledge.
- Are stakeholders already implementing their own CCA strategies?
- What new insights do they have on potential co-benefits & trade-offs? What about soft and hard CCA limits?
- How have the outcomes of this step aligned with development goals and aspirations identified in the scoping phase of 'Scoping'?

*For policy perspectives please see → Expert Material **E 2.3.1.** - Step 4 – Stakeholder feedback on potential CCA options (policy perspectives)*

Monitoring & Evaluation

Introduction

'Monitoring & Evaluation' is a critical component for adapting to climate change risks. It consists of three distinct but complementary processes:

1. **Monitoring:** covers tracking progress made in implemented CCA options or packages in relation to specific objectives;
2. **Evaluation:** aims to objectively determine the effectiveness of CCA actions in relation to those objectives, encompassing a wide variety of dimensions. Examples of such dimensions could be efficiency, resilience and equity of the CCA actions;
3. **Learning:** encompasses iterative reflection of the CCA process, including the adjustments that may be needed in CCA actions to address new challenges that may arise (i.e. due to changing climate risks), (UNFCCC, 2022a).

Thus, in a climate risk and CCA context, monitoring, evaluation and learning can be generally understood as a process to understand and navigate changing conditions, which provides opportunities to inform decision-making and creates possibilities for new knowledge generation (Outcome Mapping Learning Community, 2021).

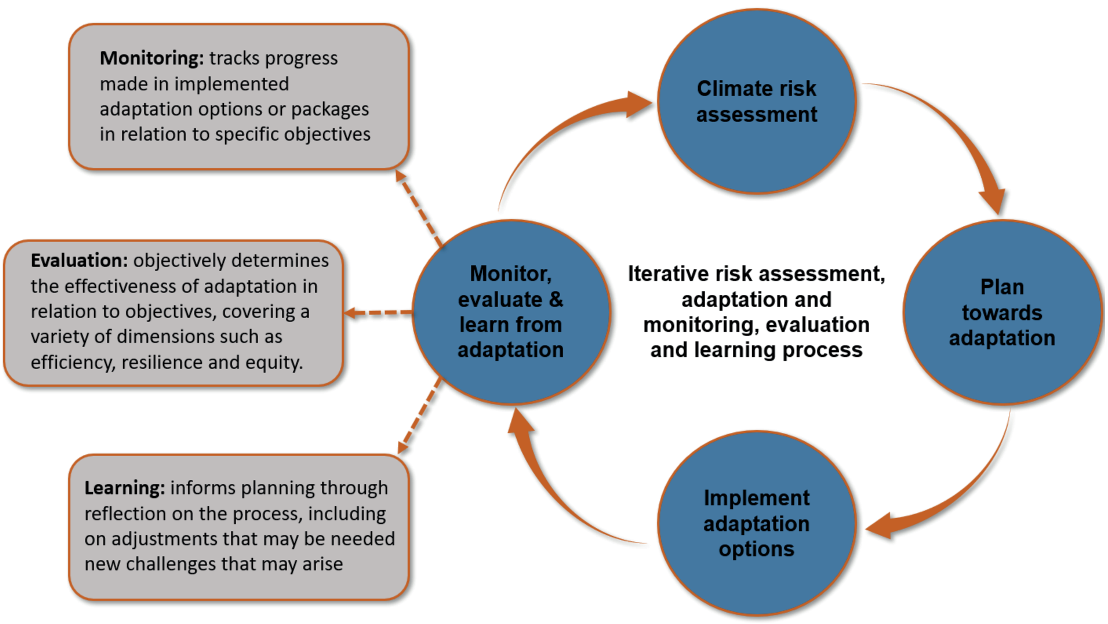
Box — F — What 'Monitoring & Evaluation' cannot provide

Given that the CR-SB only provides guidance towards CCA, (see ***Box I***), this module does not provide guidance on implementing monitoring, evaluation and learning actions. Rather, this module introduces why monitoring, evaluation and learning is important in the risk assessment and adaptation process (see Figure 29 below). When monitoring will be carried out depends on factors such as how long the risk assessment will take, when the CCA is planned and implemented, how long it takes before benefits may be shown and when resources become available to undertake activities (see Box G below). However, it is important to start thinking about monitoring, evaluation and learning early in the process of CCA. This is because the establishment and implementation of activities can require a significant investment of time and resources. Additionally, it is crucial to monitor changes in processes which are necessary for conducting comprehensive CRAs and effectively implementing CCA measures. This monitoring is equally important as it allows the evaluation of the outcomes of CCA options (see also GIZ Corporate Unit Evaluation staff, 2022).

Why is monitoring, evaluation and learning important?

Monitoring, evaluation and learning is the key enabling process to understand the effectiveness of CCA. Effective monitoring, evaluation and learning should track progress and generate data, information and new knowledge that supports decision-making to adjust policies and strengthen communities' CCA and resilience to climate risks (UNFCCC, 2022a). Additionally, the process should enhance the knowledge base about system components and functions, and thereby reduce system uncertainty. Monitoring, evaluation and learning (along with risk assessment and CCA) are an iterative process (i.e. it should not only occur once, at a fixed point, which can then be considered 'complete') (Figure 29). This is because the nature of climate risks, sectors and systems change over time, and CCA (informed by your CRA) will have effects that influence these changes.

Figure 29 : The iterative process of CRA, CCA and monitoring, evaluation and learning
(adapted from Adaptation Committee, Schipper, 2022; UNFCCC. Adaptation Committee (AC))



A well-designed and dedicated monitoring, evaluation and learning plan can ensure greater effectiveness and equity in the risk assessment and CCA process over time and provides an understanding of how best to adjust CCA to future risks. It is critical to learn what works well (or not well), in which circumstances, for whom and for what reasons. Understanding the effectiveness of your CCA options is likely going to be one of the key requirements for your monitoring, evaluation and learning plan. To understand how beneficial the CRA and CCA have been, it is critical to assess what effects CCA actions have had on targeted stakeholders, sectors and systems, to assess if CCA has provided benefits as designed. Additionally, your monitoring, evaluation and learning plan should aim to be inclusive; to reflect how the CRA and CCA process has affected everyone in your target area. This is particularly true among marginalised groups who are disproportionately affected by climate change, as they often do not have the voice or power to present their views on the outcomes of CCA processes. Use gender-disaggregated data: consider the constraints for members of certain groups or genders to attend workshops or interviews and find a solution to ensure their inclusion. Accounting for the perspectives and experiences of all stakeholders through inclusive monitoring and evaluation, regardless of gender, race, age, sexuality, disability or social status should be a key requirement for your plan (Schipper et al., 2022; UNFCCC; Adaptation Committee (AC), 2022).

Challenges of assessing CCA

Several complex challenges arise when trying to monitor, evaluate and learn about CCA. Additionally, CCA is highly context-specific; what could be considered resilient for one group of stakeholders, sector or system may not be the same elsewhere. Furthermore, people can be affected differently in the same location due to, for example, differential vulnerability, trade-offs, and maladaptation. Adaptive capacity, resilience and what can be considered 'well adapted', are not static states/end-goals. This is because GHG emissions, temperature goals and other external processes (i.e. sustainable or unsustainable development, pandemics, armed conflicts, political instability, etc.) result in changing levels of risk and changing priorities over time (Brooks et al., 2014; Singh et al., 2022; UNEP DTU Partnership, 2018).

Box — G — Timeline considerations for your monitoring, evaluation and learning plan

When your monitoring, evaluation and learning will be carried out depends on factors such as how long and in-depth the CRA will be, when planning of CCA will occur and how long it takes for projected benefits to be felt. These factors are important to consider when establishing a plan. In the earlier stages of implementing CCA options, efforts typically focus on process-based monitoring, evaluation and learning (i.e. progress in plans, institutional changes needed to facilitate implementation, decision making capacity and agency of stakeholders). This is then followed by focusing on outputs (i.e. what the CCA option has or has not delivered in terms of goods and services) and outcomes (impacts) (i.e., what are the impacts and consequences of changes in processes and outcomes for target groups and at a larger scale, and how does this affect vulnerability and risk)?

With this in mind, an effective monitoring, evaluation and learning strategy does not start after CCA has been implemented. Rather, it should be included in every step. By establishing a baseline, setting defined objectives and efficiently documenting changes in processes, outputs and outcomes in the risk assessment and CCA cycle, progress in baseline conditions can be better understood through evaluation and reflexive learning. This can strengthen institutional understanding of what has worked well, what has not worked well and what needs to be done differently to improve the risk assessment and CCA process in the future.

Some additional considerations to make the CRA more sustainable and durable:

- How frequently do you need to conduct monitoring and evaluation activities to have a robust understanding of CCA (e.g. every 3 months, 6 months, 12 months)?
- What is the suitability and longevity of the data you have collected (e.g. is it relevant for a short, medium, or long time period) and how does this affect your evaluation?
- How will budgetary constraints and project timelines influence this? If there are barriers, how can they be overcome?
- Do monitoring and evaluation activities need to be transferred to someone else?
- Do you need to set up a digital system for recordkeeping and conducting monitoring, evaluation and learning systematically over time?

Another difficulty in assessing CCA lies in the mismatch of timescales between actions and their outcomes, which tends to lend focus to the measurement of short-term results as opposed to long-term structural changes that address the root causes of risks.

Additionally, in many places, data availability is a big issue, particularly in low- and middle-income settings that are oftentimes more exposed to hazards and where people are more vulnerable.

All of these challenges result in a lack of consensus around processes and metrics to assess CCA. There is a trade-off between, on the one hand, a standardised approach that uses pre-defined indicators that may be open access, and, on the other hand, a tailored, context-specific approach that can be time consuming and resource intensive (UNEP DTU Partnership, 2018). When setting up your plan, valuable lessons on more standardised approaches can be taken from monitoring and evaluation plans at the national level (e.g. from the monitoring of NAPs or adaptation in NDCs). Ultimately, however, there is not one 'correct way' to monitor, evaluate and learn from CCA, but it will depend on the needs and goals of stakeholders and available resources of the implementing organisation. It is important to reflect that as CCA is a cyclical and iterative process, your monitoring, evaluation and learning plan will also require continual readjustment over time to account for changes in the system.

Selecting and/or developing indicators for your monitoring, evaluation and learning plan

A strong understanding of how indicators can be utilised for assessing CCA is an important step for developing a monitoring, evaluation and learning plan. Given the challenges of assessing the progress and effectiveness of CCA (see ***Box D: Ecosystem-based Adaptation***), when developing your plan, it is useful to utilise multiple data and information sources when selecting or developing indicators. A plan that follows a mixed-method approach, combining quantitative and qualitative sources (E.g. from a hydrological model output and stakeholders perceptions), will be more flexible. This flexibility is highly useful given the dynamic and changing nature of climate risks, CCA and development processes. Additionally, a mixed-method approach can help to overcome limitations of choosing one or the other, as more varied data and information can be drawn upon, compared and evaluated against each other to ensure the overall narrative of CCA assessment is more robust (Climate ADAPT; O'Connell et al., 2019).

TIP

Identification of indicators with stakeholder

- Use of existing indicator sets adapted to the local context is pragmatic and efficient.
- The change in the value of a single indicator does not always provide sufficient information about the effectiveness of CCA. Combining and assessing different indicators can provide a more meaningful picture.
- Be sure to establish baseline values (before adjustment) if possible, to represent specific changes after adjustment.
- Consider data availability and the resources available for collecting data when identifying and/or developing indicators.
- It is important to communicate that by simplifying indicators (i.e. using proxy data) contextual evidence of CCA can be lost, thereby giving an inaccurate portrayal of reality.

Remember: indicators have limitations and will not capture the full picture!

As a starting point, it may be useful to look at publicly available lists of indicators for inspiration (see ***Box E***). Using publicly available lists is helpful as methods used to calculate each indicator are usually outlined. It is critical to ensure that selected indicators are relevant to the local context, and you should always keep the objectives of your CRA and CCA in mind. Highly synthesised compound indicators, such as GDP, will likely have little relevance in the context of your assessment (O'Connell et al., 2019).

When selecting and developing indicators, it can also be very useful to engage with stakeholders who have expertise and/or local knowledge of the context. This can ensure relevance and align indicators with the development goals and aspirations of local stakeholders. Relevant indicators should map the issues that practitioners want to address, while being accessible and affordable at a reasonable cost to develop and collect data and have a clear direction (i.e. an increase or decrease in indicator value should be unambiguous in terms of the CCA impact or characteristic being monitored) (GIZ et al., 2018). Furthermore, consider the SMART rules for indicators: they need to be: Specific, Measurable, Achievable, Relevant and Timebound.

When considering indicators for your monitoring, evaluation and learning plan, try to combine process, output and outcome indicators. When evaluated, this will provide a more robust and complete picture. Remember that the effects of CCA may not be determined for many years and there will always be effects that are not possible to monitor. Therefore, indicators must evolve and be adapted to capture changes in the system.

- **Process indicators:** Provide data and information on the progress in implementing CCA options, e.g. number of drought-resilient agriculture practices implemented by small-holder farmers in a given location.
- **Output indicators:** Prove data and information of the effects that the CCA option has had on goods and services, e.g. change in crop yield and type of small-holder farmers due to drought-resilient agriculture practices implemented in a given location.
- **Outcome/Impact indicators:** Provide specific data and information regarding the impact of the CCA option on its targeted stakeholders, sectors, or systems. The data is often more contextual and driven by the evaluation process. For example, include data on the measurable change in drought resilience among smallholder farmers in the area as a result of implementing the CCA option.

Box — H — Indicator sets relevant for CCA

- *World Development Indicators, World Bank*
- *Sustainable Development Goals Indicators, FAO*
- *Sustainable Development Goals Indicator Database, UN Stats*
- *Indicators in climate-ADAPT, European Environment Agency.*

Provide a summary of the key findings to the wider user audience and communicate the applied method.

Communication

The module on **Communication** provides a common understanding on risk communication and concrete steps on how to effectively communicate climate-related risks and the outcome of the CRA to different users and target groups. A concrete communication strategy should be developed, and results should be disseminated to different users and target groups for optimal communication of the results.

Communicating climate risk ideally is a transversal and continuous activity across all modules. A well-defined dissemination strategy will help to communicate the CRA to different target groups.

Key steps you need to address in this module:

- **Step 0:** Communication of objectives and intended scope
- **Step 1:** Review the scope of the communication approach
- **Step 2:** Elaborate tools and methodologies for climate risk communication
- **Step 3:** Implement your communication approach
- **Step 4:** Evaluate the success of the communication approach and the relevance of gender issues/ vulnerable groups
- **Optional step:** Communicate the degree of confidence in climate risk & vulnerability assessment findings: a participatory step-by-step approach

What do you need to implement in this module?

- Define the objectives and aim of the communication strategy
- Identify the target audience and its needs
- Specify the expected results and outputs of climate risk communication
- Apply a diverse set of communication tools
- Understand that the communication of climate risks does not only occur at the end of the assessment

OUTCOMES OF THIS MODULE

An approach on how to communicate climate risk with concrete communication measures and a climate risk communication strategy

Which (additional) tools and information does the **website** provide?

https://www.adaptationcommunity.net/climate-risk-assessment-management/climate-risk-sourcebook/

- A showcase of and links to best practices
- Additional guidance and literature
- The GIZ guideline on Climate Risk Communication (Eucker et al., 2022) climate-risk-communication.pdf (adaptationcommunity.net)

Required efforts

- Capacities required: Communication experts, along with domain experts of the sectors/risks addressed, graphic designers and cartographers together with the local project partners.
- The scope and depth of the communications approach will depend largely on the results of the CRA, its complexity, and the degree of co-production and resources available for professional guidance (e.g. graphics, editing, communications experts, etc.).

This module describes an activity that spans the entire CR-SB approach and CRA process.

Step 0 – Communication objectives and intended scope

This step helps to answer basic questions about climate risk communication and to integrate a climate risk communication approach as a common thread throughout your entire CRA.

What is climate risk communication?

Climate risk communication can be understood as a process of exchanging and sharing information about climate-related risks and their underlying drivers.

What is the purpose of your communication strategy? Who will be your target audience? What needs to be considered in climate risk communication?

It is important to reflect on these key questions from the beginning and adjust as needed throughout the process. These four key questions can serve as a guide for your climate risk communication:

- How to communicate effectively (method)?
- Who do you want to reach (users of climate services and information)?
- What to communicate (narrative)?
- What do you want to achieve (aim)?

How to identify and involve stakeholders in climate risk communication?

It is recommended to carry out a stakeholder analysis at the beginning of the CRA to determine whose interests should be considered. The degree of stakeholder engagement depends heavily on the extent to which they are affected by the identified risks, but also on their input into the proposed solutions and decision-making processes.

*Find more hints and instructions on this step in the Expert Material chapter **E 2.4.1.***

Step 1 - Review the scope of the communication approach

What changes and updates do you need to make to your climate risk communication strategy?

After developing your strategy in 'Scoping', review it regularly for new developments, changes, or modifications that require updating or revising your approach. The following guiding questions will help you continually reflect on your communication approach and keep users informed throughout the process:

- What opportunities for collaboration and reflection exist throughout the CRA process?
- What specific data sources and associated impact chain indicators need to be discussed by experts or in consultation with stakeholders?
- Have there been any changes or updates in your approach to the CRA methodology that need to be addressed and communicated?
- Are there preliminary or final results that need to be reviewed and discussed?
- What are the potential pathways for addressing climate change-related risks and vulnerabilities so that all stakeholders can become aware of the challenges and desired CCA outcomes in the sector or region?

When choosing a communication approach, you can consider the following questions:

- What needs to be communicated and what is your intention?
- What is the context of your CRA and its related communication strategy?
- What do you want to communicate and what do you want to achieve - tangible and intangible?
- What is the final scope of your approach to communicating climate risks?

*Find more hints and instructions on this step in the Expert Material chapter **E 2.4.2.***

Step 2 - Elaborate tools and methodologies for climate risk communication

Which communication tools are relevant for your context to communicate the results and outcomes of your CRA?

The ability to communicate climate risks appropriately is not just about communicating the results of a CRA directly to users. Successful communication is highly dependent on how information and results are shared and discussed. This should include a variety of ideas and different opinions to help users understand different points of view. In addition, space and time should be allowed for reflection, which ultimately leads to greater comprehension of the topic. Therefore, good communication will help to build rapport with target audiences.

This includes:

- Choosing the right tools and degree of participation.
- Producing the report and figures/maps.
- Preparing methodological approaches for communication.

Table 19 provides an overview of potential communication tools that are useful for the dissemination process, which can be integrated and adapted depending on your context as well as communication needs.

→ *Find more hints and instructions on this step in the Expert Material chapter* ***E 2.4.3.***

Table 19 : Potential communication tools for dissemination

No.	Category
Report	A comprehensive written document that presents the detailed results of the climate risk assessment. This format is suitable for professionals, decision-makers, and selected stakeholders.
Presentation	Oral presentation using visual aids such as slides, graphics, or charts. Suitable for presenting key findings of a climate risk analysis to a broader audience.
Information sheet (and poster)	Concise document summarising the main results and conclusions of the climate risk analysis. Ideal for decision-makers and executives with limited time.
Infographics	Graphic representations that visually convey complex information in an engaging and easily understandable manner. Infographics can be shared in print or online.
Newsletters	Regular publications sent via email or in print, providing updates, key findings, and relevant information about the climate risk analysis to a specific audience or stakeholders.
Interactive Web Portals	Online platforms that enable interactive visualisation of the climate risk analysis. Users can access data, explore different scenarios, and visualise relationships.
Stakeholder Workshops	Meetings with various stakeholders to discuss the results of the climate risk analysis, gather feedback, and collaboratively develop action options.
Media Campaigns (TV, radio and others)	Utilising mass media such as newspapers, television, radio, and social media to make the results of the climate risk analysis accessible to a wide audience. Radio or TV can be a very good medium to reach illiterate people.
Training and Capacity Building (incl. training workshops for multipliers)	Targeted training and capacity-building initiatives to impart knowledge about the climate risk analysis, especially to local actors and decision-makers involved in the implementation process. Multipliers are people who can reproduce training or information sessions to reach even more people.
Manuals	Comprehensive guides or handbooks that provide detailed instructions, methodologies, and tools for conducting a climate risk analysis, facilitating its replication and implementation.
Videos	Audio-visual presentations or documentaries that visually showcase the process, findings, and implications of the climate risk analysis, making it accessible and engaging to a wider audience.
Theatre Performances (incl. also songs)	Theatrical performances and dramatic presentations that creatively communicate the findings of the climate risk analysis, engaging audiences through storytelling and emotional connection.
Other Participatory Formats	Various participatory formats, such as focus group discussions, community dialogues, or participatory mapping exercises that involve active engagement and collaboration of stakeholders in interpreting and utilising the climate risk analysis results.

Step 3 - Implement your communication approach

Communicate in simple language, adapt your messages to the local context, and make them available in the local language(s) to increase public interest and awareness of your CRA. Integrating traditional knowledge and narratives into the core messages of the CRA ensures greater engagement, understanding, and ongoing dialogue among stakeholders. This can also promote acceptance and increase resilience. Be sure to communicate any potential disadvantages to specific communities, groups, or sectors that may be negatively affected during the CCA process. Do not forget to include vulnerable and marginalized groups that may not have access to mainstream communication channels. Tailor your communications to specific user groups. Consider the participation of an influential stakeholder in the presentation of the final product to have more influence on the relevant politicians. Include any names and/or logos of relevant and involved stakeholders to enhance the credibility and impact of the deliverable. Communicate the CCA process, potential trade-offs for specific communities, groups and sectors as well as unforeseen maladaptive consequences.

→ *Find more hints and instructions on this step in the Expert Material chapter* ***E 2.4.4.***

Step 4 - Evaluate the success of the communication approach and the relevance of gender issues/vulnerable groups

Consider the information channels and communication barriers experienced by different groups. How successful was your communication strategy? How did you reach out on gender issues and to vulnerable groups? After implementing the communication approach, it may be helpful to evaluate its impact using the following criteria:

- Relevance
- Efficiency
- Effectiveness
- Impacts
- Sustainability

→ *Find an 'Optional Module - Communicating the degree of confidence in a CRA: A step-by-step approach' in the Expert Material chapter* ***E 2.5.***

E - Expert Material

E - II. Modules 144

E – I.

Conceptual Framework

E 1.1. Systems perspective

An important conceptual approach that we promote is the systems perspective. A systems perspective can be understood as a lens of analysis that avoids describing actors, processes, or elements as isolated parts, but instead takes a broader perspective and views them as interdependent parts of a whole system. A systems perspective extends the traditional approach of identifying, monitoring, assessing, and learning from information and aims to better understand the complexity of how climate risks and CCA arise and interact within an environment. This is useful as it is not possible to account for all impacts or effects of climate risks or CCA, particularly over longer time frames and at larger spatial scales (Sillmann et al., 2022), which results in the need for prioritisation of what to address in analyses (Abel et al., 2016). A systems perspective enables you to better understand interactions among 'subsystems' within the larger system and identify elements such as key impacts, affected sectors or stakeholders and feedback effects. Users of this CR-SB are encouraged to approach aspects of their analysis with a systems perspective.

Systems are made up of different subsystems, elements and actors. A system is usually defined according to its elements within defined system boundaries (i.e. endogenous system elements) and outside of its boundaries (i.e. exogenous system elements) (Sillmann et al., 2022). It is up to the team carrying out the CRA to define what the system is, what is considered endogenous and what exogenous to the system. This will depend on the scope of the CRA.

For example, a simple system model that addresses river flood risks might consist of changes in precipitation, the storage capacity of a river, and an exposed element, such as a city, in a given spatial area. In this small case study, there will be elements that are not considered in this system, such as grain prices or average temperatures. For the CRA, the boundaries of the system and the elements you want to analyse must be well defined, which should be done in 'Scoping'. If the boundaries are broader, you will capture more information and interactions with less detail, so your analysis will be subject to greater uncertainty, and it may be difficult to identify targeted CCA options. An example of this might be a risk map at the regional or continental scale. However, when the system boundaries are narrower, less information and interactions are captured, but in greater detail, so the analysis can be more targeted to specific CCA options, however, you might miss important cascading and feedback effects which come from outside your defined system. This is likely, since we live in a highly connected world. An example might be a drought risk assessment in the upper watershed of a river that does not consider downstream impacts. How you define your system boundaries ultimately depends on your specific goals and the resources you have available (Sillmann et al., 2022).

It is important to note that system boundaries change due to changing climatic or social-ecological conditions. You should not rigidly define your system boundaries and define all elements and actors in advance, as you will discover new information during your risk assessment that should not be disregarded simply because it was not defined in the scoping phase. Therefore, a flexible approach where reflexivity and learning processes take place throughout the assessment can add value (Sillmann et al., 2022).

E 1.2. Climate Risk Assessment (CRA)

E 1.2.1. Risk criteria

The IPCC recommends five main criteria for identifying key risks and for assessing the severity of the risk to be used throughout this CR-SB:

1. Magnitude of consequences
2. Likelihood of consequences
3. Importance of the system at risk
4. Timing of the risk
5. Ability for risk reduction

The first two criteria are part of the 'Risk Analysis', while the later three are part of the 'Risk Evaluation'.

Magnitude of consequences

Magnitude assesses the degree to which a system is affected, should a specific risk materialise (O'Neill et al., 2022a). An assessment of magnitude can include aspects such as:

- the degree of consequences
- the size or extent of the system
- the pervasiveness of the consequences across the system (geographically or in terms of affected population)
- the irreversibility of consequences
- potential for impact thresholds or local tipping points
- potential for cascading effects beyond system boundaries

Table 20 shows classes of magnitude of consequences, applying the IPCC criteria mentioned above. The concrete criteria for an assessment of the magnitude of consequences should be case specific. Class 3 and 4 can be interpreted as 'severe' consequences, which are often the focus of a risk assessment

Table 20 : Classes to describe the magnitude of consequences and the respective criteria

	Class	Criteria: potential for consequences with the following magnitude/severity
Severe	4 Catastrophic/ very high	Major losses and damages, loss of system functionality, irreversibility of consequences, large extent, very high pervasiveness, high potential for impact thresholds or local tipping points, cascading effects beyond system boundaries, systemic risk.
	3 Critical/high	Significant losses and damages, disturbance of system functionality, long-term effects, large extent and high pervasiveness, potential for impact thresholds or local tipping points, cascading effects beyond system boundaries and systemic risk.
	2 Moderate	Moderate losses and damages, moderate disturbance of system functionality, effects are temporary or unfolding slowly with a moderate extent/pervasiveness.
	1 Negligible/low	No to low losses and damages. No disturbance of functionality.

Likelihood of consequences

A higher likelihood, especially of serious consequences, a priori represents a greater risk, regardless of the magnitude. There are no standard categories for the probability of consequences. In some cases, the probability of consequences can be described or classified at least qualitatively. Hazards or impacts of one type of event (e.g. heavy rain event, flood damage) are described in terms of frequencies, while impacts of slow-onset events (e.g. sea-level rise, salinisation of agricultural soils and biodiversity loss) must be described in terms of probabilities of occurrence within the next ten years (Table 21).

Table 21 : Proposal of likelihood classes for hazards and consequences of the event type or the slow-onset process

	Hazardous event		Slow-onset process	
4	Frequent	Likely to occur often in a lifetime (every 0 – 10 years)	Very likely	Very likely (90%-100%) to occur in the next ten years
3	Probable	Likely to occur several times in a lifetime (every 0 – 25 years)	Likely	Likely (66% - 100%) to occur in the next 10 years
2	Occasional	Likely to occur sometime in a lifetime (every 0 – 50 years)	As likely as not	As likely as not (33% to 60%) to occur in the next 10 years
1	Remote	Unlikely but still possible to occur in a lifetime (0 – 100 years)	Unlikely	Unlikely (0% - 33%) to occur in the next 10 years

The description of the likelihood must refer to a specific level of magnitude of consequences, a specific time frame (e.g. in a ten year period) and a reference time or warming level (current situation, near future) and may focus on the potential for 'severe' consequences that urgently need CRM.

Example: Under current climate conditions, severe (critical or catastrophic) consequences, such as the destruction of large parts of settlements and infrastructure, are unlikely, while moderate consequences, such as the disruption of road infrastructure, are occasional.

In cases with a very good basis of information and knowledgeable experts, severity and likelihood combinations could be summarised in a risk matrix (Table 22).

Table 22 : Example for a risk matrix

Frequency/ likelyhood of consequences		Remote/ unlikely	Occasional/ as likely as not	Probably/ likely	Frequent/ very likely
Magnitude of consequences	Catastrophic				
	Critical				
	Moderate				
	Negligible				

Key for the risk: very high | high | moderate | low

Magnitude and likelihood of consequences depend on the magnitude and dynamics of the risk drivers (hazard, exposure and vulnerability). For the CR-SB we recommend basing the assessment of consequences on a combination of an assessment of risk drivers and direct evidence or indication of consequences (e.g. past observations, literature or model output).

The IPCC bases the assessment of consequences mainly on literature and model output on climate impacts, but recommends conducting a risk-driver-based risk assessment in cases where data on consequences (e.g. impact model output) or evidence from extensive scientific literature is scarce. Since this is a common condition in the typical application cases of the CR-SB, we recommend following this approach to assess the magnitude of consequences. Furthermore, a proper assessment of risk drivers increases the understanding or risks and allows the researcher to identify entry points for CCA.

Other risk criteria:

Timing of risk. Risks that occur sooner, or that increase more rapidly over time, present greater challenges to CCA that would otherwise reduce risks. In addition, a persistent (as opposed to temporary) risk may pose a higher level of risk. Risks may persist due to the persistence of the hazard, exposure, or vulnerability. For example, the aging of a population will make it more vulnerable to mortality risk from extreme events. Age structure does not change quickly, so this increase in risk will be persistent. By contrast, a risk may increase temporarily due to a short-term increase in the vulnerability of a population due to conflict or an economic downturn (O'Neill et al., 2022a).

Ability to respond to risk. Risks are more severe if there is limited ability to reduce exposure or vulnerability through various CCA options for both human and ecological systems, and/or to reduce hazards (through mitigation). Systems with few CCA options or systems that face limits to CCA will have increased levels of risk. For example, coastal areas where hard engineering protection measures are not feasible may instead use ecosystem-based CCA such as coral reef restoration. However, coral reef restoration as a CCA measure has hard limits, starting at 1.5C GMT, which then results in increased risk as temperatures rise and limits are surpassed. Risks are also more severe if there is limited ability to cope with or respond to the consequences, should they occur (O'Neill et al., 2022a).

Importance of the system at risk. Essential systems and functions such as food security or human health may be perceived as more important than certain economic sectors such as tourism or mining. The importance of a system may also depend on how many other systems depend on that specific system. For instance, ecosystems or water are the basis for many other systems and functions such as agriculture or health.

Severity of risk

The final assessment of the severity of risk should be based on a set or all of the five risk criteria and could be based on the criteria reported in Table 23:

Table 23 : Classes to describe the severity of risk and the respective criteria

	Class	Criteria: potential for consequences with the following magnitude/severity
Severe	4 Very high	Frequent, very likely and major losses and damages within important systems. Loss of system functionality, irreversibility of consequences, large extent, very high pervasiveness, high potential for impact thresholds or local tipping points, cascading effects beyond system boundaries, systemic risk. Low ability to respond or adapt to the risk.
	3 High	Likely significant losses and damages, disturbance of system functionality, long-term effects, large extent and high pervasiveness, potential for impact thresholds or local tipping points, cascading effects beyond system boundaries and systemic risk. Moderate ability to respond or adapt.
	2 Moderate	Likely moderate losses and damages, moderate disturbance of system functionality, effects are temporary or unfolding slowly with a moderate extent/pervasiveness. Moderate to high ability to respond or adapt.
	1 Low	No to low losses and damages. No or rare disturbance of functionality, high ability to respond or adapt.

E 1.3. Stakeholder Engagement

E 1.3.1. Why is stakeholder engagement important?

Assessing and managing climate-related risk is a highly complex and cross-cutting process that is of relevance to a diverse set of stakeholders, ranging from scientists, policy- and decision-makers, practitioners, private sector representatives, NGO representatives, to citizens and most notably vulnerable groups. Actions taken by one actor may limit or expand the scope of action of other actors and encourage inaction or 'free-rider' behaviour if those who benefit from the resources do not pay for them. Therefore, it is important to identify the relevant actors and understand their respective interests, positions, and responsibilities from the beginning of a risk assessment. Engaging these stakeholders in the different steps of the risk assessment encourages their buy-in and increases their trust in the outcomes of risk assessments. Generally speaking, people are more willing to accept results if they have been part of the process by which these insights were co-produced.

Comprehensive stakeholder engagement also enhances the use of local and specialised knowledge, such as lay, experiential, and intuitive knowledge that can lead to the emergence of new ideas that are urgently needed to deal with complex societal problems such as climate change.

Stakeholder engagement is crucial for mainstreaming co-produced risk information into evidence-based policy- and decision-making for CRM (Hagenlocher et al., 2020). The Sendai Framework, for example, suggests that a more effective and coordinated management of (climate-related) risks hinges on closer public and private collaboration (UNISDR, 2015). To promote coordination, information exchange and harmonisation between stakeholder groups, the UN Office for Disaster Risk Reduction (UNDRR) set up the Stakeholder Engagement Mechanism (SEM) (UNDRR, 2020). Participatory decision making is a core element to the principles of good governance[1] for human development as proposed by (UNDESA et al., 2012). Additionally,

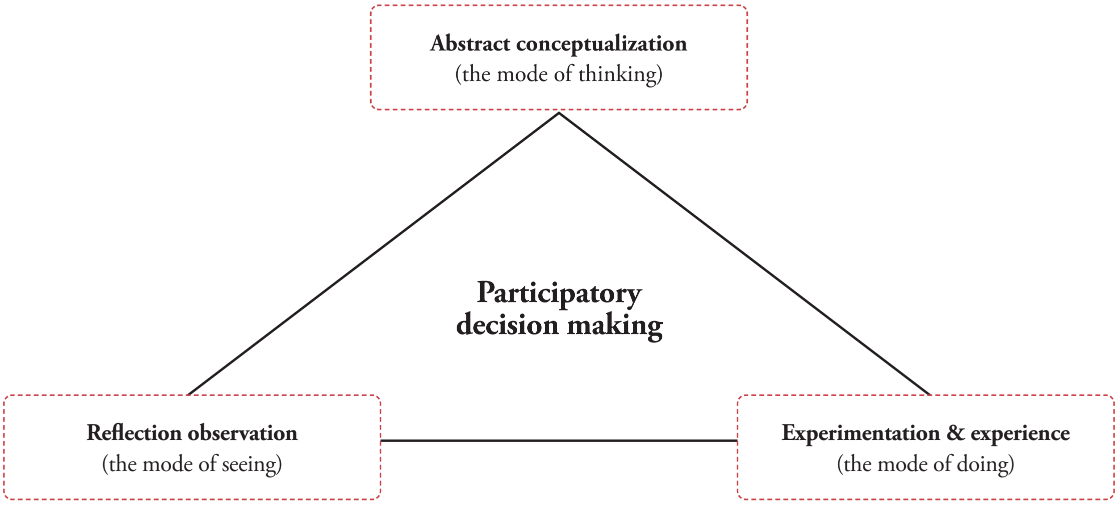
[1] In this report we understand governance as the institutions, rules, conventions, processes, and mechanisms by which policy is made and implemented. The principles of good governance comprise participation, representation, fair conduct of elections; responsiveness; efficiency and effectiveness; openness and transparency; rule of law; ethical conduct; competence and capacity; innovation and openness to change.

the World Meteorological Association identifies potentially strong merits of participatory decision making (Associated Programme on Flood Management et al., 2006).

Supporting decision making in CRM with new modes of learning through stakeholder engagement

Traditionally, decision making was thought to mainly consist of intellectual effort, or thinking, which draws on science, planning, facts, and verbal capacities. However, according to Mintzberg and Westley (Mintzberg and Westley, 2001), there are at least two other modes that can be employed. One is seeing, which involves art, visioning, imagining, and the visual representation of ideas. The other is doing, which makes use of craft, learning through experience, venturing, and the visceral (Figure 30). This claim can be further supported by the experiential learning theory (Kolb, 2015), which posits that the process of learning (understood broadly as the totality of human experience) should include and balance the following: abstract conceptualisation (the mode of thinking), reflective observation (the mode of seeing), as well as active experimentation and concrete experience (the mode of doing).

Figure 30 : The elements of participatory decision making and learning
(Own visualisation based on Mintzberg and Westley (2001) and (Kolb, 2015))



Through stakeholder engagement processes, social and experiential learning between science and society can take place (Jahn et al., 2012; Pahl-Wostl and Hare, 2004) which is an important factor for overcoming rigid positions in complex decision making processes, such as the management of climate-related risks. Concrete participatory methods can take very different forms and therefore employ only one, two or all three modes of learning as described by Mintzberg and Westley (Mintzberg and Westley, 2001). Stakeholder engagement approaches covering the mode of thinking comprise, for example, expert interviews, focus groups, a methodology that combines qualitative and quantitative methods to investigate the subjective views of those directly involved in a particular topic. Participatory approaches that employ the modes of thinking and seeing comprise, for example, participatory scenario building and modelling, participatory vulnerability analysis (PVA), Theory of Change (ToC), qualitative systems mapping and rich pictures. Finally, participatory approaches employing all three modes of learning are, for example, role-play simulations, serious games, and policy simulations. As continuous stakeholder engagement is critical for the success of a risk assessment, more detailed information on specific participatory stakeholder engagement methods and their applications will be presented in the description of the individual steps.

E 1.3.2. Different levels and depths of stakeholder engagement

There are different levels of stakeholder engagement, starting from simply informing or consulting with stakeholders to strong and continuous partnerships at all stages (Arnstein, 1969). While most levels of engagement, except the first informing (through dissemination), involve a two-way interaction between the project team and the stakeholders, the expected outcomes of each level of engagement differ. For example, while a partnership approach can lead to common goals and action, the expected outcome of consultation is simply that the views of stakeholders are considered.

The level of engagement and thus the participatory approaches used depend on the context (Jetoo, 2019) and may change over the time of the risk assessment process. Moreover, different groups of stakeholders for each level of engagement may be set up within a risk assessment project. For example, a core-team of stakeholders engages in continuous co-production partnerships, an extended team of stakeholders for regular consultations on specific topics/purposes, and a larger group of stakeholders for less frequent dissemination and information events.

Participatory processes for stakeholder engagement in development assistance

Development corporations have a long history of engaging with communities at the local level through participatory approaches. One widely known approach and methodological toolbox is the 'Participatory Rural Appraisal' (PRA), which started to evolve in the late 1980s (Chambers, 1994). In its initial development it was known as Rapid Rural Appraisal and is now referred to as Participatory Learning and Action (PLA). PLA includes various techniques which target issues of group dynamics (e.g. role reversals), sampling exercises (e.g. community mapping, wealth ranking/scoring, transect walks), interviewing (e.g. semi-structured interviews, focus group discussions and visualisations including mapping, Venn diagrams, timelines, matrix scoring). Methods are applied in the context of (socially oriented) research but mainly in development practice and are therefore relevant also in the impact chain context. A central objective of PRA/PLA is learning and self-reflection which should be facilitated through the exercises, but also should be applied by the participants to communicate and formulate their views and needs and facilitate the exploration of different interests.

As a specific instance, Participatory GIS (PGIS) approaches emerged as a spontaneous merger of PLA and GIS and is the use and application of different tools and methods "to represent peoples' spatial knowledge for spatial learning, discussion, information exchange, analysis, decision making and advocacy" (Rambaldi et al., 2006). For instance, PGIS approaches allow the integration of satellite and/or drone map data, together with GPS recordings, to develop georeferenced representations. There are a variety of guidebooks and experiences available, such as the Enhanced Vulnerability and Capacity Assessment (EVCA) from the IFRC (***https://www.ifrcvca.org/***), or related guidebooks on PGIS and risk/vulnerability assessment (Kienberger, 2014; Kienberger et al., 2009).

Usually, there are many practitioners available who can facilitate participatory approaches. The following crucial questions should be considered and raised when implementing participatory approaches at the local level (Rambaldi et al., 2006):

- Whose GIS/data/information is it?
- Whose questions are addressed?
- Who sets the agenda?
- What will happen when experts leave or when donor funding dries up?
- What is left with those who generated the data and shared their knowledge?

Lessons learned from implementing stakeholder engagement processes in practice

The successful implementation of any stakeholder engagement process requires sound planning and depends on the integration of all interests. Any dissatisfaction of participants with the content or form of a participatory process can have a negative impact on the substantive outcomes of the collaboration. Thus, the following list, building on Prutsch et al. (2014) and Schinko and Bednar-Friedl (2022), summarises important points in preparing, implementing and postprocessing a successful stakeholder engagement process.

Important considerations when preparing a stakeholder engagement process

- The objectives of the participatory engagement, identified against the backdrop of the key contextual conditions, determine who will be involved and to what extent.
- All interests that are to be integrated and considered in a certain decision context should be represented by stakeholders. To this end, comprehensive stakeholder analysis and mapping should be conducted, including stakeholder identification, stakeholder differentiation and categorisation, and identification of relationships between stakeholders.
- The key participatory process features (e.g. open dialogue and deliberation, power delegation; participation of citizens vs. organised stakeholders) have to be defined.
- The method for stakeholder engagement (e.g. workshop, focus group, role play, serious games) should be selected based on the objectives of the participatory process and tailored to the number of participants. Methods can also be combined.
- Existing participatory methods can only serve as a starting point for similar case specific stakeholder engagement process and have to be adjusted according to the respective local needs as well as environmental, socio-economic and governance framework conditions. Existing participatory methods can only serve as a starting point for similar case specific stakeholder engagement processes and have to be adjusted according to the respective local needs as well as environmental, socio-economic and governance framework conditions.
- The resources available for the participatory process (time, money, experienced personnel) must be determined in advance.
- The time resources required from participating stakeholders need to be considered, and the integration process has to be explained in detail from the very beginning (number of events, schedule, expected results, etc.).
- Guard against high expectations on the part of the stakeholders by communicating their power from the start: Will the stakeholders only be informed about the process, will they be consulted, or will they have a say in decisions?
- The roles of stakeholders in the participatory process must be clear. Of course, roles may change over the course of the process; for example, certain stakeholders may be information providers at the beginning, but active supporters in the later implementation of the project.
- The roles of scientists, experts, and process leaders must also be clearly communicated.
- From the start, explain what will happen with the results of the process.

E 1.4. Gender and differential vulnerability

Vulnerability of people

One frequently cited example of evidence for social-group-specific vulnerabilities is Hurricane Katrina, that killed approximately 1,800 people in the underprivileged coastal areas of Louisiana and Mississippi, USA in 2005. Overall, the people most affected by this storm were the elderly. However, in New Orleans a disproportionate number of the victims were impoverished, people of color and lacking the resources to prepare for, avoid, and recover from the event (Brunkard et al., 2008; Jonkman et al., 2009; Diakakis et al., 2015).

Apparent is also the unequal impact of water scarcity on different sections of exposed populations. Generally speaking, more vulnerable groups are typically not connected to piped systems, suffer from inadequate access to safe drinking water as well as sanitation services and – in the case of agricultural systems – are unlikely to be able to rely on irrigation systems in case of droughts (Grasham et al., 2019; Rao et al., 2019).

Why are women and sexual/gender minorities often more vulnerable to climate risks?

In many countries, and notably in rural contexts, women disproportionately rely on natural-resource-dependent, climate-sensitive livelihoods and often carry the responsibility for ensuring household water and energy supply from natural resources. Globally, women represent 37% of the agricultural workforce but this percentage rises to 48% in low-income countries where women (and men) are often involved in a wide spectrum of livelihood-sustaining activities (FAO, 2020). However, women often have limited access to and control over natural resources and are left out of decisions over the management and distribution of natural resources and their benefits. During extreme or unpredictable weather, women tend to work more to secure food, leaving them less time for income generation or education (UNFCCC, 2022b). Girls may drop out of school to help their mothers, and often instances of child marriage increase during or after a disaster event, resulting in a vicious cycle of poverty, inequality and vulnerability (UNFCCC, 2022b).

Sociocultural norms or caring responsibilities can prevent women from migrating to places where they would be less exposed or vulnerable to climate change risk. These sociocultural norms can also prevent women from engaging in income-generating activities, which can pose particular challenges if wage-earning men have emigrated. Similarly, people belonging to LGBTIQ+ groups may face discrimination which negatively affects their ability to find employment or access services, as well as lead to higher rates of mental health problems (Meyer, 2003). LGBTIQ+ communities are often already marginalised groups and climate change, and institutional responses to it, are likely to exacerbate already existing structural inequalities since disaster responses can reinforce heteronormative and discriminatory patterns (Whitley and Bowers, 2023).

Climate change risk may lead to conflict over resources, which disproportionately affects already vulnerable groups. According to the Office of the High Commissioner for Human Rights (OHCHR), existing gender inequalities are exacerbated by climate change risk where the impacts of climate change may lead to increased barriers to access to goods and services, or where conflict erupts over resources. In conflict situations, already-vulnerable groups (including women in all their diversity and LGBTIQ+ minorities) can be exposed to sexual and gender-based violence, exploitation and trafficking (OHCHR, 2022).

The importance of a gender-focused approach to CRA

Women in all their diversity and LGBTIQ+ minorities have specific needs when it comes to climate risk which are linked to their socio-economic status and their persistent roles in society (e.g. as caregivers, subsistence farmers, and household managers). Individuals may be especially vulnerable due to multiple and intersecting areas of marginalisation and discrimination, for example, a single mother who has no formal education or a transwoman with a disability. This is referred to as 'intersectionality'. In addition, sociocultural norms may limit an individual's agency and options for adapting and responding to climate risk. A gender-focused approach to CRA can ensure that data is collected that captures these specific needs and inequalities.

A gender-focused CRA can inform equitable climate risk mitigation and CCA planning that not only accounts for differential vulnerability but also seeks to redress the inequalities faced by women in all their diversity and LGBTIQ+ minorities. Conversely, an assessment that excludes data on differential vulnerability reinforces and perpetuates the inequalities experienced by women in all their diversity and LGBTIQ+ minorities, as these inequalities remain invisible in analysis, policy and practice (Brown et al., 2019). The integration of gender issues in your CRA may vary from 'gender-blind' (your CRA does not consider gender) to 'gender-transformative' (your CRA seeks to transform the root causes of gender inequalities) (United Nations University, 2021).

Effective CCA strategies must be informed by a robust understanding of the various ways that different societal groups are affected by climate risk and their different possibilities to act in response to such risk. Gender-disaggregated data highlights disparities between gender groups and allows for the monitoring and evaluation of progress towards climate risk mitigation and gender equality. Furthermore, a disaggregated CRA lays the foundation for designing CCA strategies that proactively address multiple vulnerabilities, giving marginalised groups the possibility to become agents of change.

E 1.5. Impact Chains

E 1.5.1. Introduction

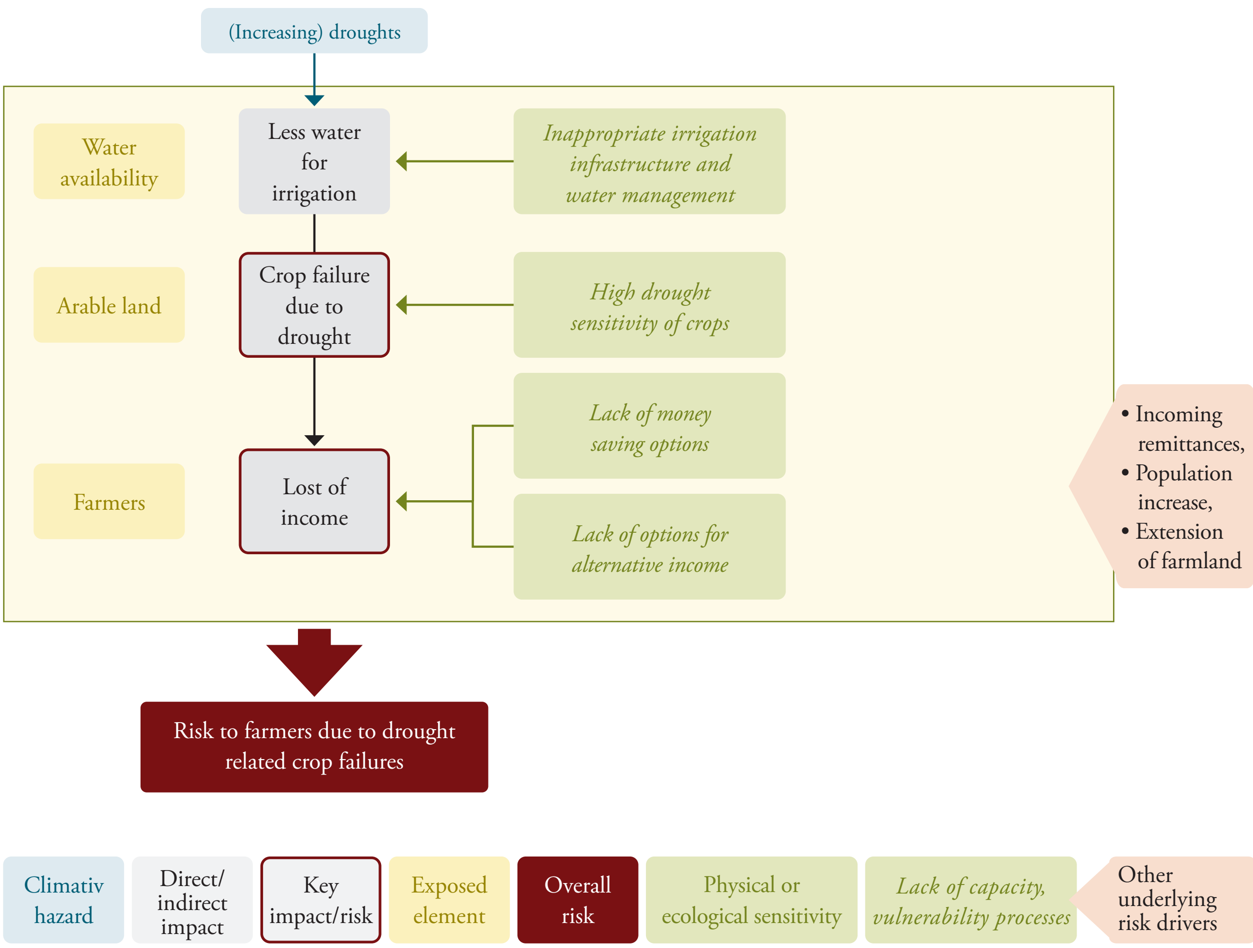
Impact chains are a powerful tool that allows us to conceptualise and represent climate risks in a specific context. This chapter intends to provide guidance on the implementation of impact chains as an effective methodology to elicit, conceptualise, represent and share a body of knowledge about climate risks within a given geographical and temporal scope.

In particular, although the impact chain methodology can be (and often is) used flexibly in participatory approaches, a more systematic and structured approach is recommended (Figure 31).

Scope of impact chains

Each impact chain is developed - and must be interpreted - within a given geographical and temporal framework, which defines the limit of validity of the underlying assumptions and the individual impact chain components. Although the scope of the impact chain is not per se a component of the impact chain itself,

Figure 31 : The elements of an impact chain
(own illustration)



it should be clearly stated and described and shared together with the impact chain. The main information describing the scope are:

- **Operational framework.** This includes the main purpose of the impact chain, the implementation details (expert workshop, desktop analysis, machine-generated, etc.)
- **Geographical context.** Indication of the specific region where the impact chain is supposedly valid (mostly relevant for the connection elements).
- **Temporal context.** Indication on the timeframe the impact chain is related to (e.g. present time, short-term future, long-term future, or an indicative range as 2060-2090).

Elements

The 'elements' are the main building components of the impact chain. They represent the objective elements playing a role in the risk assessment. In a visual depiction of impact chains, the elements can be depicted as boxes. Impact chain elements fall within one of seven types (Table 24).

Note: *Not all elements must be used in an impact chain, but every impact chain should include at least one hazard, the relevant exposed elements, one or more impacts and the related vulnerabilities.*

Table 24 : List of pre-defined types of elements of an impact chain

No.	Category
Hazard (climatic)	Hazard refers to the possible, future occurrence of natural or human-induced physical events that may have adverse effects on vulnerable and exposed elements and systems. It includes climatic influences, events or trends that may result in an impact and possibly a risk (with damage or loss).
Impact	Possible (adverse) effect caused by a hazard or another impact
Exposure	People, assets, systems, functions and values possibly exposed to impacts and susceptible to being damaged, disrupted or negatively affected.
Vulnerability	Vulnerability refers to the propensity of exposed elements such as human beings, their livelihoods, and assets to suffer adverse effects when impacted by hazard events. Vulnerability is related to predisposition, susceptibilities, fragilities, weaknesses, deficiencies, or lack of capacities to cope and adapt that favours adverse effects on the exposed elements.
(Potential) CCA options	Measures that are pursued and implemented to address climate risks or exploit beneficial opportunities depend on, first, the portfolio of adaptive capacity and, second, the agency and structure whether and how adaptive capacity is or can be accumulated and activated. Measures can be structural (e.g. engineered/conventional infrastructure), institutional (e.g. creating funds for small-scale on-farm CCA), behavioural (e.g. changing behaviour as a result of increased awareness) or ecosystem-based (e.g. nature-based solutions).
Risk (Key Risk)	The potential for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems. Combined impacts, exposure elements and vulnerabilities that describe potential risks (a key risk is highly relevant in the scope of the impact chain and should be prioritised in the assessment and evaluation phases).
External Risk Driver + Root Causes	Non-climatic driver that may significantly alter the socio-economic or environmental situations and possibly amplify negative consequences of impacts but cannot be mitigated or controlled within the scope of the impact chain.

Element features

Each element can be assigned several features to provide a thorough characterisation of the impact chain (Table 25).

Table 25 : Features of an element in an impact chain

Element Feature	Description
Type	The element type must be one of the types listed in **Table 24**.
Label	Synthetic description/title of the element for visual depiction.
Description	Extended description of the element providing all necessary information to understand the role and significance of the element in the IC scope.
Source	Source of the information about the element, if already standard, or authoring institution/author.
References	References to the information sources used to justify, validate and possibly monitor the element.
Confidence	Confidence in the validity of the element, based on the type, amount, quality, and consistency of evidence (e.g. mechanistic understanding, theory, data, models, expert judgment) and the degree of agreement. Confidence is expressed qualitatively (or by means of ordinal numbers) (IPCC, 2021a).
Relevance	Significance/relevance of the element within the scope of the IC should be assessed independently of the other elements. If possible, provide a reference to a standard or a commonly agreed definition. Assessing the relevance is usually based on a complex evaluation using empirical evidence and expert judgment, and thus is a subjective process.

E 1.5.2. Connections

Each connection represents a relationship between two elements in the impact chain. All connections have a direction that indicates the direction of the relationship between the two elements.

Types of connection

The possible connection types are defined in the following table (Table 26).

Table 26 : List of possible connection types

Connection type	Description
Leading to	Indicates a (likely) causal relationship between the two elements. This relationship can only be defined amongst elements of type 'hazard (climatic)', 'impact' and 'risk'. E.g. an.: An increase of average temperature is deemed to lead to melting of glaciers
Impacting on	Indicates mainly a relationship between an impact and an exposed asset. E.g. an increase of power outages is deemed to **impact** industrial production
Affecting	Indicates a generic relationship where one element is assumed to affect the second one in some way (not necessarily in a causal link). This relationship can be defined among every type of element but could be partially hidden in the visualisation. E.g. an increase in average temperature is deemed to **affect** the phenological cycle of vegetation
Relating to	This relationship can be used to indicate connections between elements
Mitigating	This relationship can be defined only between CCA options and vulnerability elements or between CCA options and impacts. E.g. improving irrigation techniques is deemed to **mitigate** the decrease in crop yield

Connection Constraints

To ensure consistency in the representation of climate-related impacts and risks, a few constraints must be observed on the connecting elements. The following table lists the constraints (Table 27).

Table 27 : Connection constraints

The table can be read from left to right. For instance, hazard elements can connect to other hazard elements, as well as to impact elements, but should not be connected to exposure elements.

Elements	Hazard	Impact	Exposure	Vulner-ability	CCA	Risk	External risk driver
Hazard	↙	↙		–		–	
Impact		↙	↙	–	–	↙	–
Exposure							
Vulnerability		↙				↙	–
CCA		↙		↙			
Risk	–	–	–	–	–	↙	–
External risk driver						↙	

Each connection might be characterised by the features listed in the following table (Table 28).

Table 28 : List of features of a connection

Connection Feature	Description
From element	Label and type of the starting element of the connection (it must be an element that is already defined)
To element	Label and type (see Table 26) of the ending element of the connection (it must be an element that is already defined)
Label of the connection	Synthetic description/title of the connection, also for visual depiction
Type of connection	Type of the connection. It must be one of the types listed in Table 27
Description	Extended description of the connection providing all necessary information to understand the role and significance of the element in the impact chain scope
Source	Source of the connection, if already standard, or authoring institution/author
References	References to the information sources used to justify, validate and possibly monitor the connection
Confidence	Confidence in the validity of the connection, based on the type, amount, quality, and consistency of evidence (e.g. mechanistic understanding, theory, data, models, expert judgment) and the degree of agreement. Confidence is expressed qualitatively (or by means of ordinal numbers) (IPCC, 2021a)
Relevance	Significance/relevance of the connection within the scope of the impact chain

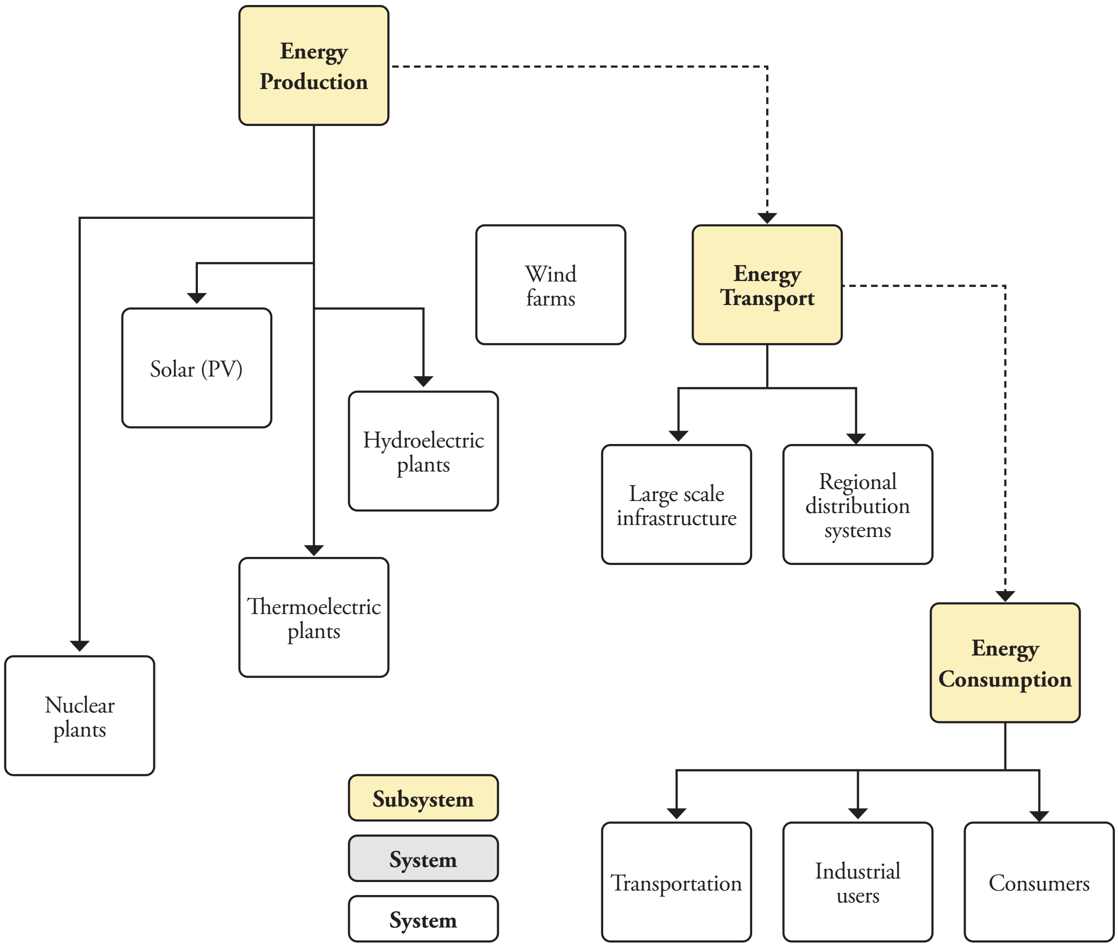
This information, along with the features associated with the individual elements described in Table 25, can be arranged in two tables and saved to a file (e.g. in excel format) for archive, sharing, or later analysis of the impact chain. This is important to ensure a more systematic, sound and sustainable management of the associated information and allow for better reuse and update of such conceptual models.

Building impact chains for sectorial risks

This section provides guidance on the implementation of an impact chain representing the climate risks related to a given sector. An example is shown in Figure 32.

Figure 32 : Example of the conceptual module for the energy sector

The yellow boxes represent the considered subsystems; the white boxes represent the exposed elements (own illustration)



Proposed workflow:

1. Describe the sector in terms of systems, subsystems, and exposed elements. A simple conceptual model can be elaborated to highlight which subsystem the potentially exposed elements belong to. A simple conceptual model can be elaborated to highlight the subsystem to which the potentially exposed elements belong. This activity can refer to and integrate the phase of risk identification. An example of conceptual model for the 'energy sector' is shown in the following Figure 32, where the yellow boxes represent the considered subsystems, and the white boxes represent the exposed elements.

2. Create a table listing the following factors for the sector: exposed elements, hazards, impacts, vulnerabilities, and underlying risk drivers.
3. Populate the table with the exposed elements from the conceptual model mentioned above, and list potentially significant hazards and vulnerability factors in the table, as well as relevant underlying risk factors. The elements can be listed freely, and the table can be populated within a collaborative workshop.
4. Transfer all factors listed in the table into an empty canvas (can be a physical or a virtual board, for instance) and connect the factors following the indications provided above (considering the constraints). Try to cluster the elements according to their associated subsystem and according to their type.
5. If relevant, add CCA elements connecting to the vulnerability elements or the impacts they mitigate.

E 1.5.3. From impact to risk

While impact chains should include hazard, exposure, impact and vulnerability elements, they do not necessarily have to include explicitly risks, at least in preliminary formulations. The concept of risk is often associated with concepts such as risk ownership, severity (of consequences), probability, etc. These are complex topics and call for strong involvement of stakeholders in the development process of the impact chains. It is, therefore, easier to start off with impact chains without explicitly considering risks, and only in a second phase, when reviewing the impact chain, select a subset of impacts as potential candidates for risk or add new ones.

From impact chains to storylines and risk pathways

The impact chains provide a very intuitive conceptual (and visual) depiction of the complex interplay of factors contributing to risk. This can be an effective starting point to generate a narrative description of this interplay while ensuring consistency and (as much as possible) objectivity. This can be done for instance in the form of a storyline.

As soon as one or more impacts are labelled as a possible risk (or risks, or relevant risks, or relevant key risks, etc. it is possible to draw one or more paths within the whole impact chain that connects one or more hazards to the risk itself (passing through other components) as well as to one or more exposure components. This can be defined as a 'risk pathway' and represents (loosely) a combination of factors (and possibly events) that are, at least partly, in a relationship among themselves and ultimately eventually contributing to the risk. A risk pathway does not necessarily completely explain the risk, but visually highlights the (most relevant, hopefully) main elements contributing to the risk along the standard DRR (now also IPCC compliant) risk framework.

The risk pathway might be useful to:

- generate narratives (storytelling) of risk within complex situations (either sector-based, or event-based, for instance) effectively including socio-economic vulnerabilities, lack of coping capacity, etc.;
- better understand entry points for specific risk mitigation or CCA (if successful, these may 'break' the risk pathway, and the earlier the pathway is interrupted by mitigation or CCA actions, the larger the set of consequences that can be reduced);
- better understand and analyse consequences of events or cascading impacts and their timing (where relationships also convey information on the time within which the impact unfolds) and to
- help attribute consequences to impacts in case of indirect or delayed impacts.

E 1.5.4. Example impact chains

Below are examples (Figure 33, Figure 34, Figure 35) of impact chains created based on the description of key risks in the latest IPCC Sixth Assessment report (O'Neill et al., 2022b). Further impact chains can be found on the CR-SB website.

Figure 33 : Impact chain 'Risk to the population from increased heat'
from IPCC key risk Chapter 6: Cities, settlements and key infrastructure & Cross-Chapter: Coastal cities (own illustration)

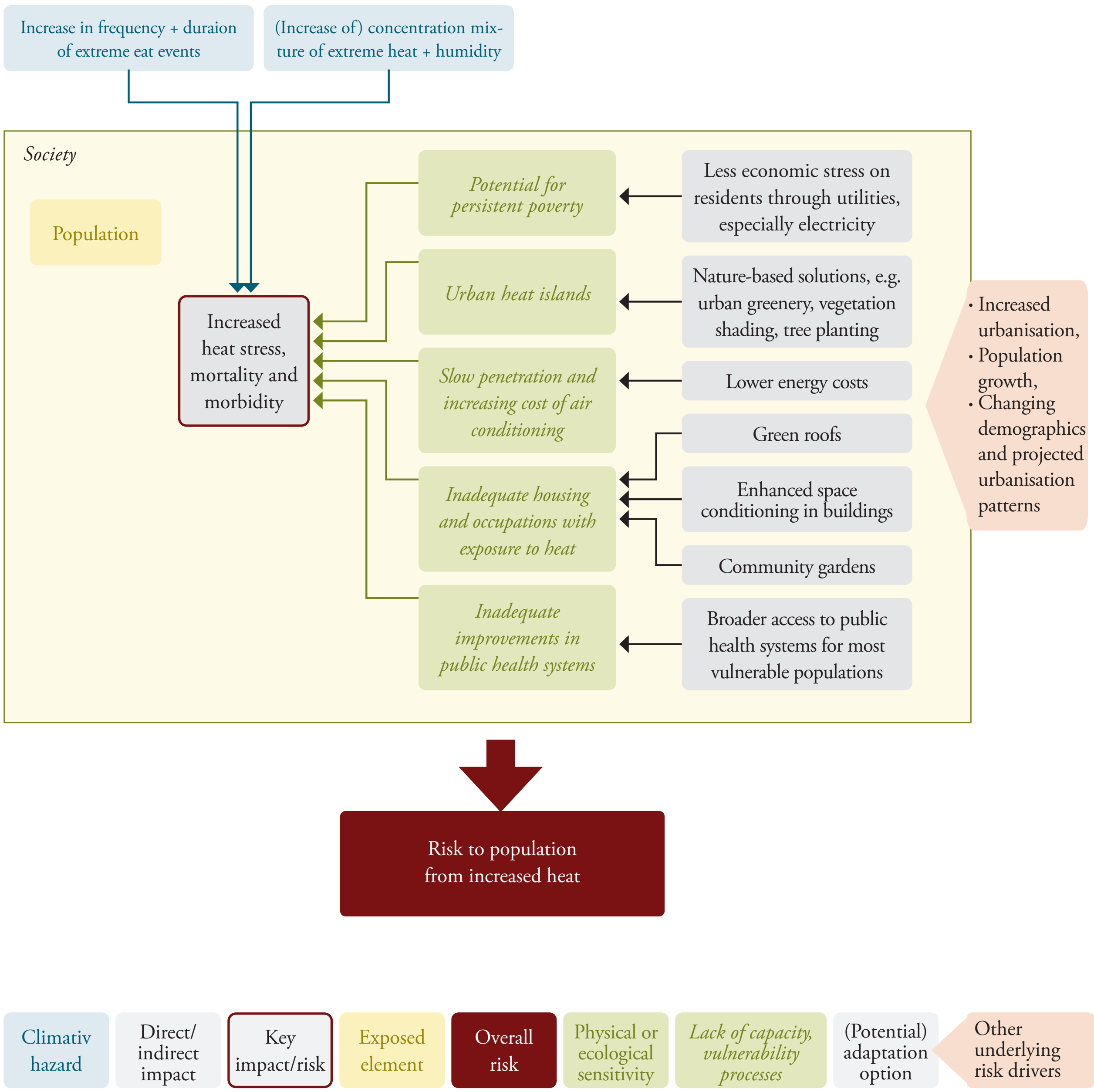


Figure 34 : Impact chain 'Risk of damage to urban infrastructure from flooding and severe storms'
from IPCC key risk Chapter 6: Cities, settlements and key infrastructure & Cross-Chapter: Coastal cities (own illustration)

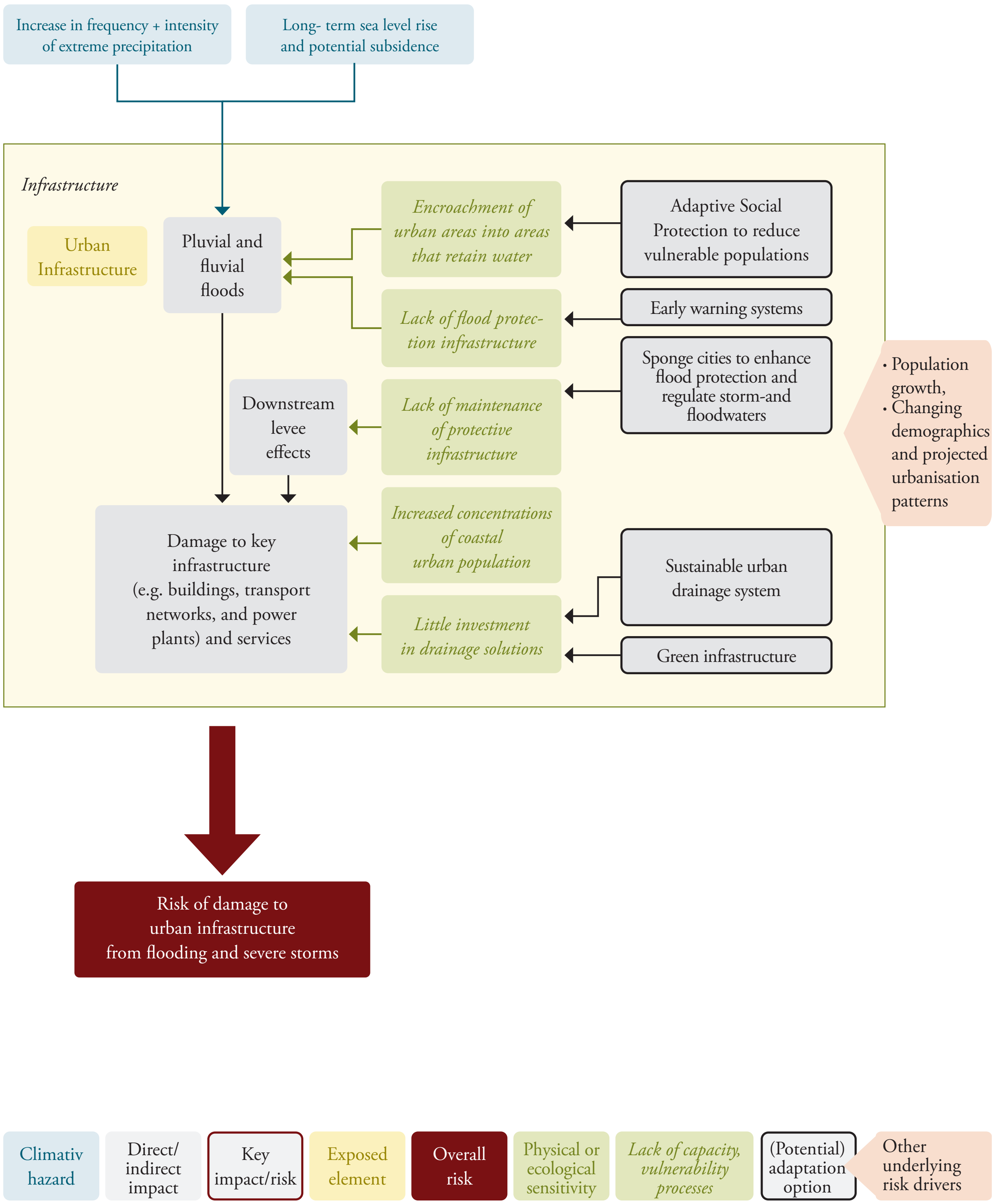
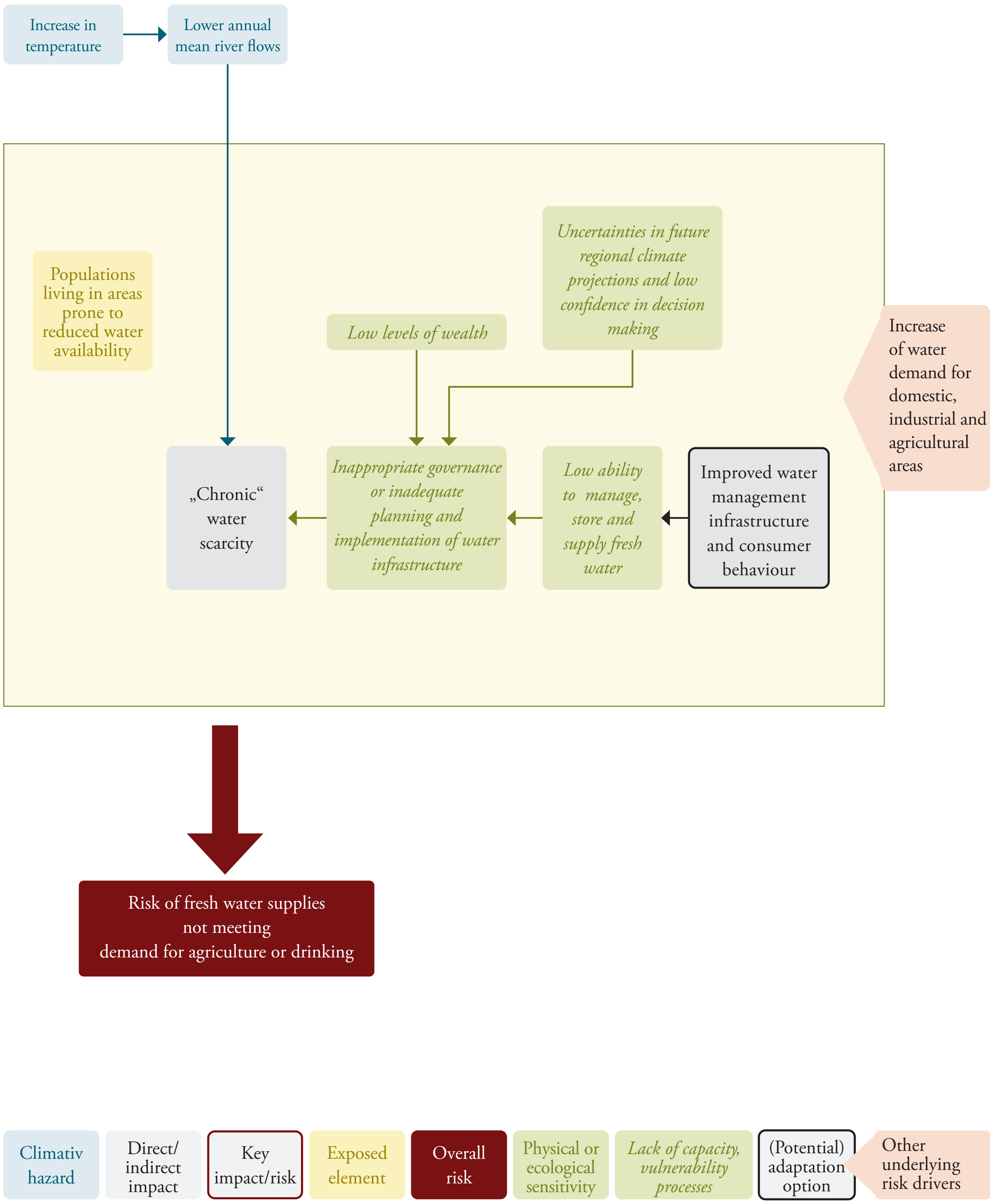


Figure 35 : Impact chain 'Risk of fresh water supplies not meeting the demand for agriculture or drinking' from IPCC key risk, Chapter 4: Water (own illustration)



E – II.

Modules

E 2.1. Data & Information

E 2.1.1. - Step 2 - Data gathering

Type of data

The data and information you need to assess climate-related hazards, impacts, exposures, and vulnerabilities were likely collected using a variety of methods. Below is a brief overview of the different ways your data may have been collected or generated:

- **Measurements:** physical measurements are made for indicators such as humidity, water runoff, and soil moisture using thermometers, hygrometers, gauges, and other instruments. They also include 'remote sensing methods', such as analysis of satellite data to determine land use/land cover or land degradation. Many assessments rely on data from measurements to quantify climate-related hazard factors or exposures.

> **TIP**
>
> **Example questions**
>
> Has the rainy season in the region shifted in the last twenty years? By how many weeks? What were the consequences of this shift in the rainy season and where did it occur? And has rainfall increased or decreased during the rainy season? What were the effects of this? What other factors exacerbated these consequences?
>
> This could be used to identify influencing factors and narratives related to the amount and timing of rainfall.

- **Censuses and surveys:** the data used to quantify vulnerability factors come largely from censuses, statistics, surveys, and similar approaches. For example, they provide information on household income, education, and traditional irrigation techniques. As with physical measurements, the expertise required for this method of data collection is highly context-specific but critical to obtaining solid results. Expertise may be needed in, for example, designing questionnaires, conducting surveys, selecting representative samples, analysing statistical data. Socio-economic data obtained through censuses or surveys can be further aggregated - for example, from the commune to the provincial level - and extrapolated before being used in your risk assessment.

- **Modelling data:** the data for your assessment may also come from models, e.g. climate models or related 'impact models' such as crop models or hydrological models. These are complex computational tools that integrate a variety of indicators to represent the functional relationship between different input parameters in a simplified way. Consequently, models are often used in risk assessments to estimate climate-related hazards (e.g. changes in temperature or precipitation) and potential future impacts of climate change (e.g. runoff for a given amount of precipitation, change in crop yields due to temperature changes). Due to the complexity of the models, this is typically a time- and resource-intensive method of data development that requires the expertise of research centres, universities, and private companies. Again, the quality of the model is highly dependent on the quality of the input data, which is usually derived from measurements. For example, the best flood model will not work without appropriate elevation models and relevant time series of meteorological data.
- **Expert consultations and participatory approaches:** the methods described above may not be appropriate for every risk assessment. Data may not be available in the required quantity or quality, or there may not be sufficient time to generate data specifically for the assessment. A very local scope in an area with poor data availability may also be a challenge. In this case, you can draw on the knowledge of local stakeholders.

Keep in mind, however, that stakeholder consultations are based on respondents' experiences and perceptions and are therefore subjective. Local knowledge could be captured through participatory workshops or interviews with selected experts and stakeholders.

Data and information gathering

It is likely that a certain set of data is readily obtained, however, other data sets may be deficient in quality or absent entirely, thereby necessitating the exploration of alternate resources. Consequently, it is important to prioritise the resolution of the following questions:

What kind of data do you need to inform the risk assessment?

While there is no universally applicable solution, most assessments will require measured or modelled data for the climate-related hazards and exposure factors. Impacts, vulnerabilities (sensitivity and coping capacity), and external drivers may be available as measured or modelled data, however, often must be enhanced by adding information generated in consultations with experts and local stakeholders.

The resolution of your assessment (e.g. 5 x 5 km, community level, national level), the extent of the area covered (e.g. one or two communities, a whole country, an entire region) as well as the outputs you aim to produce (e.g. maps, diagrams, narratives) are crucial in deciding what data to search.

In addition to the decisions reached during the 'Scoping', it is important to address the following questions:

- Who are the persons, institutions and partners in the country and the specific area that you are working in that can support the data collection process? Does this list of contacts include people with local knowledge, people from diverse and vulnerable groups?
- What kind of output is planned for your assessment? Is it necessary to compare risk values and indices of risk components between different areas? Do you plan to present the assessment results as static or interactive web maps?
- What kind of data and information is needed to meet the requirements of the communication strategy?
- What resources (time, resources, personnel, skills) has the CRA project management dedicated to data management?

Based on your answers to the questions above create a list of all the data required structured by hazard, exposure, impact, vulnerability and external risk drivers you are covering with your assessment (Table 8 in the main document).

Does the data already exist or does it have to be generated?

We recommend checking first check whether institutions at the local, national, or international level provide statistics, model results, or spatial data on the information you are seeking. The summary table developed in 'Scoping' should provide ideas for relevant institutions to contact. The large number of institutions and experts needed to obtain your data often makes this one of the most time-consuming steps, especially since renegotiations are often required. Table 29 provides some examples of regionally and globally available datasets.

TIP

Depending on the thematic scope of your assessment, your points of contact may include statistical offices, meteorological authorities and government departments covering agriculture and the environment and so on. 'National Spatial Data Infrastructures' are another key entry point for data acquisition.

Depending on the geographical extent of the area being examined, the use of locally or internationally accessible datasets may be applicable. Several organisations provide access to data sets, such as population distribution, while the IPCC and research institutions play a similar role by providing climate data.

TIP

If you are using data from different agencies, you should familiarise yourself with their data-sharing policies, which can be either relatively open or more restrictive. Obtaining data may also require formal agreements with the data-supplying agencies. Be sure to respect all proprietary rights when disseminating and publishing data or products derived from it.

Table 29 : Some examples of regionally and globally available datasets

Category	Data provider	Data elements	Weblink
Climate observations	CRU	1961-1919 monthly mean temperature and precipitation gridded observation series at 0.5° spatial resolution	https://crudata.uea.ac.uk/cru/data/hrg/
	GPCC	1961-2019 monthly precipitation gridded observation series at 0.5° spatial resolution	https://opendata.dwd.de/climate_environment/GPCC/html/fulldata-monthly_v2022_doi_download.html
	ERA5	1961-2020 hourly reanalysis series of minimum and maximum temperature and precipitation at 0.25° spatial resolution	https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-single-levels?tab=overview
	ERA5-Land	1981-2020 hourly reanalysis series of minimum and maximum temperature and precipitation at 0.1° spatial resolution	https://cds.climate.copernicus.eu/cdsapp#!/dataset/10.24381/cds.e2161bac?tab=overview
	WFDE5	1979-2019 hourly bias-adjusted ERA5 series of minimum and maximum temperature and precipitation at 0.5° spatial resolution	https://cds.climate.copernicus.eu/cdsapp#!/dataset/10.24381/cds.20d54e34?tab=overview
	CHELSA v2.1	30-arc second resolution 1981-2010 monthly climatologies of temperature	https://www.envidat.ch/#/metadata/chelsa-climatologies
Future climate projections	Worldclim	Gridded climate data; only for global level applications	http://worldclim.org
	Cordex	Gridded downscaled future climate data	https://cordex.org/
	Worldbank	Historical and future climate, vulnerabilities, and impacts	https://climateknowledgeportal.worldbank.org/
	Copernicus	Historical and future climate data	https://cds.climate.copernicus.eu/cdsapp#!/home
	IPCC regional atlas	Observations and model simulations	https://interactive-atlas.ipcc.ch/
	KFW	Climate country factsheets	https://www.climate-service-center.de/products_and_publications/fact_sheets/climate_fact_sheets/index.php.en
Impacts	CRED	Collection of impacts of disasters	https://public.emdat.be
	UNDRR	Disaster loss data	https://www.desinventar.net/index.html

Category	Data provider	Data elements	Weblink
Land cover	Copernicus Global Land Service	100m resolution land cover	https://land.copernicus.eu/global/products/lc
	ESA	10m resolution land cover	https://esa-worldcover.org/en/data-access
	ESRI	10m resolution land cover	https://www.arcgis.com/apps/instant/media/index.html?appid=fc92d38533d440078f17678ebc20e8e2
Cropland	NASA	30m Cropland cover	https://www.earthdata.nasa.gov/learn/articles/gfsad?utm_source=eo-announce&utm_medium=email&utm_campaign=articles
Population	Worldpop	100m resolution population distribution	https://www.worldpop.org/
	LandScan	1km resolution population distribution	https://www.eea.europa.eu/en/datahub/datahubitem-view/eea383c1-e3df-449c-b5b7-8198c5a38759
Buildings	Microsoft	Building footprints	https://github.com/microsoft/GlobalMLBuildingFootprints
Power Plants	WRI	Global Power Plants Database	https://datasets.wri.org/dataset/globalpowerplantdatabase
Energy infrastructure	Worldbank	Energy infrastructure	https://energydata.info/dataset
Water management	FAO	Aquastat database on dams and irrigated areas	https://www.fao.org/aquastat/en/databases/
Baseline data	Open Street Map	Baseline geographic data	http://download.geofabrik.de/
	Natural Earth	Baseline geographic data	https://www.naturalearthdata.com/
Hydrology	Hydrosheds	Stream networks, watershed boundaries	https://hydrosheds.org/
Topography	USGS SRTM	30/90m resolution elevation model	https://earthexplorer.usgs.gov/
Imagery	USGS	Satellite imagery and products	https://earthexplorer.usgs.gov/
Administrative areas	GADM	Global administrative boundaries	https://gadm.org/
Various spatial datasets	HDX	Various spatial datasets on a country level	https://data.humdata.org/
Development indices	Worldbank	Worldbank National Development Indices	https://data.worldbank.org/

What can you commit in terms of time and other resources for generating data?

Ideally, you will find all the data you need for the risk assessment at various institutions in the country or region concerned. However, if the data is not available or is of insufficient quality, you may decide to collect data yourself. You must carefully consider the costs and expertise required for data collection. Some basic rules apply here:

- To obtain meaningful results, observations of biophysical indicators such as precipitation, temperature, and run-off must be made over long periods of time – often over decades. Because of the time and expense involved, this method is certainly not practical for your risk assessment. Fortunately, however, most countries can provide such data. If you need highly localised data, stakeholder interviews may be a worthwhile alternative.

- Socio-economic data such as average household income, average size of household and livelihood strategies can be captured in surveys. The time and cost involved depend largely on the sample size. A representative survey may cover an entire country or only a few communities. At the sub-national level, surveys can be an effective way to gather information not captured by national institutions, such as perceptions of climate and environmental change. Be sure to consult a local expert who can help design the survey, select a representative sample, and analyse the data.

- Modelled data are both time and resource intensive and typically require measured data as input. However, for national or supra-national assessments, it may be worth investing several months in developing regional climate or hydrology models. To achieve meaningful results, you need to ensure that you have access to the necessary modelling skills. As you collect data, also inquire about the availability of model results. Be aware that you should also check the model outputs to see if the quality is satisfactory.

- Expert judgement and stakeholder workshops can be a good, fast way of generating information that cannot otherwise be obtained. This is usually the case at a very local level - such as a village or community - which is rarely covered by detailed statistical data and where climatic and hydrological characteristics are too specific to be captured by models. This local knowledge - captured by participatory methods as well as scoring and ranking - can either complement or replace surveys. It is important to remember, however, that information obtained in this way is always subjective. It is also difficult to replicate and limited in precision and spatial differentiation. A balanced selection of experts and stakeholders increases the chances of obtaining meaningful results.

Once you have collected your data from the available data sources, you can proceed to the next steps and ensure the quality of your data. You may find that this step uncovers major data quality issues that will take you back to Step 1 of this module. If you decide to collect your own data, you should carefully consider the quality issues discussed in Step 2 when planning your data collection.

Data and information quality check

Data and information are vital to any risk assessment and the quality of the results depends to a great extent on the quality of the data (or conversely, 'garbage in, garbage out'). Once you have gathered your data you will need to conduct a quality check. Ideally, you already have the quality criteria listed in mind while collecting data. In practice, however, you may first gather the data and then choose the most appropriate data set. For that purpose, use these questions as a guide:

Are the data in the format you expected? Are all the files legible and ready for further processing?

The data can be provided in various formats, such as Excel files or CSV, or in the more complex formats used for climate data (e.g. 'netCDF'). Make sure that you are able to read and process the data. If not, the data provider may need to provide an additional explanation of the formats; alternatively, you may need outside expertise to convert the data. If you want to attempt this yourself, there are conversion tools available on the Internet. In the worst case, if the data is not readable or cannot be processed, you will need to redefine your assessment area or find alternative data sets.

Is the temporal and spatial coverage as planned?

Geographical coverage and timeframes may vary among different data sources, so determine whether they can be combined and compared. Where data are missing or inconsistent, find out whether you can source additional data from measurements, censuses or stakeholder consultations.

Are there any missing values or 'outliers' in your data?

If your datasets fail this quality check – and you are unable to apply any of the remedies described above – you will need to consider another approach. This may be an alternative data source, a proxy, or an alternative factor (e.g. distance to school instead of census data on education levels) or alternative means of data acquisition such as expert input. As a last resort you may need to modify the indicator list from 'Risk Analysis'. 'Risk Analysis' and 'Risk Evaluation' are closely linked and may involve iterative steps.

TIP

Data collection and management

- Contact each data provider you identified in 'Scoping' – Step 3, i.e. local authorities, research institutions, NGOs and other organisations and enquire about the quality of data available and if and under which conditions the data can be shared.
- For the online data sources you identified, view the data online or download a subset, read the documentation and if the quality of the data is fit for purpose, download the required data. Check Table 29 and the CR-SB website for online resources.
- Check the quality of the data (make sure it comes in a format you can work with, check the data visually) and metadata.
- Note down gathered data sets and their quality parameters in a data summary sheet.
- Where you have more than one data set covering the same topic, conduct a quality assessment and select one of the datasets to be used.

Data and information management

Once datasets are collected and checked for quality, they should be stored in a common database to avoid the risk of redundancy and data loss. This might range from a simple data collection in a structured set of folders to more complex databases (e.g. Excel spreadsheets, geo-databases, Access databases, distributed web-based databases). You may need to transform different types of data into a common data format (e.g. coordinate system for spatial data), perhaps utilising export and transformation routines from multiple software products. If you are working with multiple partners and stakeholders, you should ensure that they can all access the different datasets required for further future analysis. Depending on the scope of your assessment you may also need to assign responsibilities for database management and maintenance.

The documentation of metadata is an important element in data management. Metadata describes the content and characteristics of the different datasets and provides instructions for interpreting values. This includes where and when the data were obtained and analysed, the institution responsible for them and instructions for searching and other functions. There are international standards (such as ISO 19115) that provide guidance on structure and mandatory fields for metadata (International Organization for Standardization, 2014). Standardised metadata editors are also often included in GIS software products. Although this is a time-consuming exercise, experience has shown the importance of documenting data, particularly when qualitative or quantitative questions regarding your data arise. Insufficient knowledge about data from third-party organisations can also lead to duplication of effort.

TIP

If you are planning to use your risk assessment for M&E, you may need to retrieve data after an interval of several years. Ensure that you store your data, including metadata, carefully and systematically – along with your assessment methodology and results – so that you can repeat your risk assessment in the future.

Setting up a structure for data management. How to store the data and analysise products?

Data collection and management for a risk assessment is a resource-intensive activity. Nowadays a large variety of datasets are freely available. Part of the data collection process is to verify the quality and adequacy of the various data sets available. The following points are important to properly manage the data collected for the assessment in a resource-efficient manner:

- Set up a clean folder structure where you differentiate original, active and output datasets.
- Follow a data naming convention.
- For each dataset store its metadata, using as a minimum the ISO norm 19115 (i.e. spatial scale, currency, completeness, spatial coverage, thematic resolution, accuracy, provenance, coordinate system, error or limitations, license restrictions).

What pre-processing do I need to conduct in order for the data to be visualised and analysed?

After you have collected and quality assessed the data you need, carry out some pre-processing. Complete the following steps:

- Create a copy of the original dataset and move it to the active data folder.
- Re-name the data according to an appropriate file naming convention.
- Set the data to your area under review.
- Set any spatial data to the project coordinate system.
- Clean the data, e.g. check for inaccuracies in the geometries of spatial datasets and correct them, and remove unnecessary information.
- Document any modifications made to the original data and make sure all team members are aware what the data represents so it can be appropriately used by others and if required can be shared with partner organisations.

Visualisation of data for communication within the project team and to stakeholders

You will need to visualise the data in different phases of the assessment including, for instance, in workshops held at different stages of the assessment. Depictions of the data can be different types of charts, tables, or maps. To ensure a high quality and consistent look and feel of these information products make sure to plan for these products as early as possible. They may be used to inform stakeholders at workshops and serve as a basis with which to elicit information. To ensure high-quality visualisation products prepare template layouts for maps, charts and tables and set up an overview of the required information products.

Free and open-source tools for data management and GIS analysis and mapping

There are several free tools that enable data management, sharing and visualisation, as well as GIS analysis and mapping. GeoNode ***(www.geonode.org)*** is a tool that allows the visualisation and sharing of geospatial and tabular data online and it contains tools for metadata creation. QGIS ***(www.qgis.org)*** is a fully-functional desktop-based GIS software providing features for editing, analysing and mapping.

Resources for further information:

- Future trends in geospatial information management: The five-to-ten-year vision is available from ***https://ggim.un.org/meetings/GGIM-committee/10th-Session/documents/***
- A guide to the role of standards in geospatial information management is available from ***http://standards.unggim.ogc.org/index.php***
- Why information matters is available at ***https://internews.org/wp-content/uploads/legacy/resources/150513-Internews_WhyInformationMatters.pdf***

E 2.1.2. - Climate Data and climate scenarios

Information on past trends and future climate projections are core pieces of information needed for any CRA. Depending on the spatial extent of your area under review, the resources available, the methodology applied and the data available, the data gathering differs. For a local-scale (small-scale) assessment the available information on past observations and future projections may not be fully representative (the available data are too coarse and/or of poor quality), and thus the information gathering will consist of expert and stakeholder consultations. In stakeholder consultations, however, you should in any case present climate change trends for the larger area. You can use this information to match existing or generated quantitative data with climate changes perceived by local stakeholders. Both stakeholder workshops and expert consultations thus serve to collect information on the occurrence of extreme events that are not covered by the measured and modelled information. The following sections describe where climate data and information can be found, what climate projections can tell us, and the aspects in which they are limited.

In the scoping phase of your CRA ('Scoping'), you should have defined the time periods and the emissions scenarios (RCPs)/Shared Socio-economic Pathways (SSPs) for future climate information. Climate projections are available as either multi-model ensembles or as individual models. Whereas multi-model ensembles show the most plausible projected outcomes of change in the climate for a chosen SSP, individual models allow a better understanding to understand variability across climates. Note that individual models can have substantial bias and we recommend that you use multi-model ensembles in your analysis.

Review existing climate information

First, review the information available in the relevant national reports, IPCC atlas, CORDEX or other portals such as the Interactive Atlas or ***https://climateinformation.org/*** (Table 29). Also, contact partners/academic institutions that are knowledgeable about your region and ask them about the availability of climate data. Check with meteorological and hydrological services (Hydromet), particularly at the national level, for past climate data and any available future projections. Ensure that the information provided by the competent authorities is not limited to the data itself, but includes sufficiently detailed metadata, including a description of the quality. For observational data, quality means length of time series, reliability of measurements, and spatial distribution of stations. Also check the availability of data on past extreme events such as heavy rain, storm events, frost, heat waves, and heavy snowfalls.

> **TIP**
>
> **Additional knowledge and expertise**
>
> Climatologies are defined as the mean climate of reference for a specific area over a certain period. They may already exist or are generated for your assessment.
>
> As a general rule, 30-year averages are used on a monthly, seasonal, or annual time span They are characterised by a certain internal variability, i.e. changes in climatic conditions from year to year. Depending on the location and specific variables, this variability from year to year can be very large, large, or small ***(see https://climateknowledgeportal.worldbank.org)***.
>
> To effectively address climate-related hazards using climate model outputs, it is crucial to conduct a comprehensive analysis of climate change signals. This analysis entails a deep understanding of climate models, including their inclusion and representation of relevant processes and their ability to accurately replicate past climate patterns. Evaluating these models has revealed consistent discrepancies in their outcomes, which can complicate the assessment of climate change-related hazards and their associated impacts. Nonetheless, there exist techniques to rectify or adjust these model results, commonly referred to as bias correction methods.

- Conduct a meeting with Hydromet office representatives to understand how the data were collected and processed. Based on the information obtained about the quality of the data, decide whether to use it. High-quality timeseries of observations from at least the last 50 years will already provide you with valuable information about trends in a changing climate that you can use in your assessment.
- Conduct a workshop with representatives of various stakeholders to gather information on past observations of trends and extreme events.

Information on climate trends and future temperature and precipitation forecasts is available on online portals such as:

- The Interactive Atlas of the IPCC (***https://interactive-atlas.ipcc.ch/***) is a tool for flexible spatial and temporal analysis of selected observed and projected global (CMIP5 and CMIP6) and downscaled regional (CORDEX) climate change information used in the Sixth Assessment Report (AR6) of the IPCC. It includes a few so-called climatic-impact-drivers identified to understand the impacts and risks to ecosystems and society.
- The Climate Knowledge Portal of the Worldbank (***https://climateknowledgeportal.worldbank.org/***) information products are available per country. You can download climatologies derived from observed data as monthly 30-year averages at a spatial variation of approximately 50km resolution, as annual data, as a seasonal cycle, or as a time series. The portal also provides aggregated values per administrative area (subnational). Trends, variabilities and significance for change are available for the last 70-, 50- and 30-year periods, as well as maps, tables and different chart visualisations. Climate projections can be viewed as

projected mean or change, as a seasonal cycle, time series or heat plot. Annual, seasonal and monthly data are available for download. You can select different projected climatologies (climate variables), emissions scenarios or SSPs. Projection data is presented at approximately 100km spatial resolution.

- The ***Climateinformation.org*** portal provides site-specific reports, a data access platform as well as the CLIMPACT website (***https://climpact-sci.org/indices/***), to calculate climate indicators. The service provides instant summary reports of climate change for any site on the globe, and easy access to many pre-calculated climate indicators, based on state-of-the-art in climate science, of the past, present and future and climate information guidance.
- Current climate models are not able to compute extreme events. There are globally available databases (EM-DAT, DesInventar, Table 29) covering some of these events, but only if the impact was beyond a given threshold. Thus, a great number of events (smaller impact) may not be recorded in those databases. Future climate projections may also be available from national authorities or any other regional and international sources (IPCC atlas, CORDEX, other climate service portals, etc).

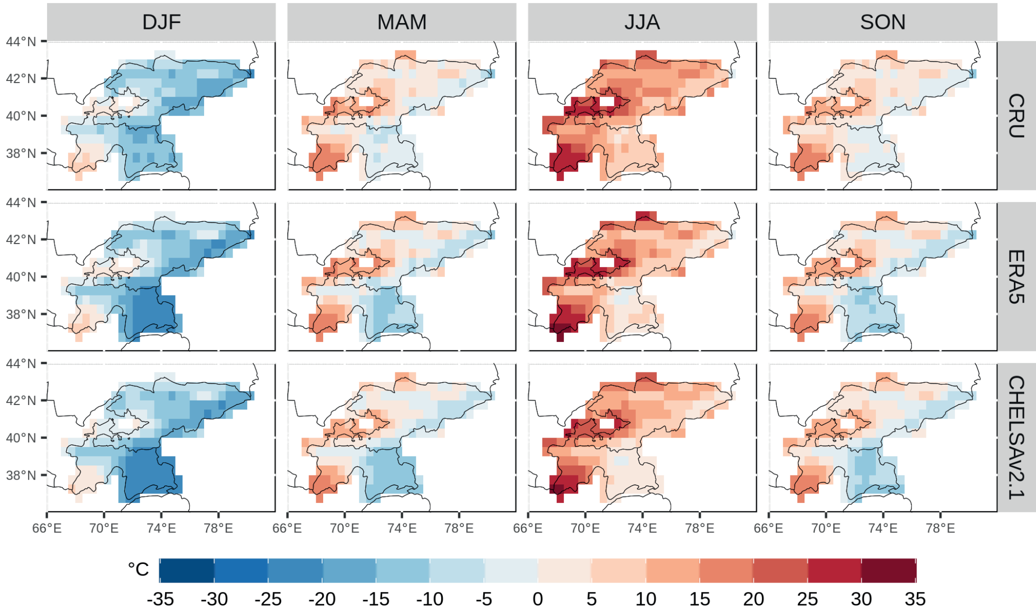
See the CR-SB website to further links to climate data portals and country factsheets. See the CR-SB website for further links to climate data portals and country factsheets.

Collection and processing of climate observations

This section gives some indications and an example workflow to conduct if you do not have access to past climate data and need to generate it. Firstly, you need climate observations to analyse the past and current climate conditions allowing you to identify trends. Secondly, you also need observation data as a reference to validate and calibrate model simulations (bias-correction). A historic time series of in-situ observations collected by national meteorological services represents your primary source of local climate information. These data are usually provided as a station, i.e. point data, which you use to create gridded datasets enabling a continuous representation of the climate distribution over the area under review. If for your area there is no suitable national gridded observation data available, e.g. because the time series is too short, the data is unreliable or the records are not suitable in terms of spatial distribution, you can use existing global data to characterise the past and future climate. See ***Table 29*** for a list of publicly available global products. We suggest analysing multiple past climate products as this allows a better understanding of the robustness and uncertainty of the extracted information. In order to assess the differences among the considered data sources, extract 30-year averages for seasonal climatologies and compare the spatial distributions for both temperature and precipitation for each dataset (Figure 36 and Figure 37). In your comparison analysis identify what causes the differences between observations and reanalyses. The differences could be, for example, due to the lack of weather stations in remote areas leading to underestimations of interpolated observations in these areas. Knowledge of how the different datasets were calculated is required in order to assess their accuracy. Based on your analysis of the available datasets choose the one most suitable and derive 30-year mean values of temperature, precipitation, and other bioclimatic indicators.

Figure 36 : 1981-2010 Seasonal climatologies of mean temperature (top) and precipitation extracted from different climate data products gridded onto a common 0.5° resolution grid (bottom)

(Skrimizea et al., 2023)



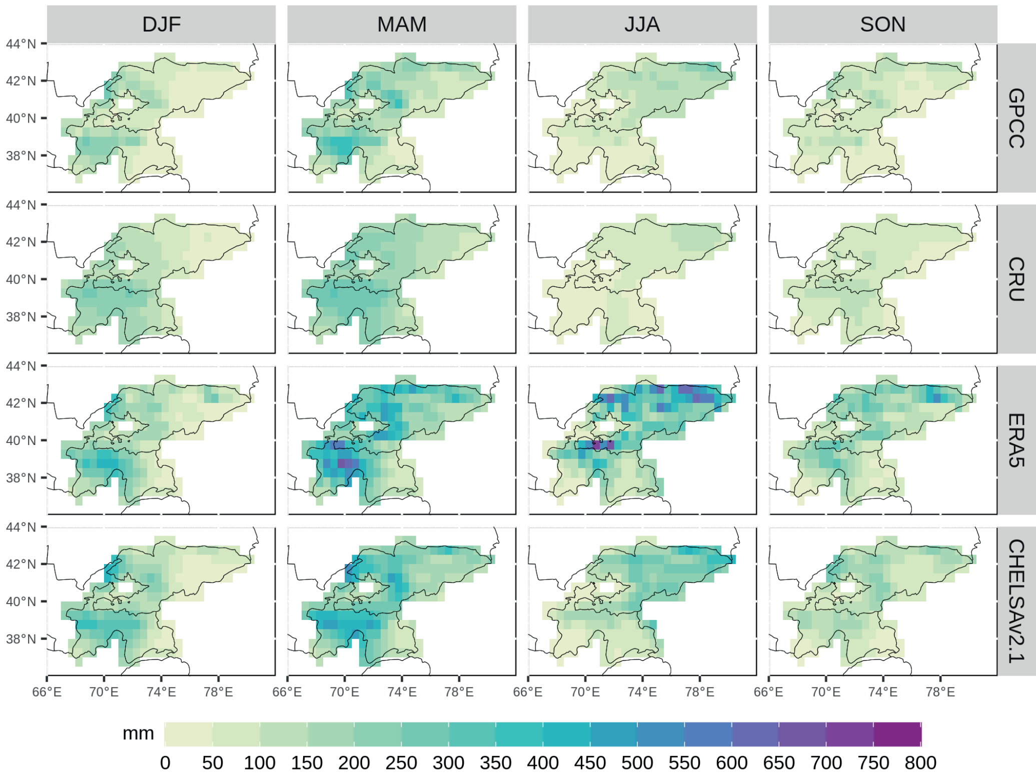
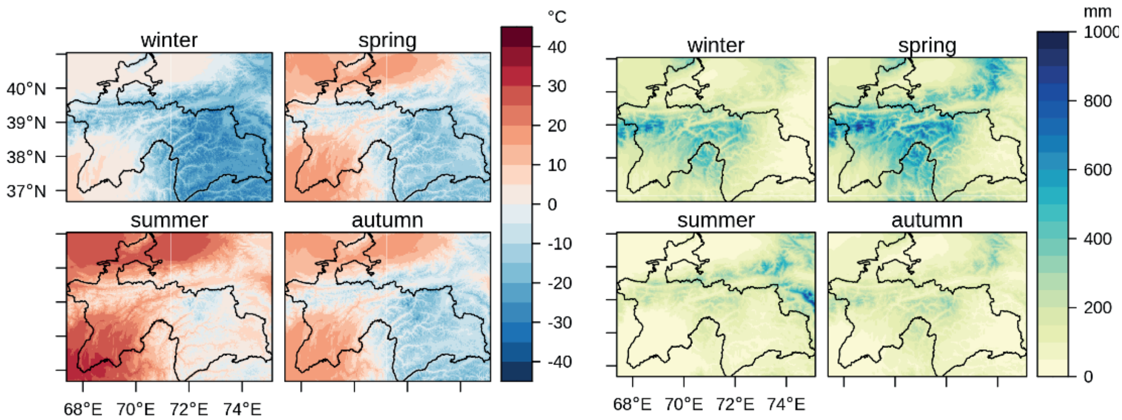


Figure 37 : 1981-2010 Seasonal climatologies of mean temperature (left) and total precipitation for Tajikistan (right).

The maps are based on the 1-km downscaled ERA5 reanalysis from CHELSA database (Skrimizea et al., 2023)



Collection and processing of future climate projections

You can derive data on future global projections for your area under review from the most recent global simulations, such as for instance provided by Coupled Model Intercomparison Project Phase 6 (CMIP6) available on ***www.cordex.org***. For the analysis you collect daily temperature and precipitation simulations from 1950 to 2100 from an ensemble, in this case, of 23 GCMs and for the selected scenarios (Socio-economic Pathways): you may want to select a moderate emissions scenario and a high emissions scenario. Next, you evaluate the models against the available observations data to better assess the variability and discrepancies of the ensemble simulations. Before computing the various metrics, you first re-grid all models to a common grid. Subsequently, you compare each model with observations regarding the mean annual cycle, interannual variability, mean climate conditions, spatial distribution and long-term trends (Skrimizea et al., 2023). After you have identified the models performing best for your area under review you might decide to discard some of the models and continue the analysis with a subset of models.

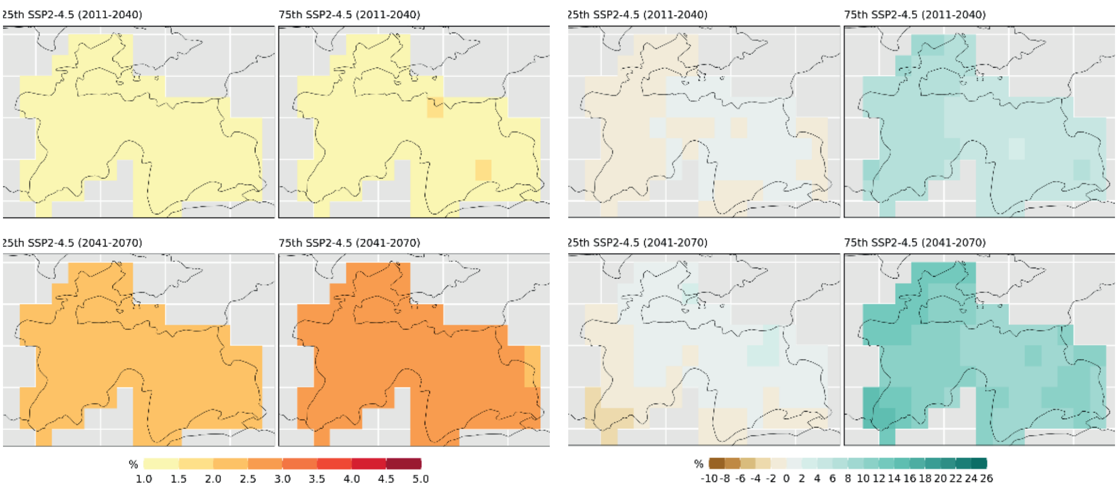
After having re-aligned the data in a common grid you can calculate the differences in 30-year mean climate conditions for your future periods with respect to the reference period. Lastly, you calculate the median and as a measure of uncertainty, the interquartile range (25th – 75th percentiles) of the model ensemble.

For a local risk assessment, you need to process the climate information at a finer spatial resolution. If available for your area under review use a gridded dataset of a time series based on local in-situ observations as a reference. If local data is not available then use existing high-resolution global products, such as 1 km downscaled CMIP6 projections made available by the CHELSA repository ***https://www.envidat.ch/#/metadata/chelsa-climatologies*** (Skrimizea et al., 2023).

Now for each scenario compute the differences for your future periods with respect to the reference period. It is recommended to analyse temperature and precipitation regimes and changes at seasonal and annual scales (Figure 38).

Figure 38 : Distribution of changes in mean annual temperature (left) and annual precipitation in near (right top) and middle future (right bottom) with respect to 1981-2010 under the SSP2-4.5 scenario

The results are reported for the 25th and 75th percentiles of the CMIP6 model ensemble on a 0.5°x0.5° grid (Skrimizea et al., 2023)



Climate indices and extremes

As monthly, seasonal, or annual averages of temperature and precipitation smooth over a lot of information relevant for sectoral impacts, you also need climate indices describing extreme climate conditions. Indices range from simple statistics and threshold exceedances (e.g. frost days, consecutive dry days, heating degree days) to more complex indices working as models on their own (e.g. drought indices SPI and SPEI). Most indices focus on counts of days crossing a threshold relative to the local climate. Others describe absolute extreme values such as the warmest, coldest or wettest day of the year. Indices are calculated for both past observations as well as future projections, globally as well as regionally. The selection of indices is based on the relevance of risks and impacts in your area under review, and expert judgement. Climate indices are classified in the following types: heat and cold, wet and dry, wind, snow and ice, coastal, open ocean, and other as per Table AV1.2 in IPCC Sixth Assessment Report (IPCC, 2021c).

Examples of climate indices:

- **Heat days:** Number of days with a maximum temperature greater than a certain threshold relevant to the area under review

TIP

Quality check of the climate data

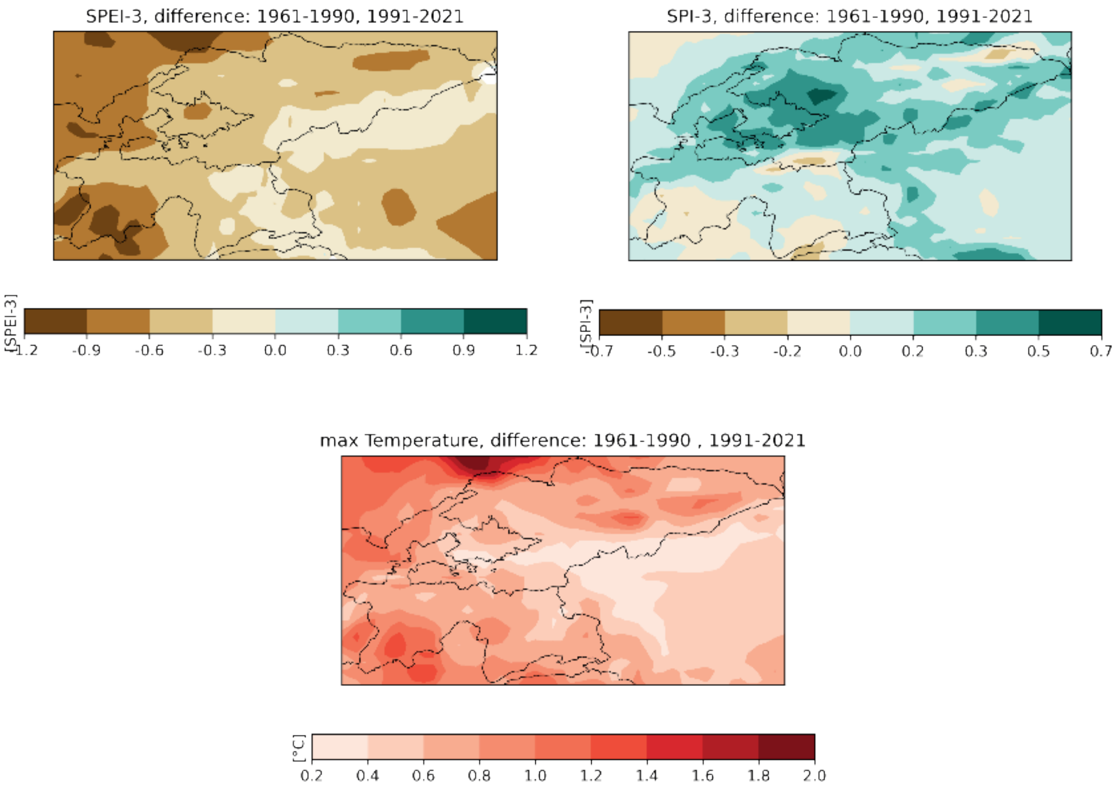
- Check model scales; global model vs regional models vs downscaled
- Check how ensemble was created, do not use single models or very limited if valid
- Check if bias-corrected data is required
- Check spatial resolution of data vs the scale you are interested in
- Check scenarios required/warming levels
- Check time frame required (climate periods); additionally do you need e.g. daily resolutions for modelling, or only climatic means?
- Check if you need proxies e.g. climate extreme variables
- Check link and integration into hazard/impact models
- Check consistency and validity
- Document all your decisions and communicate transparently

- **Tropical nights:** Number of tropical nights, annual count of days when TN (daily minimum temperature) >20°C
- **Heavy rain:** Number of days with precipitation greater than a certain threshold relevant to the area under review
- **Number of dry days:** Maximum number of consecutive days with less than 1 mm of precipitation per day
- **Maximum dry period:** Maximum period of consecutive dry days
- **Standardised precipitation index (SPI)**
- **Standardised precipitation evapotranspiration index (SPEI)**

For a detailed list of climatic impact drivers and extreme indices see Annex VI of the WGI report of the Sixth Assessment Report of IPCC (IPCC, 2021c), the CLIMPACT site ***https://climpact-sci.org/indices/*** or Climdex ***https://www.climdex.org/learn/indices/***.

The selected relevant climate indices are calculated for the past and future and visualized as maps (Figure 39).

Figure 39 : Example of maps showing spatial changes
(absolute difference with respect to the baseline) in SPI-3, SPEI-3, and maximum temperature (Skrimizea et al., 2023)



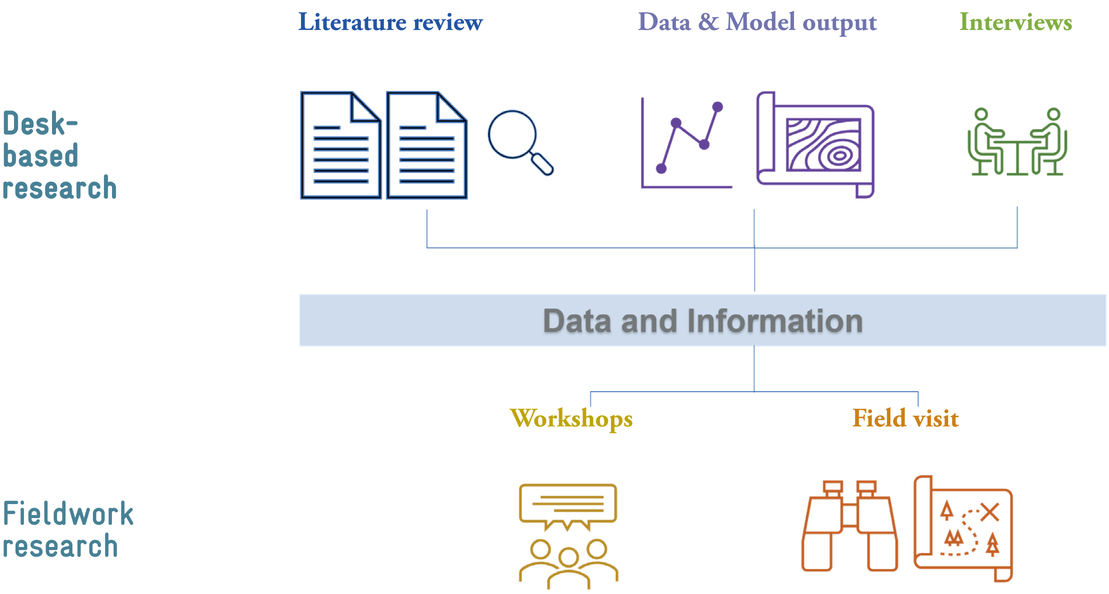
Additional knowledge and expertise:

Climpact is an online tool that allows the calculation of climate indices for station data based on either daily station or gridded data (***https://climpact-sci.org/***).

How to analyse and bring together different types of data and information?

Here you will use all the information you gathered through literature review, analysis of data and model outputs, and through expert consultations as a basis for risk identification and screening (Figure 40) (see also module *'Risk Identification'*).

Figure 40 : Schematic overview of different types of information gathering in a CRA
(own illustration)



E 2.1.3. - Development of scenarios for risk drivers at the local level

Data on exposure and vulnerability

Note that data and information on impact, exposure, vulnerability and external drivers for the past and the future are just as important to gather and analyse as climate data. In fact, vulnerability is usually the risk component that contributes most to intermediate impacts and risks.

As described in detail in the Conceptual Framework vulnerability includes 1) physical vulnerability such as, for example, construction type of infrastructure, crop types and 2) socio-economic vulnerability, based on factors such as, for instance, poverty levels, inequality, literacy rate, institutional capacities and governance (e.g. accountability, rule of law, political stability, government effectiveness, control of corruption). Data to describe such factors can be retrieved from national statistical offices, social protection registries, or by conducting household surveys. Some factors such as access to infrastructure, healthcare, and electricity can be calculated in a GIS.

Check 'Scoping', ***Step 2 - Define the scope*** to find which exposed systems and subsystems you identified as relevant. They encompass the exposed elements for which to gather data. Moreover, see the data needs a plan that you developed (Table 8), for which data on impact, exposure, vulnerability and external drivers' data is relevant to your assessment. Check in your list of available data which components of the data are available, and at what quality, for both past and future, and identify data gaps. Often future projections on population growth and in some cases even spatial distribution are available, however for most other elements data is often lacking.

We recommend that the information on future trends of socio-economic aspects, vulnerabilities and external drivers are generated in expert consultations and stakeholder workshops. Narratives and storylines on future developments can be included in the risk assessment. International and national reports may provide a starting point for creating those storylines.

The following steps aim to provide guidance on how to develop scenarios for risk drivers at the local level. It aims to develop localised scenarios, especially for exposure and vulnerability, which have different causal drivers than common climate scenarios.

The method can be seen as optional guidance and is independent from the other modules and serves as a stand-alone tool. However, there are relevant cross-links to the different modules (e.g. data integration, risk identification and analysis etc.). The recommended steps serve also as a backbone for experts in developing scenarios as well as facilitation on the local level. The recommended steps also serve as a backbone for experts in developing the scenarios as well as for facilitation at the local level.

Scenarios for exposure and vulnerability – key steps:

1. Systematically analyse the literature and observed patterns of development and trends.
2. Explore general and global scenarios, if applicable, and familiarise yourself with how they may be relevant to your case.
3. Conduct a local expert workshop to develop risk scenarios:
   3.1. Inform participants of relevant background information and the status of the assessment.
   3.2. Develop a scenario matrix, based on key drivers of the impact chain.
   3.3. Develop two potential future scenarios – A scenario that mirrors the ideal development and in contrast a business-as-usual scenario.
4. Describe your scenarios qualitatively and with a storyline.
5. If relevant, develop quantitative scenarios.

TIP

For further information, we recommend consulting these sources:

Birkmann et al., 2020 – New methods for local vulnerability scenarios at the local level, guidance and linkages to quantitative scenarios

Birkmann et al., 2021 – Further guidance on local scenarios, development of scenario matrices

Cradock-Henry et al., 2021 – Integrating the different domains of the SSPs into the scenario approach and adapting them to local needs

Hama et al., 2016 – development of local risk scenarios and burning embers

Hama et al., 2016 – development of role play simulations in the context of local risks

Werners et al., 2018 – integration of storylines as well as business-as-usual and aspiration scenarios

What do you need to implement this?

- The impact chain and relevant background information of past trends and possible future climate scenarios.
- Experts who can facilitate local workshops as well as experience in developing scenarios.
- What kind of stakeholder engagement is needed?

- As this guidance addresses local levels, local knowledge is key. Representation should be diverse and local experts should be able to inform on different, relevant aspects of the community.
- In addition, experts from the national/sub-national level should be included, especially to integrate independent expertise and knowledge.

E 2.1.4. - Step 1 - Systematic literature analysis and the identification of observed development patterns and trends – address all risk drivers

Which background information is available? Which information can support the development of localised scenarios? Are there relevant past trends and patterns which can be observed?

Analyse existing literature and reports on available scenarios for your region/area of interest. This can range from local-level scenarios to sub-national and national approaches and/or regional initiatives. Gather relevant information to have a solid starting point. Also, consider reports that go beyond climate change since they may contain information on development scenarios for your area of interest.

In addition, it is advised to identify past and current patterns and trends for your area of interest. This issue may also be taken up in the steps below, especially when dealing with the different risk drivers as identified in the impact chains. The main issue here is whether there are there any major patterns of change which are key for your local level analysis e.g. major environmental change due to human activity, major socio-economic changes such as population increase/decline, economic transformation process and/or any major impacts in the recent past which initiated relevant change in your area.

E 2.1.5. - Step 2 - Familiarise yourself with general and global scenarios, and how they can be relevant to your case

How to develop your scenarios?

What are the findings from global/national level scenarios? How can they support your local scenario development process? What are the key domains around which you would like to develop your future scenarios?

As a starting point, you can familiarise yourself with the key concepts and insights about scenarios at the global level (e.g. the RCP SSP scenarios) and consider how these can be applied to your area of interest. Once you are acquainted with this, you can review what the SSPs are and the assumptions behind the SSPs, and how or if this can be applied to your local context. This may include looking at what the 'global' SSPs deliver for your country in terms of future population and development corridors. At this stage, it is important to ascertain a general picture and possible trends, but it is not necessary to delve into the full logic or details of the RCP SSP logic.

However, an important step is to figure out which of the following areas (resulting from the SSPs) should be focused on in your local case. You can focus on a few or only the most important domains (demographics, economy, welfare, environment, resources, governance, technology, society) or modify them. These domains will help you in the following steps to develop possible future scenarios.

Additionally, you may consider carrying out qualitative research to supports your local-level scenario identification e.g. through focus group discussions. In addition, you may consult domain experts on existing knowledge of development scenarios for your region of interest.

E 2.1.6. - Step 3 - Carry out a stakeholder and/or local expert workshop to develop risk scenarios

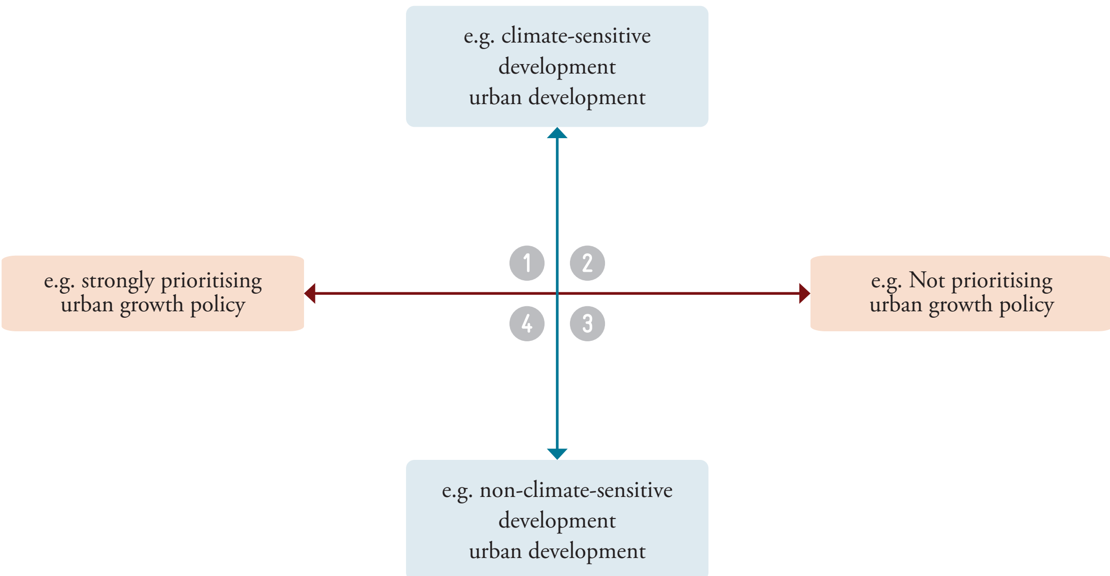
How could potential futures look based on a business-as-usual scenario as well as an opposing aspiration scenario?

The following is the core step to develop your local level risk scenarios. This workshop will develop the cornerstones around your possible future scenarios. You and what this will need to gather a diverse set of local stakeholders relevant to the scope of your CRA. In addition, it is advised to also include domain experts without a specific stake or vested interest, who can support the development of the scenarios with their specific domain knowledge and advice. General principles in organising such workshops apply, a summary of which is provided below.

- **Phase 1:** Inform the participants on the status of the assessment (e.g. to illustrate the impact chain) as well as current patterns/trends which can be observed from data and/or qualitative research. It is important that you also present possible future climate scenarios and outline how key parameters could evolve for your region. Focus on the time scale until 2050, to be relevant for the policy scale as much as possible. (Note: There is no significant change between the RCP scenarios until 2040; so you may focus on one only). In addition, summarise the key messages from the global SSPs/scenario process relevant to your local context. Also, confirm the selection of the domains from Step 2 with your group.

- **Phase 2:** Reflect together with your participants on the impact chain and identify the key drivers. Rank the drivers to identify a manageable number of key drivers that can be discussed using meaningful resources. Identify two key drivers for your risk context to use as two intersecting axes for the scenario matrix (if necessary, choose only one axis). See the following example from a land use planning context in an urban setting (Figure 41).

Figure 41 : Intersecting axes for the scenario matrix of land use planning in an urban setting
(Adapted from Birkmann, 2011).



- **Phase 3:** For the domains chosen, develop two future vision scenarios (independent from any CRM measures foreseen) based on the matrix identified. The scenarios should be built around the following structure:
  - » BAU scenarios: If the world/country/local context continues to develop as it is.
  - » Aspiration scenario: Together with the participants, develop a desirable scenario for an ideal case - what the world/your own country could look like. Since this can be a fairly basic task, be clear and pragmatic. You can support this with additional consultation at the local level, as well as expert advice on possible 'ideal solutions'.

To help guide your discussion and scenario development, you can use socio-economic parameters (see the SSP ranges above, but feel free to customise them). These ranges serve as a checklist for describing possible scenarios. For the two contrasting scenarios, you can contrast positive trends in a parameter in one scenario with a more negative or undesirable trend in the other scenario. In this case, you can also develop the Aspiration scenario as opposed to the business-as-usual scenario (Figure 42 and Figure 43).

Figure 42 : Scenarios 'Stagnation' and 'Boom' for system infrastructure
(Adapted from Hama et al., 2016).

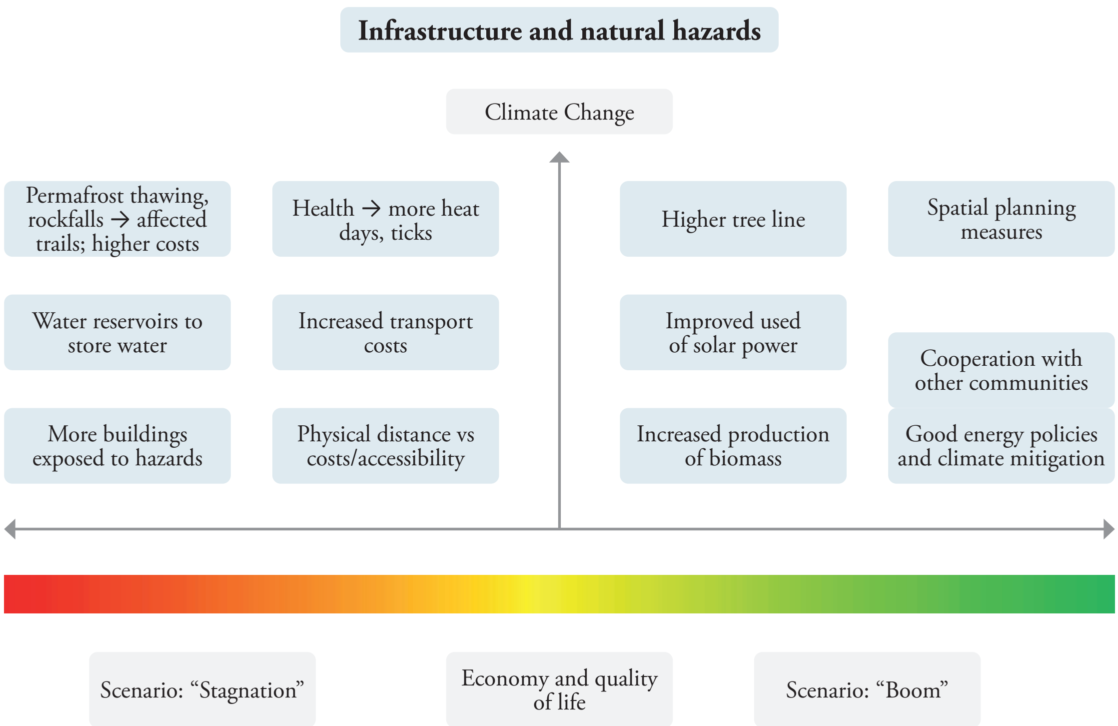


Figure 43 : How to create different local participatory scenarios

(Adapted from Hama et al., 2016)

Creation of local participatory scenarios

At least two clearly distinguishable local socio-economic scenarios with a long-term time horizon (2030/2050) should be created, e.g. one scenario of a growing, prosperous economy (referred to here as the „boom“ scenario) and one scenario of an economy without dynamism („stagnation“ scenario). Depending on the project budget and duration, any number of other scenarios can be created. The scenarios should describe essential socio-economic parameters characteristic of the region and their drivers, such as population development (ageing), sector-specific employment structure and value added. The following economic sectors serve as orientation: Tourism, Agriculture and Forestry, Industry and Manufacturing, Education, Health and Other Services, Politics and Administration, Infrastructure and Natural Hazards etc. The stakeholders and decision-makers participating in the scenario workshop should represent a cross-section of all industries and sectors as well as a gender balance.

Economy

Which industries/sectors are significantly involved in the local economic dynamics, what does the future development look like in a boom and stagnation scenario in these industries/ sectors?

Population development

What do the long-term regional population scenarios look like in a boom and stagnation scenario (ageing/migration/in-migration)? Which (global) trends determine this development? Can regional deviations occur, if so, by which developments / measures/policies (e.g. reversal of the urbanisation trend)?

Jobs

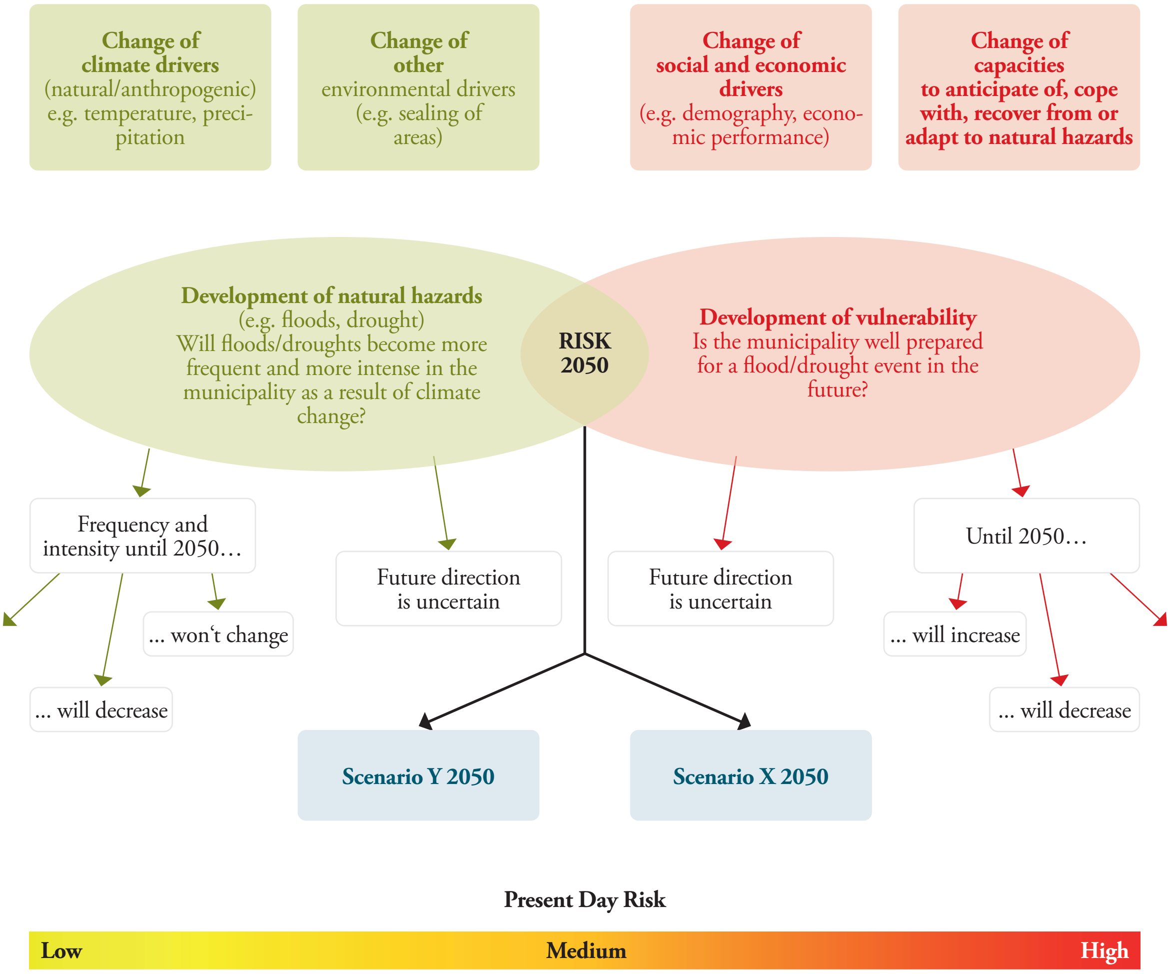
Which industries/sectors provide the most jobs in the region and how will these develop in light of (global) trends and influencing factors such as population dynamics and technological change?

E 2.1.7. - Step 4 - Development of qualitative scenarios

Summarise the results of the risk scenario workshop in a scenario synthesis. Describe the key assumptions along your domain and how the possible futures might manifest as narratives. Summarise the key findings as shown below, which can also be done in a matrix along with your assumptions. Figure 44 can help you describe potential trends in hazard, exposure and vulnerability in combination with potential impacts.

Overall, the results of this step aim to better appraise and assess future climate risks, incorporating not only climate scenarios but also potential development pathways as described above. In addition to providing a more informed risk analysis, the potential future pathways can support the identification of potential CCA options.

Figure 44 : Summary of results of scenario workshop
(Adapted from Lintschnig et al., 2019)



E 2.2. Optional – Quantitative assessment based on composite indicators

The section on quantitative CRA provides guidance on how to quantify indicators along the impact chain as composite indicators. The 'integration' of a variety of datasets may provide a condensed view on the complexity of climate risks, while at the same time will allow the exploration of specific risk drivers and their characteristics. The quality of a quantitative CRA largely depends on the soundness of the impact chain and the quality and availability of data. Because a modelling approach is always an abstract representation of reality, the chosen approach as well as its limitations need to be communicated transparently and clearly.

Key steps you need to address in this module

- Step 1: Identification of indicators based on impact chains
- Step 2: Indicator/data modelling (e.g. impact models, development of single indicators etc)
- Step 3: Indicator pre-processing & normalisation
- Step 4: Data aggregation and index calculation
- Step 5: Analytics, visualisation and metadata documentation
- Step 6: Identification of key findings and storylines

What do you need to implement this module?

- The final version of the impact chain
- Clarity on the spatial scale to be addressed

- Access to and availability of relevant datasets from a variety of institutions, ranging from environmental/ climate data, domain-specific to socio-economic datasets
- Potential pre-arrangement for data access and sharing among institutions
- GIS (Geographic Information System) expertise, statistical experience, and knowledge of composite indicator development
- Flexibility and time

OUTCOMES OF THIS MODULE

A quantitative CRA, with the potential identification of hotspots and their characteristics (where are they? What potential CCA options could be applied?); possible past and future trends, typology of climate risk regions as well as statistics and data insights.

Key questions for a quantitative CRA based on composite indicators:

How to develop composite indicators?

- How to develop indicators out of the impact chains?
- How to normalise and aggregate indicators?
- How to identify findings based on the developed of composite indicators?
- How to visualise your results and document your data?

Which (additional) tools and information does the website provide?

- A showcase of and links to best practices
- Additional guidance and literature to guiding documents (e.g. JRC composite indicator tools)

Effort Required

Capacities required: Communication experts, along with domain experts of the sectors/risks addressed, graphic designers and cartographers; together with the project partners in the country.

Effort drivers: The extent and depth of the communication approach largely depend on the results achieved, its complexity as well as the level of co-production and efforts available for professional guidance (e.g. graphics, writers, academics, communication experts etc.); overall this can also be a time intensive process, due to the uptake and professional visualisation of results, including the preparation of material (e.g. websites) and joint workshops.

Additional comments

Capacities required: GIS and spatial analysis experts; statistical and data analysis capacities, graphic and map design; knowledge of the country-specific data situation.

Effort drivers: The effort required largely depends on data availability and the resources and time available for developing sound results and/or closing data gaps by data collection/modelling approaches; the first steps, in which you must 'translate' the impact chains into indicators and identify relevant data, are time consuming.

E 2.2.1. - Step 1 - Identification of indicators based on impact chains for the three risk domains

This step helps to identify and select indicators for the assessment. It provides criteria for deciding which indicators are suitable for quantifying the risk factors identified in the impact chain.

Appropriate indicators for risk components are:

- valid and relevant: they represent the topic you would like to address;
- reliable and credible: they come from trustworthy sources and allow future data collection for a possible monitoring concept;
- are precise in meaning: indicators either represent the factor in the impact chain directly or are labelled as approximations (proxies); in addition, stakeholders agree on what the indicator measures in the particular context;
- clear in direction: an increase in value is clearly positive or negative in relation to the factor and the risk component;
- practical and affordable: they are accessible with reasonable efforts and resources;
- appropriate: the temporal and spatial resolution of the indicator is well chosen for the scope of the risk assessment.

Hazard indicator selection

Select indicators that describe climate drivers or hazards, such as temperature extremes or heavy precipitation events that lead to intermediate consequences. Ideally, use hazard models that incorporate climate model outputs. Alternatively, you can select proxy indicators through climate extremes indices if appropriate. To quantify hazard factors, it is particularly advisable to use numbers representing intensities (e.g. 'water level > 1 m from the mean') or frequencies (e.g. 'heat days per year') to describe the potential occurrence of a hazardous event. For example, the hazard factor 'too much precipitation' could be formulated as 'number of days with more than 100 mm of precipitation' and thus refer to a critical condition. It should be noted that the intervening impacts are not themselves risk components but are only a tool for understanding the cause-effect relationship that leads to the risk. For this reason, they are not considered in the aggregation to total risk and therefore do not need to be represented by indicators.

Selection of vulnerability and exposure indicators

To determine indicators of vulnerability, you need to select indicators of the degree of vulnerability and (lack of) capacity. For each indicator, determine the direction: does a high value represent high risk or low risk? When selecting indicators for the capacity component, you need to consider anticipation, coping, CCA, and recovery capacities. For exposure, useful indicators are usually numbers, densities, or proportions (e.g. 'percentage of the population living in a floodplain').

TIP

Check that your indicators are specific enough: make sure that each indicator is an appropriate description of the factor, that it is explicitly formulated, and that it has a clear direction in relation to the risk under consideration.

Create a list of provisional indicators for each risk factor

At this point, you 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 for each indicator: the reasons for selecting the indicator, the spatial and temporal coverage, the unit of measurement, the update intervals, and the potentially required data sources.

E 2.2.2. - Step 2 - Indicator/data modelling (e.g. impact models, development of single indicators etc.)

Which models can be used to develop specific indicators?

As noted in the previous step, you may need to model some hazard indicators. For example, these could be models for floods or droughts, or models for diseases (such as the potential spread of infectious malaria bites). Appropriate current climate observation data are needed to apply such models, as well as robust climate models for the future. In this case, you may also need specific expertise from national/international experts to run such models.

Develop your own indicators when data are missing or needed: this could be thought of as modelling access to markets, access to schools, or similar. In addition, collected data from surveys could be used for this purpose.

E 2.2.3. - Step 3 - Indicator pre-processing: How to prepare the relevant indictors based on scientific best practice?

Before aggregation, indicators may need to be pre-processed and normalised. This step builds on best practices for which further and detailed guidance can be found, for example, in the OECD/JRC Guidelines for the Development of Composite Indicators (OECD, 2008). In addition, guidance and tools (such as R-scripts, etc.) can be found on the website of the European Commission's JRC Competence Centre on Composite Indicators and Scoreboards (OECD, 2008).

Is your data in a common measurement scale? Is the recalculation of values required?

Check if your data has a common measurement scale; such as the correct unit (km, m etc; relative measures; number of water wells per person etc.). Check this for all indicators and recalculate/modify your indicators where appropriate.

Are there any missing values or 'outliers' in your data?

Data gaps are a recurring problem in the area of quantitative data (e.g. regions omitted from geographical data, time periods missing from time series data). You can try and close smaller gaps with interpolation, that is, finding existing data nearest to the gaps (in space or time) most likely to match the missing data. In your data, 'outliers' may also turn up. These are values that are far outside the expected range; they may indicate an error in the data capture method. The OECD guidelines offer sound guidance on data imputation methods and dealing with outliers, such as winsorisation. In short, visualise the distribution of each indicator using histograms and scatter-plots (OECD 2008). Plot first and consider indicators for outlier treatment if: (1) absolute skewness > 2.0 and kurtosis > 3.5 or, (2) kurtosis is very high > 10. Winsorisation is one way to treat data in which outliers are assigned the next highest/lowest score.

How to normalise your indicators?

In the literature (e.g. OECD, 2008), the term 'normalisation' refers to the transformation of indicator values measured on different scales and in different units into unit-less values on a common scale. Consider the different units used for measurement: US$/household, hospitals/1000 inhabitants, literacy rate percentage, soil type, land use – and many more. These different units mean that your indicators cannot be aggregated without normalisation. In this CR-SB we use a standard value range from 0 to 1.

A second important aspect of normalisation is to derive meaning from numbers by evaluating the criticalness of an indicator value. We define '0' as 'optimal, no improvement necessary or possible' and '1' as 'critical, system no longer functions'. For instance, an annual precipitation of 600 mm/year may be '0 – optimal', while precipitation of 200 mm/year may be '1 – critical'.

- Determine the scale of measurement: In order to normalise the data, you first have to determine the scale of measurement for each indicator. Is your data metric (such as percentage values or the amount of precipitation) or of categorical nature (such as land cover/land use classes, which can be transferred into ordinal data).
- 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. The stretch of indicator values between the minimum and maximum threshold follows Formula 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.

Formula 1 : Formula to normalise indicator values

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

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

Indicators specified by categorical values and an ordinal scale (e.g. land cover, soil type, government efficiency) are normalised using a five-level rating scheme. This scoring scheme follows a rating scale by defining classes of importance applicable to risk assessment. Experts in the field should assign the different characteristics for each indicator (e.g. 'forest' or 'cultivated' in the case of land cover) to the different classes.

Finally, check whether the indicator values are increasing in the right direction. That is, lower values should reflect positive conditions in terms of vulnerability and higher values should reflect more negative conditions.

Are your indicators independent from others or do multi-collinearities exist?

Check your indicators for multicollinearities to ensure that they are independent and double counting is avoided. Multicollinearities in the data are best assessed using the Pearson correlation coefficient r (with r > 0.9) following the guidelines described by the (OECD, 2008). If you find that the indicators are highly collinear, you can either eliminate one of the indicators or assign half the weight to both indicators.

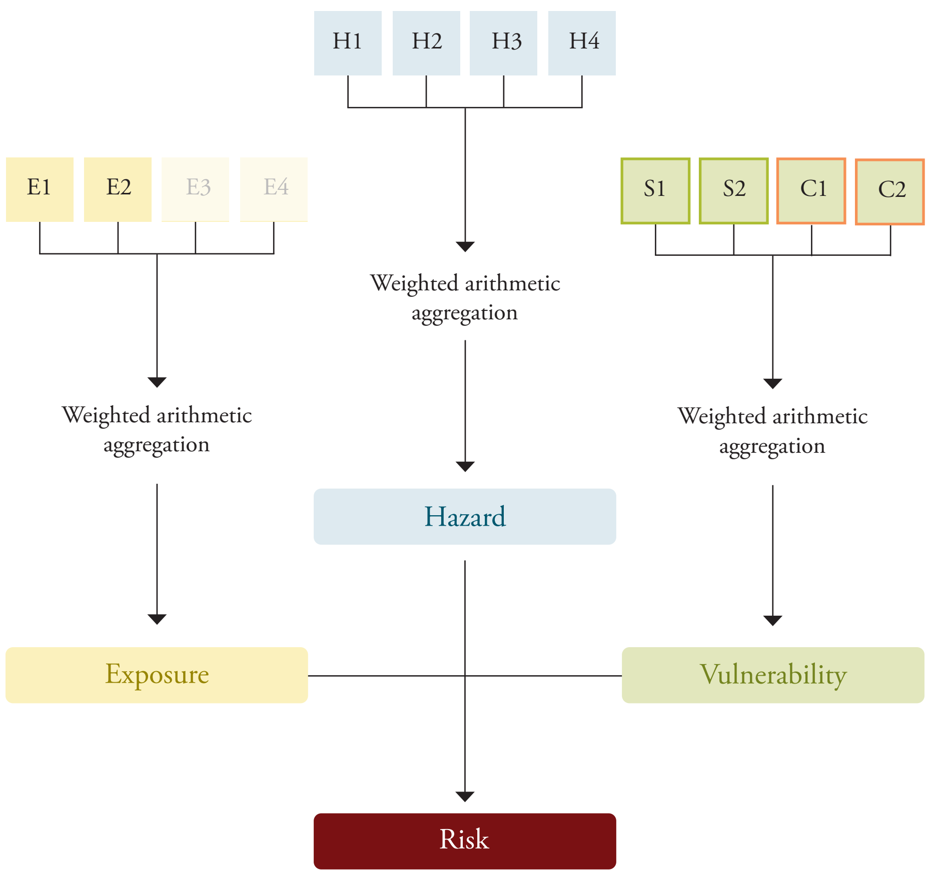
E 2.2.4. - Step 4 - Data aggregation and index calculation

How to weigh and aggregate indicators towards a composite indicator?

The weighting of indicators helps you to describe the risk components hazard, vulnerability and exposure. If certain factors are more important than others, they and the corresponding indicators should be assigned dif-

Figure 45 : Aggregating single factors to risk components

In practice the number of indicators may derivate from the count of indicators shown in this conceptual visualisation (Zebisch et al., 2017).



ferent weights. This means that indicators that receive a greater (or lesser) weight will have a greater (or lesser) impact on the respective component and on the overall risk. The various weights assigned to indicators may be derived from existing literature, stakeholder information, or experts' weighting. There are various methods for assigning weights: from sophisticated statistical methods (such as principal component analysis) to participatory methods such as budget allocation or the Analytic Hierarchy Process (AHP). It should be noted that neither participatory nor statistical methods provide an 'objective' way to determine weights. Consequently, weights should be considered value judgments (OECD, 2008a).

Aggregation of indicators:

Aggregation allows you to combine the normalised indicators into a composite indicator that represents a single component of risk. There are several aggregation methods such as matrix approaches, arithmetic/geometric mean, and visual overlays. In this guidance document, the approach taken is to aggregate the vulnerability, exposure, and hazard subcomponents using an arithmetic mean (Formula 2). To integrate these subcomponents into a composite risk indicator, the geometric mean is proposed (Formula 3). As with the geometric mean, if either hazard or susceptibility is zero, the overall risk is also zero, rather than an arithmetic mean of the two. If a multi-risk approach is also chosen, an arithmetic mean can be chosen to aggregate and combine the individual risks for simplicity.

Formula 2 : Formula to calculate the arithmetic mean

$$CI_c = \sum_{q=1}^{Q} w_q I_{qc}$$

with $\sum_q w_q = 1$ and $0 \leq w_q \leq 1$, for all $q = 1,\ldots,Q$ and $c = 1, \ldots, M$.

Formula 3 : Formula to calculate the geometric mean

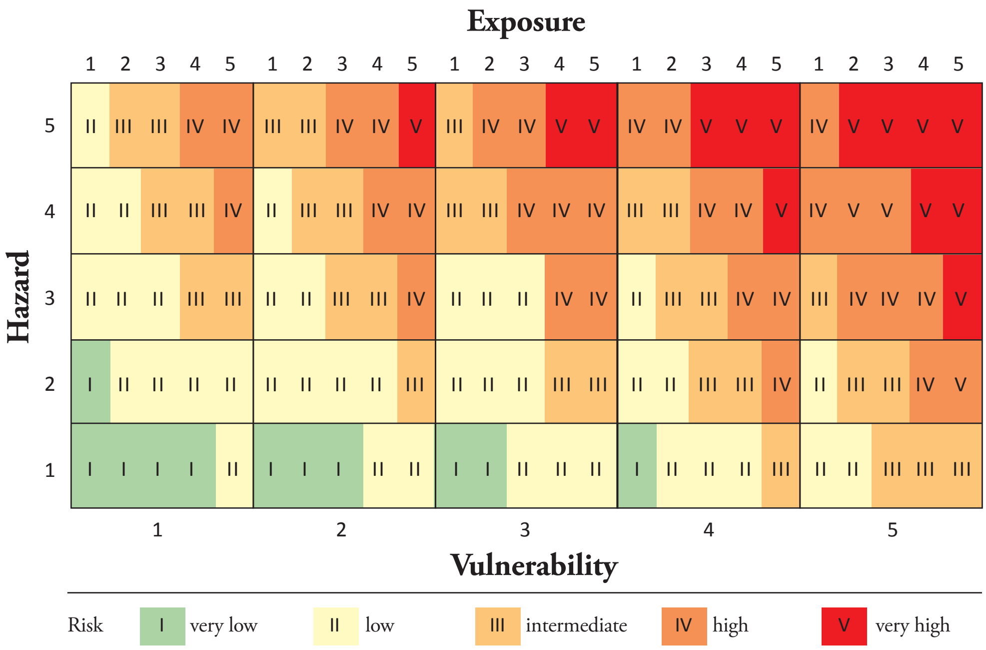
$$CI_c = \prod_{q=1}^{Q} x_{q,c}^{w_q}$$

An alternative approach for aggregation

A common approach to risk assessment is to combine risk factors using an assessment matrix. In a probabilistic risk assessment, the two aspects 'probability' and 'consequences' are usually combined in this way. The general advantage of a matrix approach over an arithmetic/geometric approach is better control over the aggregation result. The disadvantage is that it can only be applied to categorical values (five classes are common) and that one must agree on the exact configuration of the matrix. For the IPCC AR5 risk concept, a matrix must combine the three risk components (hazard, vulnerability, and exposure), as shown in Figure 46. Here, risk is assessed by combining the degree of hazard (y-axis), vulnerability (lower x-axis), and exposure (upper x-axis) into a risk class (from 1 = very low to 5 = very high).

Figure 46 : Visualisation of hazard, vulnerability and exposure

(Zebisch et al., 2017)



E 2.2.5. - Optional Step - Sensitivity Analysis

What is the influence of a single indicator on the composite indicator?

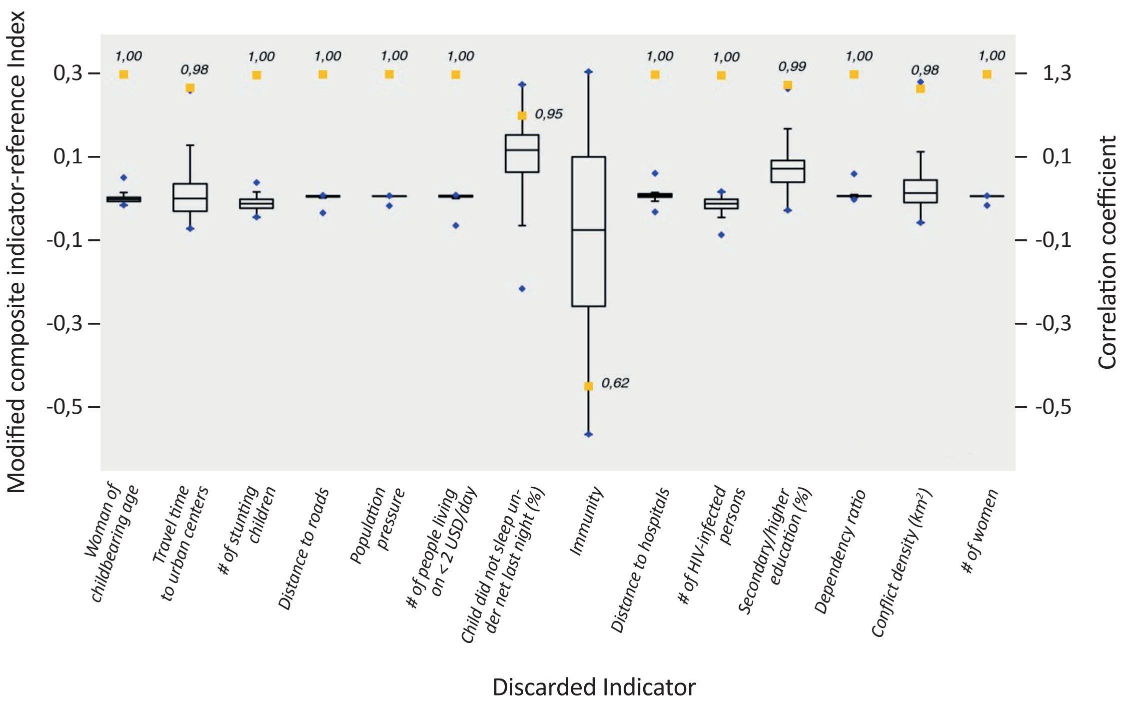
According to GFS/OECD, uncertainty analysis quantifies the uncertainty in the composite indicator values resulting from the uncertainty in the underlying assumptions. Sensitivity analysis quantifies the uncertainty caused by individual assumptions. This step includes:

- Identifying key uncertainties underlying the composite indicator (e.g. methodological choices, indicator selection, alternative frameworks, etc.).
- Assessing the impact of uncertainties on scores or ranks (e.g. by assigning confidence intervals). Use sensitivity analysis to determine which assumptions cause the greatest uncertainty.
- Explaining why certain units of measure (e.g. provinces or countries) significantly improve or worsen their relative position when assumptions are changed.

One possibility for a local sensitivity analysis is the method of Lung et al. (2013). In this case, you calculate a set of alternative indices by discarding one indicator at a time while keeping all other settings (normalisation, weighting, aggregation) the same. Once you have calculated all alternative indices, you can compare them with the reference index. The results can be displayed in boxplots showing, for each of the alternative indices (x-axis), the interquartile range (IQR), the minimum and maximum values, and the correlation (r) with the reference index (y-axis). The higher the IQR, the greater the influence of the respective indicator on the index with interquartile range (dispersion of the indicator) and correlation with the reference index.

Figure 47 : Discarded indicator

(Kienberger and Hagenlocher, 2014)



E 2.2.6. - **Step 5 -** Analytics, Visualisation and metadata documentation

What does the data tell us? How to communicate the results?

Based on the analysis and composite indicators developed, there is an opportunity to further investigate and analyse the results. This could include, for example, a statistical hotspot analysis such as Getis-Ord Gi* or a cluster analysis to identify underlying patterns, etc. and gain further insight into the results achieved. Such data analysis can reveal unseen features of the results achieved and help you identify key messages in the next step. Examine the data to find narratives and stories for your key questions and stakeholders. What was the main purpose of the evaluation and what did you want to answer? However, do not conclude causality from correlation.

For more information see ***E 2.4.***

As already done in Step 2a, provide final documentation of indicators/indices through standardised metadata documentation. In a more technical report, you may describe your methodology in detail as well as include a discussion of the results.

Both the technical report and the data should be prepared in a format that can be read as a stand-alone document. This is important if the data and results will be shared with different partner institutions. This could include the following:

- A data package including the raw data used, and the results achieved (single indicators, composite indicators);
- Using common geodata file formats, such as 'geojson', shapefiles or geodatabases (or 'netcdf' data for climate data);
- Metadata information;
- Instructions on how to read/use the data;
- Guidance and recommendations for archiving and handing-over of data/results to partner institutions.

E 2.2.7. - Step 6 - Identification of key findings and storylines

What are the insights we gained from the analysis? What does the data tell us?

To finally communicate your results, focus on what your key messages and findings are and to whom you are aiming to communicate them. Based on that, you may have to develop a storyline/narrative of the results. You may also select visualisation tools that clearly communicate the key findings without hiding important and relevant information. It is also recommended to avoid over-complicated visualisations and too much cognitive load. Guiding questions include the following:

Plan your CRA report

- What did you learn from the assessment?
- Who is your target audience?
- What information should you include in your report?

Describe your assessment

- What's the best way to structure your report?
- What processes will the vulnerability assessment support or feed into?
- What have you learned that you consider to be crucial for this process?

Illustrate your findings

- How should you illustrate your findings?
- How can you avoid misinterpretation?

E 2.3. Towards Adaptation

E 2.3.1. - Step 4 – Stakeholder feedback on potential CCA options (policy perspectives)

Policy Perspective

To increase opportunities for the uptake of potential CCA options and CCA packages identified in this module, it can be effective to align with governmental policies. Aligning with governmental policies can create synergies between potential CCA options and packages and existing and upcoming plans and can help to overcome barriers such as access to finance or planning. In step two you have already reviewed existing CCA plans, which is a useful step to build on here. Engaging with policymakers across governance levels (i.e. regional, national, sectoral, local) diversifies feedback and widens the margins of opportunity for integrating CCA into policies.

- What feedback do policymakers have about the identified CCA options and packages?
- Do they see potential synergies between the identified CCA options and CCA packages and their existing or upcoming climate action or development plans?
- Where do they see opportunities for accessing finance for CCA in the context of your assessment?
- Do they see legal or political barriers to the identified CCA options and packages?

Box — I — Climate-resilient development pathways to facilitate implementation towards CCA

Decision-making occurs against a backdrop of widespread and rapid changes in climate and extreme weather, increasing socio-political challenges and complex risks (Schipper et al., 2022). The complexity that practitioners, policy-makers and researchers now face means that decision-making and planning is becoming increasingly difficult. Development decisions need to include choices and actions that improve livelihoods, counteract climate change and are equitable towards the most vulnerable. To ensure that these decisions address the intricacies at a local level, are socially and culturally relevant and inclusive, they must be informed through participation with the communities they affect. Doing this creates more resilient development processes over time.

Climate-resilient development pathways are a methodology that aims to achieve these goals, by consolidating CCA, mitigation and development decisions towards long-term sustainable development. Climate-resilient development pathways build on CCA pathways approaches, which are a decision-focused tool that can accommodate for stakeholder perspectives and account for future uncertainties in planning and implementation of CCA options. The pathways approach incorporates flexibility into decision-making to accommodate for changing conditions over time. Pathways can reduce undesirable path dependencies and map maladaptive consequences and trade-offs of CCA (Werners et al., 2021).

This box lists through six steps to co-create climate-resilient development pathways with stakeholders, which builds on Werners et al. (2018) 'Stepwise approach for CCA pathways development'. These steps can help develop and facilitate plans to implement CCA options that have been identified earlier in this module.

The six main steps are:

1. Identification of current situation and drivers of change
2. Desired future and intergenerational aspects
3. How to get to the desired future: What keeps us back? What moves us forward? Who moves us forward?
4. Back-casting process: Drawing the pathways map, using the identified CCA options, including which stakeholders are needed to facilitate comprehensive CRM
5. Reflection and feedback on pathways with stakeholders
6. Synthesis of pathways and monitoring, evaluation and learning

(Note: This box only contributes to one of many possibilities for practitioners aiming to operationalise climate-resilient development pathways and should not be viewed as a prescriptive and one-size-fits-all package.)

E 2.4. Communication

E 2.4.1. - Step 0 - Build on the communication objectives and intended scope of the communication approach as identified during the inception phase

This step helps to answer basic questions about climate risk communication. The main goal is to understand what climate risk communication is about and how to integrate a climate risk communication approach as a common thread throughout your CRA.

What is climate risk communication?

Climate risk communication can be understood as a process of exchanging and sharing information about climate-related risks and their underlying drivers. Risk information may relate to the presence, nature, form, likelihood, severity, acceptability, response actions, or other aspects of the risk and is shared among various knowledge holders, decision-makers, and other stakeholders, including researchers, technicians, consultants, managers, practitioners, members of the public, government agencies, media, interest groups, etc. Climate risk communication can also include the concept of climate services, which combine climate information and data with other relevant information that can be used by targeted end users.

What is the purpose of your communication strategy and who will be your target audience? What needs to be considered in climate risk communication?

- How to communicate effectively (method)? The most common method of communicating information about climate change by experts or communicators is (still) the use of 'one-page' public presentations and lectures, which may include the results of studies on climate risks and vulnerabilities and related data. Yet there is increasingly widespread recognition of the importance of participatory approaches (see chapter ***1.4.***). The aim is not to simply 'inform' different target groups and users about the results, but to enable them through a specific and tailored approach utilising the available sources for informed decision-making. A key principle for effective climate change communication is the creation of opportunities and the use of methods that are engaging and co-produced. These could include the establishment of engaging dialogues that allow the communicator a better understanding of the audience's values and interests.
- Who to reach (users of climate services and information)? Target groups and users of climate services and information can vary depending on the scope of the communication approach. They may include employees working in the public and private sector, civil society organisations, media, education, and can range from actors from the national to the local level, but, for example, can also include multipliers (for

example, training of trainers) as well as vulnerable communities. In engaging with these groups, it can make sense to question how to reach out to new and/or specific audiences instead of addressing an audience often composed of the same, already engaged people.

- What to communicate (narrative)? Climate risk is a complex topic characterised by a high level of uncertainty affecting people all over the world in different ways. A strategic communication approach gives the opportunity to increase understanding and awareness of the user group through scientific clarity and accuracy. Regardless of the narrative chosen, it is highly advisable to avoid catastrophism in communication, as it can lead to a defensive reaction by the audience. Rather, using stories and target group-specific narratives which may include 'good' and 'promising' examples is a powerful tool to build common ground on which effective communication can take place. By integrating narratives and context-specific examples into climate risk data, information can resonate with the audience (see also McLoughlin et al., 2018).
- What do we want to achieve (aim)? A goal for all communication should be that it catalyses action, which is based on the acquired knowledge and needs of the users and target groups. Although awareness of climate risks already exists, this awareness often does not yet result in enough action to achieve long-term targets and results. It will therefore be important to translate technical and scientific data into financial and management information for decision-makers.

TIP

According to scientific evidence, high levels of public awareness regarding climate risks does not necessarily lead to action. Several factors such as social, cultural, economic, political, infrastructural, and natural influences appear to be involved. It is essential to consider these factors adequately in order to encourage problem-solving and action-oriented thinking among the target audience and foster a willingness to take action.

E 2.4.2. - Step 1 - Review the scope of the communication approach

The GIZ Guide to Climate Risk Communication (Eucker et al., 2022) identifies four key points to determine the scope of the chosen approach. These key points summarise the most important questions and points to consider and also help to continuously reflect on one's own approach. For further details, it is recommended to consult the detailed guide.

What needs to be communicated and what is your intention?

Reflections on a communication approach that also takes participatory and gender-specific aspects into account:

- Communicate your chosen approach in a way that motivates and enables target users to consider it when making decisions.
- Ensure a two-way communication approach throughout the process, not only during the specific final step to communicate results, but also during the preparation and implementation of the CRA.
- Consider how the communication approach will ensure the participation of intended users of climate services and information in the communication process and how their respective levels of knowledge and experience can be taken into account.
- Consider gender-specific issues, e.g. gender-specific impacts of climate change.

What is the context of the CRA and the related communication?

To improve your understanding of the context of your communication approach, it's a good idea to think about context:

- The identification and participation of the intended user group(s);
- The involvement of stakeholders who will be part of the process;
- The availability of data and information that will support your communication strategy;
- The resources available, including the number of communicators (team members, consultants, and involved partners) planned for the communications approach, and the time available for the project, including budget considerations;
- The time available to plan and implement your communication approach;
- The decision to communicate the results to a broader audience - including language that is specific to the target audience, yet appropriate and universally understood.

What do you want to communicate and what do you want to achieve – tangible and non-tangible?

Once the communication approach has been analysed, the next step should be to identify the goals and expected outcomes, which may include:

- General objective: to make information on climate risks (more) accessible or understandable to a specific group of users of climate services and information.
- Raise awareness of project partners to better integrate climate risks into decision-making processes at the national and/or sub-national level.
- Consider that appropriate approaches in risk communication supports knowledge building and social learning.
- Broadly speaking, objectives can range from better understanding a CRA in the context of a particular hazard scenario or region, to motivating national or sub-national governments to support policies that enable vulnerable populations to adapt and build their resilience to climate change, and ultimately to provide incentives for these groups to adopt and implement individual or collective CCA measures to reduce the actual magnitude of climate risk.

What is the final scope of your climate risk communication approach?

The scope of the communication concept determines the depth of information to be achieved for the intended results:

- Communication baseline: identify and document the CRA data and information needed for communication purposes
- Allow for some flexibility and necessary updating when relevant
- Note the seven basic considerations:
    1. climate signals (which parameter? Which reference period?);
    2. risks and vulnerabilities (be clear on the definition of key risks and potential impacts);
    3. territorial (e.g. national, regional, local) and/or sectoral approach;
    4. time horizon (past, current, or future climate risks);
    5. uncertainty (uncertainty and robustness of data);
    6. CCA options (are they part of your communication approach?);
    7. CCA and mitigation (can mitigation issues be addressed together with CCA options in your communication approach?).

E 2.4.3. - Step 2 - Develop tools and methodologies for climate risk communication

Choosing the right tools and degree of participation

First, a distinction should be made between approaches that use participatory (two-way) forms of communication and those that generally do not (e.g. websites, podcasts, radio broadcasts).

Non-participatory formats are most appropriate when the focus of communication is only on communicating datasets and/or absolute values. However, tools such as websites that contain CRA results can be more effective if they are also linked to a participatory communication approach (e.g. creating a dialogue platform). Another form of non-participatory communication approach is to involve journalists and tools used in the media. For example, a media briefing can provide an opportunity for dialogue and engagement between key stakeholders and media representatives.

To reach different stakeholders, the following actions can be considered: Exhibits, artwork, short videos, songs, and other creative outlets, including contests, can be used as incentives to promote dialogue, publicise research, and raise awareness about CRA and CRM. In addition, programs can range from commercials to photographs, real-life stories, radio call-in shows, television panels, or a collection of articles and opinion pieces. Different stakeholders can also be encouraged to find solutions to the various climate risks faced by different sectors such as fisheries, agriculture, water, etc. Websites, blogs, social media and other means of awareness and dissemination can also be explored to ensure that everyone is reached when communicating the key findings of a CRA.

A special case is the communication of climate risks without relying on written material in a direct and participatory way. This is often seen in street theatre or artist performances at events such as trade shows, conferences, conventions, etc.

Elaborating the report and figures/maps

Second, the development of figures, maps and charts should be included in the communication approach. These are often included in the CRA assessment report and should serve as the main basis for the development of all communication-related tools and methods, as the reports contain all essential background information, content and results. Overall, the assessment report should consist of four key parts, i.e. (a) context and objectives, (b) methodology and implementation, (c) results, and (d) conclusions and lessons learned. The style and language of the report should be appropriate for the target audience.

You can use various types of diagrams and graphs. When you're designing a chart, it is particularly important that you include any information the reader needs. Maps allow the visualisation of geographic information and make it easier to compare regions. Maps are particularly valuable in participatory processes and are great for involving local stakeholders in risk assessment.

Preparing methodological approaches for communication

Third, it is necessary to prepare appropriate methodological approaches for communicating the results of the CRA.

- Maps, charts, and graphs are valuable and meaningful tools for illustrating assessment results. While map-based displays are recommended for spatial assessments, climate impact maps can be more easily communicated if the climate change, spatial exposure, and vulnerability indicators included in the assessment are also mapped. The spatial resolution of all data should be considered in map-based communication.

- Impact chains are also a very important communication tool to facilitate discussions about climate risks, vulnerabilities, and CCA. The visual representation makes complex situations and relationships easier to understand.

However, figures, maps and charts can be very complex. One should ask about the relevance and intent associated with the presentation of each element, e.g. what is the communicative value of each of the elements to be presented and what are the key messages associated with them? To what extent is the information they contain relevant to the target audience?

Integrating personal stories and experiences of individuals or populations (narratives) affected by climate risks and how they (successfully) cope with them can be a possible and promising way to show the relevance of the topic to users and make the results of a CRA understandable.

Combining quantitative information (e.g. also on costs and what-if scenarios) with other tools and qualitative analyses facilitates the communication process. Qualitative approaches are important to capture individual risk factors that would otherwise be missing from the communication approach. For more details, see the Guide to Communicating Climate Risks (Eucker et al., 2022).

E 2.4.4. - Step 4 - Elaborate tools and methodologies for climate risk communication

How successful was your communication strategy? How did you reach out on gender issues and to vulnerable groups?

After the communication approach has been implemented, it may be helpful to evaluate its impact and successes to contribute to broader knowledge management and experience building on climate risk communication. This will help build a broader understanding of what went well in preparing and implementing the approach and draw conclusions about what can be improved in future approaches. Use the following key aspects to evaluate your communications approach:

- **Relevance:** Did CRA participants feel the information was needed by data users and/or the target audience to better understand the CRA results? Was the communication approach consistent with the country's climate risk-related policies and strategies? Was it relevant to the success of the CRVA itself?
- **Efficiency:** What do participants think worked well in implementing the communication approach? Was the approach sufficiently participatory? Was the approach sufficiently supported by relevant stakeholders? Were the methodology and tools appropriate? Were gender issues and the interests of vulnerable groups sufficiently addressed? Was the timeframe adequate to address all relevant aspects of climate risk and vulnerability assessment? Were all requirements and questions adequately considered and answered?
- **Effectiveness:** Was the purpose achieved? Was the knowledge of the participants adequately reflected in the discussions and results? Did the information provided contribute to an increase in knowledge among participants? How did participants' knowledge of climate risks change as a result of the information provided and discussed?
- **Impacts:** Based on information about the results of the climate risk and vulnerability assessment, do participants feel able to make informed decisions about planning and implementing CCA actions? If so, how?
- **Sustainability:** Do the results and impacts of the communication approach continue to be reflected and incorporated into ongoing decision-making processes and future CCA actions?

E 2.5. Optional Module – Communicating the degree of confidence in a CRA: A step-by-step approach

The level of confidence in the information provided plays an important role in decision-making. While uncertainties can rarely be completely eliminated, the level of confidence in the information helps in assessing the urgency of action or alternative ways of dealing with ambiguities.

Building on the IPCC approach the degree of confidence is defined by two dimensions:

- **Consistency** of the sources used: the more sources agree with respect to an outcome or trend, the higher the agreement. Data analysis can be used to determine the degree of agreement.
- **Evidence** in the sources that lead to a finding, based on the consistency, quality, quantity, and type of sources used: evidence can be assessed using model results and/or statistical analysis or expert judgment. In general, evidence is most solid when there are multiple, consistent, and independent sources of high quality.

Each result of both metrics can be ranked on a qualitative or quantitative scale. The higher the agreement and evidence, the higher the confidence in the results. The following stepwise approach (adapted from Becher et al., 2019) allows both the evidence and the level of agreement with the results to be determined in a participatory manner with different user groups.

E 2.5.1. – Step 1 – Identify the sources of information

The first step is to collect all sources of information to be evaluated by the CRA. These may be climate data, workshop results, interviews, articles, or other sources. The sources can be categorised by the types of information they relate to (e.g. climate signals for different climate parameters, causes of vulnerability, exposure). In this exercise, a level of 'high' or 'low' evidence should be attributed to each of the sources.

E 2.5.2. - Step 2 - Determine the level of robustness of information sources

In a second step, a matrix is discussed and filled out - if possible, together with the group of information users - in order to determine how resilient the information sources are in terms of their levels of evidence (see Table 30, results are for illustrative purposes only):

- **Information about the category addressed:** because some sources (such as newspaper articles) can provide information for multiple categories, they can be used for multiple categories.
- **Data type:** Describe what data or information the source provides that leads to the results.
- **Data source:** Briefly describe the data source. Since some sources are more reliable than others, this is already an indicator of confidence.
- **Data quality:** Evaluate - qualitatively or quantitatively - the data quality provided by each source. To do this, answer questions such as 'Was the information produced according to the state of the art?'; 'Does the information apply well to the region in question?'; 'Is any information missing?'; 'Were tools used for data collection that meet technical standards?'; and 'Is metadata provided?'
- **Consistency of data:** Describe whether the data and information from this source are consistent, both in terms of the number of sources and the methodology used.
- **Level of robustness:** for each source, assess the level of robustness of the available data and information using the previously conducted assessment. The degree of robustness can be described qualitatively or on a scale from 1-7 (not robust to extremely robust). The degree of robustness can be described qualitatively or on a scale from 1 - 7 (from not robust to extremely robust).

Table 30 : Matrix to define the robustness of climate data and sources
(Adapted from Becher et al., 2019).

Information category	Type of data	Source of the data	Quality oft the data	Consistency of the data	Level of robustness
Annual precipitation	Histroical weather data	National Meterological Institute	Good quality, 53 years of data with no gaps, measuring 4 times per day	Good consist-ency, no change in location on measuring equipment	7 (extremely robust)
	Global Climate Models: HadGEM2, MIROC and CanCM4, for RCP 4.5	Met Office UK	Good quality, although only in grids of 150x150 Km	Good consistency, but only three models and one scenario	5 (robust)

E 2.5.3. - Step 3 - Determine the level of confidence

Table 31 can be used to assess the degree of confidence in the results. The matrix can be filled in again category by category to enable a comparison to be made:

1. Put all the data sources previously evaluated in the matrix into one column. Also transfer the previously determined level of robustness.
2. For each category of data, assess what type of trend it provides for your system. The trend refers to the type of information that is relevant to the category. For example, categories related to climate sig-

nals might show trends toward lower precipitation, while categories related to vulnerability might show trends toward higher vulnerability.

» Use '+1' for an increasing trend, '-1' for a decreasing trend, and '0' for no trend to change the assessed parameter and justify your choice in writing.

» Climate trends and Climate outcomes: The reason of focusing on trends rather than final outcomes has to do with the fact that climate-related information rarely shows 100% concordance, what can be the result of using different climate models or scenarios or gathering different type of data. For this reason, focusing on trends is at least an indicator for tendencies in agreement.

3. Sum up the weighted number for each source within each category, counting rising trends as positive and falling trends as negative. If there is no trend or the trend is uncertain, it is not counted.
4. Sum up all calculated figures for each category.
5. Finally, compare the final scores for each category. The higher the score (both negative and positive), the greater the confidence in the trend shown.
6. When comparing the different categories, the confidence level of the findings on different categories can be assessed – as the result of analysing both the evidence and agreement in trend. The confidence can be described either qualitatively or on a scale of 1-7 (no confidence to extreme confidence).

Table 31 : Matrix for determining the level of confidence
(Eucker et al., 2022).

Information category	Historical weather data (7)	Global Climate Models: HadGEM2, for RCP 4.5 (4)	Review of local newspapers (3)	Literature review (6)	Confidence (final score)
Annual precipitation	+1 (an average of +0.2 mm/year) (+1)*7 = +7	0 (no perceived change) 0*4 = 0	-1 (perceived reduction of precipitation in the last years) (-1)*3 = -3	+1 (an average of 0.3 mm/year until 2050) (+1)*6 = +6	7+0-3+6 = 10 Confidence in the trend: 5
Exposure of critical infrastructuere to extreme temperatures	…	…	…	…	+18 Confidence in the trend: 6

III.

References

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Glossary

Key term	Definition
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 (MA, 2005).
Baseline/reference	The baseline (or reference) is the state against which change is measured.
Capacity building	The practice of enhancing the strengths and attributes of, and resources available to, an individual, community, society or organisation to respond to change.
Climate Change Adaptation (CCA)	In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects. See also CCA options, Adaptive capacity and Maladaptive actions (Maladaptation).
CCA gap	The difference between actually implemented CCA and a societally set goal, determined largely by preferences related to tolerated climate change impacts and reflecting resource limitations and competing priorities (UNEP, 2014; UNEP, 2018)
CCA limits	The array of strategies and measures that are available and appropriate for addressing CCA. They include a wide range of actions that can be categorised as structural, institutional, ecological or behavioural.
CCA pathways	A series of CCA choices involving trade-offs between short-term and long-term goals and values. These are processes of deliberation to identify solutions that are meaningful to people in the context of their daily lives and to avoid potential maladaptation.
Climate extreme (extreme weather or climate event)	The occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable. For simplicity, both extreme weather events and extreme climate events are referred to collectively as 'climate extremes'.
Climate indicator	Measures of the climate system including large-scale variables and climate proxies.
Climate information	Information about the past, current state, or future of the climate system that is relevant for mitigation, CCA and risk management. It may be tailored or 'coproduced' for specific contexts, taking into account users' needs and values.
Climate model	A qualitative or quantitative representation of the climate system based on the physical, chemical, and biological properties of its components, their interactions and feedback processes and accounting for some of its known properties. The climate system can be represented by models of varying complexity; that is, for any one component or combination of components a spectrum or hierarchy of models can be identified, differing in such aspects as the number of spatial Climate Risk Sourcebook -CR-SB dimensions, the extent to which physical, chemical or biological processes are explicitly represented, or the level at which empirical parametrisations are involved.
Climate projection	Simulated response of the climate system to a scenario of future emissions or concentrations of greenhouse gases (GHGs) and aerosols and changes in land use, generally derived using climate models. Climate projections are dependent on the emission/concentration/radiative forcing scenario used, which is in turn based on assumptions concerning, for example, future socio-economic and technological developments that may or may not be realised.
(Climate) Risk Assessment	The qualitative and/or quantitative scientific estimation of risks.

Key term	Definition
Climate Risk Management (CRM)	Climate Risk Management includes all mechanisms and measures (such as plans, actions, strategies or policies) to reduce current and future climate risks. The management of current risk to climate extremes is typically covered by the existing Disaster Risk Reduction (DRR) mechanism. Climate Change Adaptation (CCA) involves the process of adapting current CRM practices to the actual or anticipated impacts of climate change in order to limit damage or take advantage of positive opportunities. This includes adapting to the increasing intensity and frequency of climate extremes, as well as slow-onset processes (such as sea-level rise) and emerging climate risks. Today, CCA and DRR are seen as integral constituent parts of successful CRM.
Climate scenario	A plausible and often simplified representation of the future climate, based on an internally consistent set of climatological relationships that has been constructed for explicit use in investigating the potential consequences of anthropogenic climate change, often serving as input to impact models. Climate projections often serve as the raw material for constructing climate scenarios, but climate scenarios usually require additional information such as the observed current climate.
Climate variability	Deviations of climate variables from a given mean state (including the occurrence of extremes, etc.) at all spatial and temporal scales beyond that of individual weather events. Variability may be intrinsic, due to fluctuations of processes internal to the climate system (internal variability), or extrinsic, due to variations in natural or anthropogenic external forcing (forced variability).
Climatic driver (Climate driver)	A changing aspect of the climate system that influences a component of a human or natural system.
Confidence	The robustness of a finding based on the type, amount, quality and consistency of evidence (e.g. mechanistic understanding, theory, data, models, expert judgment) and on the degree of agreement across multiple lines of evidence. In this report, confidence is expressed qualitatively (IPCC, 2012; UNISDR, 2009).The robustness of a finding based on the type, amount, quality and consistency of evidence (e.g. mechanistic understanding, theory, data, models, expert judgment) and on the degree of agreement across multiple lines of evidence. In this report, confidence is expressed qualitatively (IPCC, 2012; UNISDR, 2009).
Compound risks	They arise from the interaction of hazards, which may be characterised by single extreme events or multiple coincident or sequential events that interact with exposed systems or sectors.
Composite indicator	A composite indicator (also called index) is a complex indicator, composed by combining several (weighted) individual indicators. Composite Indicators are able to measure multi-dimensional concepts (vulnerability against climate change effects) which cannot be captured by a single indicator. The methodology of its composition should entail the details of the theoretic framework or definition upon whereas indicators have been selected, weighted and combined to reflect the structure or dimension of the phenomena being measured (OECD, 2008a).
Coping capacity	The ability of people, institutions, organisations and systems, using available skills, values, beliefs, resources and opportunities, to address, manage and overcome adverse conditions in the short to medium term (IPCC, 2012; UNISDR, 2009).The ability of people, institutions, organisations and systems, using available skills, values, beliefs, resources and opportunities, to address, manage and overcome adverse conditions in the short to medium term (IPCC, 2012; UNISDR, 2009).
Disaster	A 'serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts' (MA, 2005).
Disaster risk	The likelihood over a specified time period of severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery.

Key term	Definition
Disaster risk reduction (DRR)	Denotes both a policy goal or objective, and the strategic and instrumental measures employed for anticipating future disaster risk; reducing existing exposure, hazard, or vulnerability; and improving resilience.
Driver	Any natural or human-induced factor that directly or indirectly causes a change in a system (adapted from MA, 2005).
Ecosystem	A functional unit consisting of living organisms, their non-living environment and the interactions within and between them. The components included in a given ecosystem and its spatial boundaries depend on the purpose for which the ecosystem is defined: in some cases, they are relatively sharp, while in others they are diffuse. Ecosystem boundaries can change over time. Ecosystems are nested within other ecosystems, and their scale can range from very small to the entire biosphere. In the current era, most ecosystems either contain people as key organisms or are influenced by the effects of human activities in their environment.
Ecosystem-based Adaptation (EbA)	The use of ecosystem management activities to increase the resilience and reduce the vulnerability of people and ecosystems to climate change (Campbell et al., 2009). See also Nature-based Solution (NbS).
Ecosystem services	Ecological processes or functions having monetary or non-monetary value to individuals or society at large. These are frequently classified as (1) supporting services such as productivity or biodiversity maintenance, (2) provisioning services such as food or fibre, (3) regulating services such as climate regulation or carbon sequestration and (4) cultural services such as tourism or spiritual and aesthetic appreciation. See also Ecosystem.
Emissions scenario	A plausible representation of the future development of emissions of substances that are radiatively active (e.g. greenhouse gases (GHGs) or aerosols) based on a coherent and internally consistent set of assumptions about driving forces (such as demographic and socio-economic development, technological change, energy and land use) and their key relationships. Concentration scenarios, derived from emissions scenarios, are often used as input to a climate model to compute climate projections. In the context of climate change responses, risks result from the potential for such responses not achieving the intended objective(s), or from potential tradeoffs with, or negative side-effects on, other societal objectives, such as the SDGs. Risks can arise for example from uncertainty in the implementation, effectiveness or outcomes of climate policy, climate-related investments, technology development or adoption, and system transitions. See also Hazard and Impacts.
Ensemble (climate simulation ensemble)	A group of parallel model simulations characterising historical climate conditions, climate predictions or climate projections. Variation of the results across the ensemble members may give an estimate of modelling-based uncertainty. Ensembles made with the same model, but different initial conditions characterise the uncertainty associated with internal climate variability, whereas multi-model ensembles including simulations by several models also include the effect of model differences. Perturbed parameter ensembles, in which model parameters are varied in a systematic manner, aim to assess the uncertainty resulting from internal model specifications within a single model. Remaining sources of uncertainty unaddressed with model ensembles are related to systematic model errors or biases, which may be assessed from systematic comparisons of model simulations with observations wherever available.
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.
Hazard	Hazard The potential occurrence of a natural or human-induced physical event or trend 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.
Impact chains	They permit the structuring of cause – effect relationships between drivers and/or inhibitors affecting a system. Impact chains allow for a visualisation of interrelations and feedbacks, help to identify the key impacts, on which level they occur and allow visualising which climatic hazards may lead to them. They further help to clarify and/or validate the objectives and the scope of the CRA and are a useful tool to involve stakeholders (adapted from (Fritzsche et al., 2015).

Key term	Definition
Impacts	Impacts generally refer to effects on lives, livelihoods, health and wellbeing, ecosystems and species, economic, social and cultural assets, services (including ecosystem services), and infrastructure. Impacts may be referred to as consequences or outcomes and can be adverse or beneficial.
Indicator	Measurable characteristic or variable which helps to describe a situation that exists and to track changes or trends – i.e. progress – over a period of time (GIZ, 2013).
Intergovernmental Panel on Climate Change (IPCC)	It is perceived as the leading international body for the assessment of climate change. In the 23 years since its founding, it has become a key framework for the exchange of scientific dialogue on climate change within the scientific community as well as across the science and policy arenas (Edenhofer and Seyboth, 2013).
Key risk	Key risks have potentially severe adverse consequences for humans and socialecological systems resulting from the interaction of climate-related hazards with vulnerabilities of societies and systems exposed.
Likelihood	The chance of a specific outcome occurring, where this might be estimated probabilistically. Likelihood is expressed in this Special Report using a standard terminology (Mastrandrea et al., 2010). See also Confidence and Uncertainty.
Loss and Damage and losses and damages	Research has taken Loss and Damage (capitalised letters) to refer to political debate under the United Nations Framework Convention on Climate Change (UNFCCC) following the establishment of the Warsaw Mechanism (WIM) on Loss and Damage in 2013, which is to 'address loss and damage associated with impacts of climate change, including extreme events and slow-onset events, in developing countries that are particularly vulnerable to the adverse effects of climate change.' Lowercase letters (losses and damages) have been taken to refer broadly to harm from (observed) impacts and (projected) risks and can be economic or non-economic (Mechler et al., 2019).
Maladaptive actions (Maladaptation)	Actions that may lead to increased risk of adverse climate-related outcomes, including via increased greenhouse gas (GHG) emissions, increased or shifted vulnerability to climate change, more inequitable outcomes, or diminished welfare, now or in the future. Most often, maladaptation is an unintended consequence.
Mitigation (of climate change)	A human intervention to reduce emissions or enhance the sinks of greenhouse gases.
Models	Structured imitations of a system's attributes and mechanisms to mimic the appearance or functioning of systems, for example, the climate, the economy of a country, or a crop. Mathematical models assemble (many) variables and relations (often in a computer code) to simulate system functioning and performance for variations in parameters and inputs.
Monitoring and evaluation (M&E)	Mechanisms put in place to respectively monitor and evaluate efforts to reduce greenhouse gas emissions and/or adapt to the impacts of climate change with the aim of systematically identifying, characterising and assessing progress over time.
National Adaptation Plan (NAP)	'National adaptation plans (NAPs) are means of identifying medium- and longterm CCA needs, developing and implementing strategies and programmes to address those needs. It is a continuous, progressive and iterative process to formulate and implement NAPs which follows a country-driven, gender-sensitive, participatory and fully transparent approach' (UNFCC, 2021).
Nature-based Solution (NBS)	Actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively. Therefore, they provide human wellbeing and biodiversity benefits (IUCN, 2016).
Normalisation	It refers to the transformation of indicator values measured on different scales and in different units into unit-less values on a common scale (OECD, 2008a). Normalisation is a prerequisite for aggregating individual indicators measured in different scales to a composite indicator (Fritzsche et al., 2015).

Key term	Definition
Ordinal scale	It indicates that one given value is greater or lesser than another, but the interval between values is undefined or unknown. Examples of ordinal scales include school marks, education level, and rankings of suitability of soil types for certain crops (Fritzsche et al., 2015).
Participatory approaches	Their participatory nature leads to outputs that reflect many different voices, perceptions and experiences. This requires an ability to synthesise and identify priorities for action. Qualitative approaches are often more in-depth and able to consider local specificities but do not yield comparable results (Fritzsche et al., 2015).
Pathways	The temporal evolution of natural and/or human systems towards a future state. Pathway concepts range from sets of quantitative and qualitative scenarios or narratives of potential futures to solution-oriented decision-making processes to achieve desirable societal goals. Pathway approaches typically focus on biophysical, techno economic and/or socio-behavioural trajectories and involve various dynamics, goals and actors across different scales.
Proxy	A proxy climate indicator is a record that is interpreted, using physical and biophysical principles, to represent some combination of climate-related variations back in time. Climate-related data derived in this way are referred to as proxy data. Examples of proxies include pollen analysis, tree ring records, speleothems, characteristics of corals and various data derived from marine sediments and ice cores. Proxy data can be calibrated to provide quantitative climate information.
Resilience	The capacity of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure. Resilience is a positive attribute when it maintains capacity for CCA, learning and/or transformation (Artic council, 2016).
Risk	The potential for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems. In the context of climate change, risks can arise from potential impacts of climate change as well as human responses to climate change. Relevant adverse consequences include those on lives, livelihoods, health and wellbeing, economic, social and cultural assets and investments, infrastructure, services (including ecosystem services), ecosystems and species. In the context of climate change impacts, risks result from dynamic interactions between climate-related hazards with the exposure and vulnerability of the affected human or ecological system to the hazards. Hazards, exposure and vulnerability may each be subject to uncertainty in terms of magnitude and likelihood of occurrence, and each may change over time and space due to socioeconomic changes and human decision-making.
Risk assessment	The qualitative and/or quantitative scientific estimation of risks. See also Risk management and Risk perception.
Risk management	Plans, actions, strategies or policies to reduce the likelihood and/or magnitude of adverse potential consequences, based on assessed or perceived risks.
Risk perception	The subjective judgement that people make about the characteristics and severity of a risk. See also Risk assessment and Risk management.
Scenario	A plausible description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (e.g. rate of technological change (TC), prices) and relationships. Note that scenarios are neither predictions nor forecasts but are used to provide a view of the implications of developments and actions. See also Pathways.
Sensitivity	The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g. a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g. damages caused by an increase in the frequency of coastal flooding due to sea level rise).
Social justice	Relations within society that seek to address the distribution of wealth, and access to resources, opportunities and support, according to principles of justice and fairness.

Key term	Definition
Social-ecological systems	Social-ecological systems are complex adaptive systems in which people and nature are inextricably linked, in which both the social and ecological components exert strong influence over outcomes. The social dimension includes actors, institutions, cultures and economies, including livelihoods. The ecological dimension includes wild species and the ecosystem they inhabit (IPBES, 2023).
Stakeholder	"A person or an organisation that has a legitimate interest in a project or entity or would be affected by a particular action or policy" (IPCC, 2007).
United Nations Framework Convention on Climate Change (UNFCCC)	A Convention of the United Nations, adopted in May 1992 and ratified by 197 parties (in 2018), with the ultimate objective being the "stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system". The provisions of the Convention are pursued and implemented by two treaties: the Kyoto Protocol and the Paris Agreement (IPCC, 2022a).
Transformation	A change in the fundamental attributes of natural and human systems.
Uncertainty	A state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from imprecision in the data to ambiguously defined concepts or terminology, incomplete understanding of critical processes or uncertain projections of human behaviour. Uncertainty can therefore be represented by quantitative measures (e.g. a probability density function) or by qualitative statements (e.g. reflecting the judgement of a team of experts) (IPCC, 2004; Mastrandrea et al., 2010; Moss and Schneider, 2000).
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. See also Exposure, Hazard and Risk.
Vulnerability assessments	The practice of identifying, measuring and ranking vulnerabilities of a system. They are usually applied to inform decision makers and to support processes of CCA. Measures in the context of policymaking and for specific sectors and subsystems aim to enhance the ability to resist or avoid harmful consequences of climate change (Fritzsche et al., 2015).
Weighting	Describes the process of attaching a numerical modification (weight) to an indicator to emphasise the importance of this indicator against other indicators (OECD, 2008b). Weighting (i.e. adding a multiplier or divisor to the respective factor) is used to enhance or reduce the influence of that factor in its interaction within the composite indicator (Fritzsche et al., 2015).

Note: This glossary is based on definitions used by the IPCC (IPCC, 2022a) and for some terms adapted from the Vulnerability Sourcebook (Fritzsche et al., 2015).

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