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Adaptation to climate change — Guidelines on vulnerability, impacts and risk assessment

Adaptation au changement climatique — Lignes directrices sur la vulnérabilité, les impacts et l'évaluation des risques

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 207, E*nvironmental management*, Subcommittee SC 7, *Greenhouse gas management and related activities*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/SS S26, *Environmental management*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Climate change is impacting organizations in various ways and it is anticipated that these impacts will continue well into the future. Organizations have an increasing need to understand, mitigate and manage climate change risks. Climate change risk assessment is key in this context. For responses to be delivered at the necessary pace and scale, it is important that risk assessment approaches are systematic and replicable, permitting learning within and between assessments as new knowledge, technology and experience arise. This document provides guidelines on approaches to assess climate change-related risks.

Risk assessments improve planning of adaptation to climate change and inform the implementation and monitoring of climate change adaptation activities. Adaptation is usually more effective when initiated at an early stage of project development, and when undertaken as a planned process rather than in response to experienced impacts. Better knowledge of climate change risks will make it easier and less costly to respond.

Climate change risks differ from other risks. It is often difficult or even impossible to quantify their short- or long-term probability so a conventional risk assessment that uses statistical probabilities can be ineffective. For this reason, various approaches have been developed for assessing climate change risks. This document provides guidance on the use of screening assessments and impact chains. The screening approach can serve as a stand-alone, simplified risk assessment for a straight-forward system at risk or for organizations with a limited budget, or serve as a pre-assessment prior to the use of impact chains. Based on a participatory and inclusive process, impact chain approaches are more comprehensive, providing an opportunity to address all relevant factors. Both screening assessments and impact chain assessments allow for qualitative and quantitative analysis.

This document is relevant to any organization regardless of size, type and nature. For example, it can help financial institutions with decisions in project financing, companies operating in climate-sensitive business sectors or local governments developing adaptation strategies.

This document covers risks that result from a changing climate. It does not address risks that result from the transition to a low carbon economy. This document recognizes that climate risks can be threats or opportunities.

This document emphasizes comprehensive documentation and communication of climate change risks; these are essential for all subsequent activities. Risk assessments, among other purposes, provide information on identifying adaptation actions and prioritizing them. Risk assessments conducted in accordance with this document also strengthen planning activities on disaster risk reduction (DRR).

This document can be applied by organizations that want to carry out climate change risk assessments [in the sense of the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC)] as well as by organizations that want to carry out vulnerability assessments (in the sense of the IPCC AR4). However, it uses risk assessment as the central term.

This document belongs to an emerging family of standards on adaptation to climate change under the umbrella of ISO 14090, which describes the following elements of climate change adaptation:

— pre-planning;

— assessing impacts including opportunities;

— adaptation planning;

— implementation;

— monitoring and evaluation;

— reporting and communication.

This document is part of the second item on the above list: “assessing impacts including opportunities”. ISO/TS 14092:2020 helps define adaptation planning for local governments and communities. Other

International Standards also deal with climate change or are in some way linked to this document. For example, ISO 31000 is an excellent companion because it can help organizations manage the risks that are identified and assessed in this document, which itself is a specialized expansion of the limited risk assessment portion of ISO 31000. ISO 14001 allows for the integration of climate change adaptation into an environmental management system and this document provides additional information to support this.

This document is a guidance document for people working in the field of climate change.

This document is structured starting with an introduction to the concept of climate change risk assessment, followed by the preparation, the implementation and the documentation and communication of the climate change risk assessment.

The guidelines provided in this document are accompanied by supporting examples and information.

In this document, the following verbal forms are used:

— "should" indicates a recommendation;

— "may" indicates a permission;

— "can" indicates a possibility or capability.

Adaptation to climate change — Guidelines on vulnerability, impacts and risk assessment

1 Scope

This document gives guidelines for assessing the risks related to the potential impacts of climate change. It describes how to understand vulnerability and how to develop and implement a sound risk assessment in the context of climate change. It can be used for assessing both present and future climate change risks.

Risk assessment according to this document provides a basis for climate change adaptation planning, implementation, and monitoring and evaluation for any organization, regardless of size, type and nature.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
organization
person or group of people that has its own functions with responsibilities, authorities and relationships to achieve its objectives

Note 1 to entry: The concept of organization includes, but is not limited to, sole-trader, company, corporation, firm, enterprise, authority, partnership, charity or institution, or part or combination thereof, whether incorporated or not, public or private.

[SOURCE: ISO 14001:2015, 3.1.4]

3.2
interested party
person or *organization* (3.1) that can affect, be affected by, or perceive itself to be affected by a decision or activity

EXAMPLE Customers, communities, suppliers, regulators, non-governmental organizations, investors, employees and academia.

Note 1 to entry: To "perceive itself to be affected" means the perception has been made known to the organization applying this document.

[SOURCE: ISO 14001:2015, 3.1.6, modified — "academia" has been added to the example and "applying this document" has been added to Note 1 to entry.]

3.3
system
set of interrelated or interacting elements

[SOURCE: ISO 9000:2015, 3.5.1]

3.4
climate
statistical description of weather in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years

Note 1 to entry: The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization[26].

Note 2 to entry: The relevant quantities are most often near-surface variables such as temperature, precipitation, and wind.

[SOURCE: ISO 14090:2019, 3.4]

3.5
climate change
change in *climate* (3.4) that persists for an extended period, typically decades or longer

Note 1 to entry: Climate change can be identified by such means as statistical tests (e.g. on changes in the mean, variability).

Note 2 to entry: Climate change might be due to natural processes, internal to the climate *system* (3.3), or external forcings such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use.

[SOURCE: ISO 14090:2019, 3.5]

3.6
adaptation to climate change
climate change adaptation
process of adjustment to actual or expected *climate* (3.4) and its effects

Note 1 to entry: In human *systems* (3.3), adaptation seeks to moderate or avoid harm or exploit beneficial opportunities.

Note 2 to entry: In some natural systems, human intervention can facilitate adjustment to expected climate and its effects.

[SOURCE: ISO 14090:2019, 3.1]

3.7
climate projection
simulated response of the climate *system* (3.3) to a scenario of future emission or concentration of greenhouse gases and aerosols, generally derived using climate models

Note 1 to entry: Climate projections are distinguished from climate predictions in order to emphasize that climate projections depend upon the emission/concentration/radiative forcing scenario used, which are based on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realized.

[SOURCE: Adapted from IPCC, 2014]

3.8
hazard
potential source of harm

Note 1 to entry: The potential for harm can be in terms of loss of life, injury or other health *impacts* (3.14), as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources.

Note 2 to entry: In this document, the term usually refers to climate-related physical events or trends or their physical impacts.

Note 3 to entry: Hazard comprises slow-onset developments (e.g. rising temperatures over the long term) as well as rapidly developing climatic extremes (e.g. a heatwave) or increased variability.

[SOURCE: ISO/IEC Guide 51:2014, 3.2, modified — Notes 1 and 2 to entry have been added to reflect the definition of "hazard" in IPCC, 2014: Annex II: Glossary. Note 3 to entry has been added.]

3.9
exposure
presence of people, livelihoods, species or ecosystems, environmental functions, services, resources, infrastructure, or economic, social or cultural assets in places and settings that could be affected

Note 1 to entry: Exposure can change over time, for example as a result of land use change.

[SOURCE: ISO 14090:2019, 3.6]

3.10
sensitivity
degree to which a *system* (3.3) or species is affected, either adversely or beneficially, by *climate* (3.4) variability or change

Note 1 to entry: 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).

[SOURCE: Adapted from IPCC, 2014]

3.11
adaptive capacity
ability of *systems* (3.3), institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences

[SOURCE: ISO 14090:2019, 3.2]

3.12
vulnerability
propensity or predisposition to be adversely affected

Note 1 to entry: Vulnerability encompasses a variety of concepts and elements including *sensitivity* (3.10) or susceptibility to harm and lack of capacity to cope and adapt.

[SOURCE: ISO 14090:2019, 3.15]

3.13
risk
effect of uncertainty

Note 1 to entry: An effect is a deviation from the expected. It can be positive, negative or both. An effect can arise as a result of a response, or failure to respond, to an opportunity or to a threat related to objectives.

Note 2 to entry: Uncertainty is the state, even partial, of deficiency of information related to, understanding or knowledge of an event, its consequence, or likelihood.

[SOURCE: ISO 14001:2015, 3.2.10, modified — Note 1 to entry has been modified. Notes 3 and 4 to entry have been deleted.]

3.14
impact
effect on natural and human *systems* (3.3)

Note 1 to entry: In the context of *climate change* (3.5), the term "impact" is used primarily to refer to the effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services and infrastructure due to the interaction of climate change or hazardous climate events occurring within a specific time period and the *vulnerability* (3.12) of an exposed society or system. Impacts are also referred to as consequences and outcomes. The impacts of climate change on geophysical systems, including floods, droughts and sea level rise, are a subset of impacts called "physical impacts".

[SOURCE: ISO 14090:2019, 3.8]

3.15
impact chain
analytical approach that enables understanding of how given *hazards* (3.8) generate direct and indirect *impacts* (3.14) which propagate through a *system* (3.3) at *risk* (3.13)

3.16
indicator
quantitative, qualitative or binary variable that can be measured or described, in response to a defined criterion

[SOURCE: ISO 13065:2015, 3.27]

4 Introduction to climate change risk assessment

4.1 Concept of climate change risk

Climate change risk describes the potential impact of climate change on societies, economies and the environment.

NOTE 1 This document focuses on the risks induced by the impacts of climate change and not risks from climate change mitigation policies, e.g. transitional risks.

NOTE 2 The impacts of climate change can arise from gradual changes in climate conditions as well as an increase in extreme weather events.

The main components for a risk assessment are (illustrated in Figure A.1):

a) the hazard;

b) the exposure of a given system to the hazard;

c) the sensitivity of the system to the hazard;

d) the (potential) climate change impact, i.e. risk without adaptation;

e) the risk with adaptation (in the future).

Future potential climate change impacts can be modified by the adaptive capacity of a system.

EXAMPLE A system can be a region, a community, a household, a supply chain, an economic sector, a business, a population group, an ecosystem, infrastructure and its components.

Climate change impacts occur because a system is exposed to hazards (e.g. drought, flooding, heat stress). The sensitivity of the system (e.g. types of crops, land-use, age of the population) will determine the extent to which these hazards affect it. Impact is a function of both the exposure and the sensitivity of the system to hazards. The system's adaptive capacity influences the degree to which the potential impact becomes a tangible risk. The vulnerability of the exposed system can be expressed as a combination of an organization's sensitivity and its lack of adaptive capacity (the concepts of vulnerability and climate risk are illustrated in Figures A.2 and A.3).

NOTE 3 Though hazards are defined as sources of potential harm (e.g. heatwaves causing agricultural losses), they can sometimes lead to opportunities (e.g. higher temperatures leading to additional tourism opportunities).

NOTE 4 For further information on the concept of climate change risk, see Annex A. Table A.1 offers a comparison between concepts of vulnerability and risk.

4.2 Assessing climate change risk

4.2.1 Objectives

Risk assessments fulfil diverse objectives depending on the information needs of an organization, and on challenges caused by climate change. These can include the following.

- Raising awareness: Risk assessments help increase awareness of the consequences of climate change.
- Identification and prioritization of risks: Many factors contribute to a system's sensitivity, exposure and adaptive capacity. Climate change risk assessments provide insight into these factors and this helps the organization to prioritize the risks to be addressed.
- Identification of entry points for climate change adaptation intervention: The final results and the process of risk assessment can help identify possible adaptation responses. Risk assessments can show where early action is required, e.g. to avoid locking-in future impacts and to highlight the need for development of adaptive capacity.
- Tracking changes in risk, and monitoring and evaluating adaptation: Repeating risk assessments can help to track changes over time and generate knowledge on the effectiveness of adaptation[12].

4.2.2 Value-based judgements

Value-based judgements are necessary in climate change risk assessments. If impacts cannot be measured in the same units (e.g. monetary losses, reduced life expectancy in years), the selection of the most relevant climate change impacts involves value-based judgements. Another instance of a value-based judgement is the establishment of critical thresholds, if these cannot or can only partially be inferred from empirical evidence. For example, a threshold for critically low precipitation (say 200 mm/year) for maintaining a certain type of agriculture (e.g. fruit growing) in a given region can be set based on past experiences and agro-scientific know-how, but it also depends on judgements as to what is considered "critical". To facilitate the interpretation and evaluation of the results of the risk assessment, it is important to be transparent about where value-based judgements have been applied[10]. While value-based judgements cannot be avoided, fact-based approaches should be used wherever possible.

5 Preparing a climate change risk assessment

5.1 Establishing the context

Each risk assessment has a unique context that determines its scope, objectives and planned outputs (such as a report). The organization should define the context of the assessment by considering the following.

- The system at risk: Providing a broad outline of the system exposed to the impacts of climate change, including general understanding of its sensitivity, exposure and adaptive capacity.
- Hazards: Identifying which hazards can potentially affect the system at risk, choosing which ones to include in the risk assessment, and specifying the type of information required.
- Processes: Identifying existing or planned processes and activities related to the risk assessment such as assessments of supply chains.

— Knowledge: Identifying the available knowledge of climate change and variability, of impacts and existing risk, of existing impact assessments (e.g. including research results and local knowledge) and of the adaptive capacity of the organization, keeping in mind that the spectrum of possible impacts can be very broad (see ISO 14090).

— Interested parties: Identifying and involving interested parties in the process as far as it is practicable (e.g. aspects referring to risks raised by interested parties, such as environmental associations, can provide relevant inputs to facilitate the broader acceptance of the risk assessment).

— Resources for the assessment: Establishing the availability of financial, human and technical resources and information/data.

— External developments: Identifying external factors that could influence the system at risk (e.g. demographic changes, land use changes, technological developments, changes in the political and institutional context, market changes, global developments)[12].

— Regulatory obligations, responsibilities to others: Identifying regulatory or other obligations that can influence the objectives, the process or the outcomes of the risk assessment.

NOTE Additional guidance on preparing and conducting a risk assessment can be found in ISO 31000. It places this document in the broader context of risk management.

5.2 Identifying objectives and expected outcomes

An organization's decision to conduct a risk assessment is driven by a need or an information gap.

The organization should:

— determine the objectives and expected outcomes of the risk assessment and the processes that the risk assessment will support or feed into;

— identify the information gaps that the risk assessment is to address;

— define how the knowledge and results that will be generated are to be used (e.g. input into ongoing adaptation efforts or planning new adaptation actions);

— clarify how the results of the risk assessment will be depicted (e.g. map with risk hotspots, ranking of vulnerable sectors, narrative analysis of risk and its relevant factors);

— involve the experts, institutions and interested parties needed to conduct the assessment and support the implementation of the results in adaptation decisions;

— identify and inform the target audience, at an early stage, about the process and the expected outcomes and outputs of the risk assessment.

5.3 Establishing a project team

The organization should appoint a project team to carry out the risk assessment. The project team should have an understanding about the content of this document and the following:

— the organization, the system at risk and the organization's relation to the system at risk;

— the context of the system at risk (e.g. relationships up and downstream, geographical location(s), regulatory obligations, responsibilities to others, supply chain);

— climate change and its general impacts.

The project team should have informed leadership with decision-making capacity within the organization, as well as including specialists to assist in forming action plans and defining objectives. Organizations can benefit when decision-maker(s) are engaged early in the process. This is because value judgements are often required and because involvement in the process improves ownership of the results.

The organization can involve external experts in its project team or in an advisory role.

Roles and responsibilities of all parties (including internal and external experts as well as decision-makers) should be defined.

The project team should communicate regularly to coordinate central assessment steps and results and on the sufficiency of resources and the need for high-level support.

Other interested parties can be involved through a participatory process. Interested parties can be engaged at the outset of the assessment (to understand context, to gather information) as well as during and after the assessment (to validate). The organization should sufficiently account for gender differences and ensure that especially vulnerable groups are represented and measures taken to ensure that they are able to effectively contribute to the risk assessment.

5.4 Determining the scope and methodology

The project team in coordination with the relevant decision-makers should define the scope of the risk assessment, considering the following:

— the specific system at risk;

— the level of detail needed for the assessment to be fit-for-purpose;

— population groups involved (e.g. rural communities, elderly people, indigenous people, women/men, certain parts of the work force);

— the range of hazards to be included (e.g. flooding, rising temperatures, sea level rise, heatwaves) and their nature (e.g. extremes, changes in the mean and variability);

— the areas under review (e.g. countries, districts, provinces), and whether it is a single spatial unit (e.g. one district) or a comparison of areas (e.g. two or more districts);

— the spatial resolution of the assessment (a decision on spatial scale can be influenced by the availability of data relevant to the assessment);

— the temporal resolution of the assessment (see 5.5);

— the methodology to be used in the assessment (e.g. quantitative, qualitative, mixed approaches);

— the resources (e.g. financial, human) available for the risk assessment.

5.5 Setting the time horizon

When setting the time horizon of the assessment, the organization should consider:

— the lifetime of the system at risk;

— the timescales over which the impacts of climate change reach critical thresholds for the system at risk;

— the lead time for adaptation actions to address impacts. This may be related to the lifetime of the system.

The choice of time horizon can be influenced by aspects such as:

— the availability of data, including climate projections;

— the longer-term uncertainties in projected impacts of climate change;

— the potential for interactions between impacts to occur over different timescales.

The organization can benefit from considering more than one time horizon. For example, a reference period of the recent past (e.g. the last three decades) or the present, one near future (e.g. the next three decades) and one distant future (e.g. 2070 to 2100).

The near future is often more important for decisions on adaptation to climate change than the distant future. However, using the distant future is essential for systems that require very long periods of time to adapt, e.g. forest ecosystems.

Time periods longer than 100 years can be considered as the time horizon of a risk assessment. They can be relevant, for example, in the case of sea level rise for coastal cities or for long-lasting assets.

The time horizon for assessing the hazard should be at least 30 years, the standard period as defined by the World Meteorological Organization[26].

5.6 Gathering relevant information

Where available, existing knowledge on hazards, sensitivities, exposure, climate change impacts, vulnerabilities related to the system at risk, adaptive capacity, existing risk assessments and tools used to manage risks should be collected early on. It can be useful to collect knowledge of other drivers of change (such as investment cycles) to align the risk assessment with organizational decision processes.

NOTE For further information on methodologies, various national and international guidance documents and tools can be found online. Be aware that some of them apply different terminology (compare Annex A).

5.7 Preparing an implementation plan

Having completed the steps described in 5.1 to 5.6, the project team should develop a plan for implementing the risk assessment. The following should be covered in the implementation plan.

— Specific tasks: What needs to be done?

— Responsibilities: Who will be doing this?

— Time planning: When will this happen?

When developing the implementation plan, the project team:

— can involve interested parties to help define tasks and responsibilities;

— should be aware that carrying out a climate change risk assessment is an iterative process.

The results of every step of the risk assessment can trigger the need to return to an earlier point and to restart from there.

5.8 Transparency

Transparency should be integral to the entire risk assessment process, from inception to presentation of the results. This helps to achieve understanding and ownership, and to ensure that the outputs are practical and relevant. The organization should give particular attention to transparency with regard to the following.

— Methodology: Is the methodology known to all involved and documented adequately to allow newcomers to understand the steps and decisions taken?

— Decision-making process: How are decisions taken to identify impacts, and to select, normalize, weight and aggregate indicators? How are aspects of data availability and other challenges dealt with? How are these documented and communicated?

— Uncertainty: How will uncertainties be reduced as far as possible (see Annex B)? How will remaining uncertainties be dealt with? How are these documented and communicated?

— Strengths and weaknesses: Are the strengths and weaknesses of the approach identified? How are these explained so as to ensure credibility and allow for practical use? How are these documented and communicated?

5.9 Participatory approach

Participation of interested parties helps to ensure the delivery of comprehensive assessments by involving appropriate expertise and supports high-quality decision-making. Participation raises awareness and develops capacity among interested parties as well as fostering common understanding and ownership. Participation should be ensured in many, if not all, phases of the assessment.

6 Implementing a climate change risk assessment

6.1 Screening impacts and developing impact chains

6.1.1 General

To carry out a risk assessment, the project team needs to understand cause-effect relationships. The project team should develop impact chains based on relevant climate change impacts. For this, a sound understanding of the system at risk and expert knowledge are required. The project team can use the help of (additional) external climate change experts and other experts appropriate for understanding the system (e.g. scientists, association representatives, insurance representatives, local authorities, representatives of affected sectors or communities) to identify relevant impacts and prepare impact chains. Participatory workshops with interested parties or other means of consultation for the development of the impact chains should be considered (see 5.9).

Annex C gives worked examples for screening and developing impact chains. Table C.1 provides examples of relevant risk factors and indicators for different risk components.

6.1.2 Screening and identifying impacts

The project team should identify and list potential climate change impacts. The project team should also consider how climate change impacts in other regions of the world can impact the system at risk (systemic dependencies, e.g. through supply chains)[19]). To identify the relevant impacts, the project team can use tools such as spreadsheets to guide the process and document findings. The project team can start with the risks under the current climate. They should identify the hazards, combinations of hazards, sensitivities and exposures applicable to the system at risk. The hazards can be listed along one axis of a table. The project team should select the elements of the system at risk that can be exposed to climate change and are likely to have sensitivity to the hazards. These can be listed on the other axis to form a matrix (see Annex D; examples are shown in Tables D.1 and D.2). The project team should then consider the potential consequences from each hazard on each element of the system at risk and make their best estimate of likely impacts. They can mark the cells according to the level of risk, e.g. high, moderate or low, or use a numerical or letter grading. They should include notes to describe the rationale behind this preliminary risk ranking. The completed table is a record of screening and constitutes a preliminary output. It can serve to inform the next steps of the risk assessment or as a basis for adaptation planning if no deeper risk assessment is deemed to be necessary.

Decision-makers should select those climate change impacts that appear particularly relevant in the assessment and to the objectives of the organization. The more precisely the objective has been defined, the more precisely the selection criteria can be identified. This will result in an initial prioritization of climate change impacts. This is a very important step and should be carried out with due care.

6.1.3 Developing impact chains

Impact chains serve to better understand, visualize, systemize and prioritize those factors that drive risk in the system. Impact chains serve as an analytical starting point for the overall risk assessment. They specify which hazards potentially cause direct and indirect climate change impacts. They thus represent the basic structure for the risk assessment. They serve as important communication tools for discussing what is to be analysed and which climate and socioeconomic, bio-physical or other parameters should be taken into account. In this way, they facilitate the identification of targeted adaptation actions[8][12].

Beginning with the selected impacts from the screening assessment, the project team should develop impact chains building on existing knowledge. This should be done independently of whether these impacts can be quantitatively assessed or not. Annex C gives guidance on how to develop impact chains, with examples.

The project team should keep in mind the interdependencies between the impact chains as they are developed. To maintain the necessary focus and keep impact chains understandable, each impact chain should concentrate on the most relevant relationships between the various risk factors (see Annex C). It should be noted that this constitutes an iterative process and new aspects can emerge throughout the development of an impact chain.

At this point, the project team will have gained substantial knowledge regarding climate change risks by identifying the relevant impacts and determining the relevant risk factors and their relationships in the form of the impact chains. Depending on the objectives of the risk assessment, that knowledge can be sufficient and it is possible to proceed with the interpretation and evaluation of the results (see 6.6).

Alternatively, adaptive capacities of the system at risk can be identified. The key question for this step is: “Which capacities and resources of and within the system will reduce climate change impacts?” (see 6.5). The adaptive capacity can be directly integrated into the impact chain (see Annex C).

6.2 Identifying indicators

6.2.1 General

In general, indicators are parameters providing information about specific states or conditions. When these states or conditions are not directly measurable, proxy indicators are used (e.g. incidence of a specific pest as proxy for crop damage). The objective of applying indicators in a risk assessment is to use quantitative, semi-quantitative or qualitative information to estimate and evaluate the effects of climate change (i.e. by comparing indicator values against critical thresholds or previous estimations). Often, quantitative information does not exist or thresholds are not defined. Then, only qualitative information can be used and the evaluation of indicators will depend on expert judgement.

Where possible, at least one indicator for each relevant risk factor should be selected (see Annex C). Indicator values can be aggregated according to the risk components (hazard, exposure, sensitivity and eventually adaptive capacity) quantitatively, semi-quantitatively or qualitatively and can later be aggregated to establish a composite risk score[12]. Annex E provides examples of sample indicators for risk components.

6.2.2 Selecting indicators

Indicators should be specific. In this context, five aspects should be considered when selecting indicators:

— spatial coverage and resolution;

— temporal coverage;

— representativeness;

— replicability (for subsequent repetition of risk assessments);

— feasibility.

If possible, indicators that provide information on critical thresholds should be included. Table E.1 provides examples of indicators for risk assessments.

The selection of indicators is an iterative process. Individual experts or workshop discussions with specialists can help in the selection of relevant indicators for each risk factor. In practice, availability and quality of data, or resource constraints (time and budget) can limit the number of indicators.

Hazard indicators will largely consist of directly measurable or modelled climate parameters such as average temperature, or amount of precipitation.

For exposure and sensitivity indicators, ideally bio-physical or socioeconomic data from measurements or models such as demographic/hydrological/crop models can be sourced[23]. More likely, the definition of such indicators will rely on the availability of national statistics, past observations, expert judgement (as a substitute for numerical data), or a combination thereof.

6.2.3 Creating a list of indicators

The candidate indicators can be documented in a table or spreadsheet, and recorded with further relevant information (metadata). This includes, for each indicator:

— a brief description;

— the risk component (e.g. hazard) and risk factor (e.g. precipitation) the indicator represents;

— a brief explanation outlining the reason for selecting the indicator;

— the spatial coverage required for the indicator data;

— the unit of measurement or spatial resolution required for the indicator data;

— the temporal coverage required for the indicator data;

— an explanation whether a high or low indicator score decreases or increases risk;

— the existing and potential data sources, where possible.

An indicator factsheet template is provided in Reference [13].

6.3 Acquiring and managing data

6.3.1 Gathering data

Data for the reference period and the future are necessary. For the past and present, measurement data are often available. For the future, scenarios and projections are used to describe hazards, sensitivities and exposure. ISO 14033 can serve as a guideline for gathering data. It provides support on how to acquire quantitative environmental information and data.

Different methodologies can be used to collect the data required for the estimation of risk components (hazard, exposure, sensitivity and adaptive capacity). These can include the following.

— Expert judgement: Expert knowledge, local and indigenous knowledge are important sources of information for all risk assessments. Expert judgement should be used and complemented with quantitative data where available.

— Measurement: Physical measurements are carried out for indicators such as air humidity, stream height and soil moisture. Measurement can encompass remote sensing methods, such as analysis of satellite data to determine land use.

— Censuses and surveys: Information on, for example, household income, education and traditional irrigation techniques is normally gathered by census or survey. Census or survey data are often aggregated (e.g. from community to province level), interpolated or extrapolated before they are incorporated in risk assessments.

— Modelling: Models can be used in risk assessments to estimate current and future hazards (e.g. change in temperature or precipitation), sensitivity or exposure risk factors as well as current and potential future climate change impacts (e.g. runoff for a certain amount of precipitation, change in crop yields due to temperature change).

The following sources are relevant for future data.

— Climate projections: The results of models that simulate climate change are frequently used to represent the possible climate of the future. Global climate models use assumptions of future greenhouse gas emissions (emission scenarios) or their future concentration in the atmosphere (concentration scenarios) and result in climate projections. For many applications, such as crop modelling, it is necessary to use downscaled projections (i.e. projections with a higher spatial resolution) relevant to the location of the system at risk. Climate projections are inherently uncertain. Using ensembles of climate projections is one option to better understand uncertainty. Expert advice on uncertainties related to scenarios and downscaling should be sought.

— Sensitivity scenarios and scenarios for exposure: Sensitivity and exposure scenarios should, where possible, be consistent with climate projections. As exposure is closely linked to the development of (socioeconomic) sensitivity, sensitivity and exposure scenarios should be developed together. Uncertainties should be taken into account.

— Scenario combination: Climate projections, sensitivity scenarios and scenarios for exposure should be combined for the analysis of potential climate change impacts in the future.

Annex B provides detailed information on uncertainties.

6.3.2 Evaluating data quality and results

Checks on data quality and results should be made. For quantitative data, checks should include:

— quality and format of the data and legibility of files;

— spatial and temporal coverage;

— missing data values;

— outliers in the data and, if possible, their origin (see Reference [24]).

For qualitative information, checks should include:

— representation of interested parties' viewpoints;

— correct interpretation of words or terms (can vary between languages or regions).

Input data, as well as the results, whether quantitative or qualitative, are subject to uncertainties. Uncertainty in climate change impact assessment arises among other reasons from the models and scenarios used, and the data and the nature of the selected indicators. An assessment of the confidence level of the results should be carried out to inform the interpretation of the results (see Reference [22]). An assessment of the degree of confidence for each climate change impact should be carried out, at a minimum distinguishing "low", "medium" and "high", with appropriate definitions for the categories (see Reference [12]).

6.3.3 Managing data

Details of the data used in the risk assessment should be documented. Lack of awareness of existing data, or insufficient knowledge of the details of existing data, can lead to duplication of effort in data collection.

Datasets should be stored to avoid data loss. Metadata should be documented systematically with descriptions of the content, characteristics of the different datasets and instructions for interpreting values.

International Standards (such as ISO 19115-1) provide guidance for describing geographic information using metadata.

The indicator fact sheet provided in Reference [13] can be used as a guideline for documenting indicators.

6.4 Aggregating indicators and risk components

In climate change risk assessment, the aggregation of indicators and risk components is optional. Several methods, qualitative or quantitative, can be used, and several stages of aggregation are possible. Indicators can and may be aggregated to form one assessment for each climate change impact and be aggregated further for sub-units of the system at risk, e.g. by sector or business unit. Further aggregation can follow, leading to a single indicator for the system at risk, or one general assessment result in qualitative form[23].

The organization should consider whether aggregations are feasible, useful and justifiable. In some cases, a qualitative, interpretative summary of the individual results can be preferred. Aggregations can be useful for complex and cross-sectoral assessments; however, they should not mask individual results.

Annex F gives details of methods for aggregation.

6.5 Assessing adaptive capacity

Adaptive capacity should be taken into consideration when assessing risk. If this step is omitted, the resulting assessment is usually referred to as a climate change impact assessment.

An assessment of the capacity of an organization to deal with the potential impacts of climate change allows for a more realistic assessment of the risk it is facing, and of the need for additional adaptation measures. This aspect is particularly important in the case of a comparative risk assessment that considers several systems at risk (e.g. different sectors, regions or business units) with different levels of adaptive capacity. Furthermore, a detailed adaptive capacity assessment can identify ways the organization can reduce its vulnerability to climate change impacts.

Assessing adaptive capacity can be done either in parallel or subsequent to the assessment of climate change impacts. There are various dimensions of adaptive capacity, e.g. organizational capabilities, technical capacity, financial capacity, ecosystem capacity. Annex G describes these components.

All dimensions of adaptive capacity have the potential to contribute to reducing risk. Methods for assessing adaptive capacity are often qualitative or semi-quantitative. If quantitative or semi-quantitative indicators are used, a quantitative combination with other risk components is possible. Annex E provides example indicators of adaptive capacity.

The adaptive capacity assessment should integrate local knowledge and establish consent between experts and other interested parties[12]. Annex H provides examples of how to determine the level of adaptive capacity required for dealing with challenges of different complexity arising from climate change. Table H.1 provides an overview of the target levels of adaptive capacity required to manage different levels of risk.

In some cases, the adaptive capacity assessment can provide valuable information to distinguish risk levels between scenarios such as no adaptation, limited adaptation based on current adaptive capacity and enhanced adaptation based on additional adaptive capacity. Such a comparison can increase the visibility of the results and underline the importance of adaptation measures in reducing risk. This is especially the case if the risk assessment is designed to support the development, as well as the monitoring and evaluation, of adaptation interventions.

When the risk assessment considers risks for several systems (such as different regions or different production plants), the assessment of adaptive capacity should be done for each system separately.

6.6 Interpreting and evaluating the findings

The purpose of evaluating and interpreting the findings is to understand the identified risks and contribute to the achievement of the risk assessment's objectives. Consideration of uncertainties is important when evaluating results (see Annex F).

Climate change impacts should be prioritized to determine where adaptation needs are highest. This prioritization should be carried out by relevant decision-makers (or by the project team together with the decision-makers) and should include consideration of possible adaptation actions and responsibilities. The proposed priorities can be validated in a meeting with interested parties.

The magnitude of a potential climate change impact is not the same as its significance. In some cases, small changes can be of great significance (e.g. small disturbances of traffic flow in a given area), while in others even large climate change impacts can be easily managed. If thresholds are defined (e.g. a 10 % increase in traffic flow disturbances is considered as problematic), then the magnitude of a change can indicate its significance (see 4.2.2 and compare ISO 14090:2019, Annex B).

If the objective of the assessment is to compare impacts or risks across different areas of activity, e.g. sectors or regions, the evaluation should be done in an integrated way, either quantitatively or qualitatively. Since uniform quantitative evaluation criteria (e.g. normalized indicators or monetary values) are difficult to apply, a qualitative comprehensive evaluation is often the only way to draw comparative conclusions.

6.7 Analysing cross-sectoral interdependencies

Analyses of cross-sectoral interdependencies can deliver relevant additional information.

Impact chains can, among others, serve to identify and analyse the interrelationships between individual sectors, for example. In the graphical representation, such relationships can be shown, for example, by different colour assignments per area of activity (e.g. agriculture, forestry) or when an effect from climate change in one area of activity causes an impact in another area of activity.

Similarly, where different areas are under review, an analysis of cross-boundary interdependencies can provide further insight (e.g. interdependencies of traffic disturbances or impacts along the production line).

6.8 Independent review

An independent review of the risk assessment can be helpful. This review can be:

— a comprehensive review by an individual expert or a small group of experts;

— a series of critical evaluations of the most salient features of the risk assessment;

— an expert workshop where the results are presented and evaluated.

7 Reporting and communicating climate change risk assessment results

7.1 Climate change risk assessment report

Where a report is used to present risk assessment results, the report should provide:

— a description of the objectives of the risk assessment;

— the methods applied;

— the key findings;

— background information needed to understand and interpret the results.

The report should contain the following.

— A) Context and objectives:

  — the context in which the risk assessment was conducted (e.g. as part of a specific programme);
  — the objectives and approaches of the risk assessment;
  — institutions and interested parties involved;
  — the scope of the risk assessment including the system and impact(s) under review, as well as the geographical scope and timeframe.

— B) Methodology and implementation:

  — the assumed cause-effect relationships underlying the assessment, including the impact chains;
  — the selected risk factors and their indicators and the method(s) used, any data gaps and how they were handled;
  — the selection criteria for involved interested party(ies);
  — the information on the involved experts, including the sectors/geographic areas or professional backgrounds that were represented;
  — the weighting used (if any) and the process(es) by which it was determined (e.g. participatory processes with interested parties) (see Annex F);
  — the aggregation approach used (if any) for assessing risk;
  — the information on data sources and calculations to be used in future assessments for monitoring and evaluation.

— C) Findings:

  — the summary of the quantitative information on the overall risk as well as values for individual and aggregated indicators for hazard, sensitivity, exposure, potential impact and adaptive capacity;
  — the relevant qualitative information on the overall risk as well as any further relevant qualitative information on hazard, sensitivity, exposure, potential impact and adaptive capacity;
  — the challenges and opportunities encountered at the various stages of the risk assessment;
  — the uncertainties of the results;
  — the lessons learned;
  — the illustrations (maps, diagrams, graphs, etc.) that help explain the findings.

— D) Conclusions and recommendations:

  — the conclusions regarding the objectives of the risk assessment (e.g. prioritization of climate change impacts, identification of regional hot spots);
  — the conclusions for ongoing or forthcoming (policy) processes, such as adaptation strategies;
  — the suggestions for adaptation planning and monitoring and evaluation;
  — the recommendations for further assessments (methodology and content).

7.2 Communicating climate change risk assessment results

The results of climate change risk assessments can be communicated in a range of ways (e.g. overall risk reports, videos, outreach events, webinars, scientific articles, poster presentations, segments of sustainability reports). The most appropriate communication method should be selected to suit the target audience(s) of the risk assessment, who may comprise a diverse group of actors (e.g. government agencies, private sector, the public).

The results of the assessment should inform the management processes of the organization.

7.3 Reporting findings as a basis for appropriate adaptation planning

Risk assessment findings are used for planning, mainstreaming and implementing strategies and measures for adaptation to climate change. The presentation of the results should thus be tangible and contain conclusions and recommendations[25]. The following should be considered.

— Tangibility: Those involved in adaptation planning should understand the findings of the risk assessment even if they have not been involved in the preparation. Can they retrace the steps and decisions taken, correctly interpret any graphics, and acknowledge the key strengths and weaknesses of the findings?

— Conclusions and recommendations: The findings should give (or allow for) first impressions of adaptation priorities. Do they provide recommendations relating to, for example, how to fill identified gaps, and adaptation processes and planning?

Where the organization is planning to establish adaptation policies, information in the report should cover the time horizon of the risks and information on possible actions and priorities.

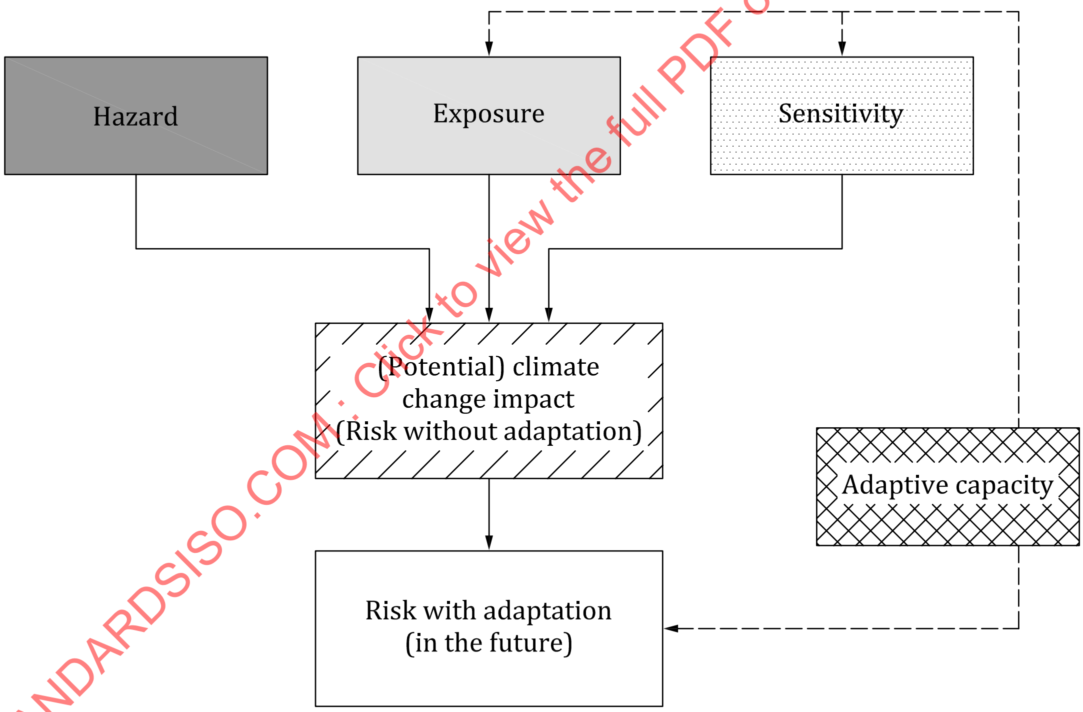
A description of the adaptation planning process, implementation and monitoring and evaluation of adaptation plans can be found in ISO 14090.

Annex A
(informative)

Linking vulnerability and risk management concepts — Change of the conceptual framework between IPCC AR4 and IPCC AR5

Figure A.1 illustrates the relationship of the various risk components according to the concept used in this document (see 4.1). The concept mostly follows the AR5 of the IPCC[19][20], but distinguishes more clearly between sensitivity and adaptive capacity. Furthermore, the conceptual framework avoids as much as possible the term “vulnerability”, as that term has become very ambiguous due to the changes made by the IPCC.

In 2014, IPCC changed its conceptual framework for determining the impacts of climate change from a vulnerability-based approach[17] to a more risk-oriented conceptual framework[19][20].



Key

The dotted line means that adaptation actions have been implemented.

NOTE 1 The vulnerability of the exposed systems is a combination of its sensitivity and its adaptive capacity.

NOTE 2 The illustration is compatible with the IPCC AR4 vulnerability concept and the AR5 risk concept. Potentially, IPCC will change it further in future reports.

SOURCE Based on Reference [14].

Figure A.1 — Relationship of the main components of the risk concept

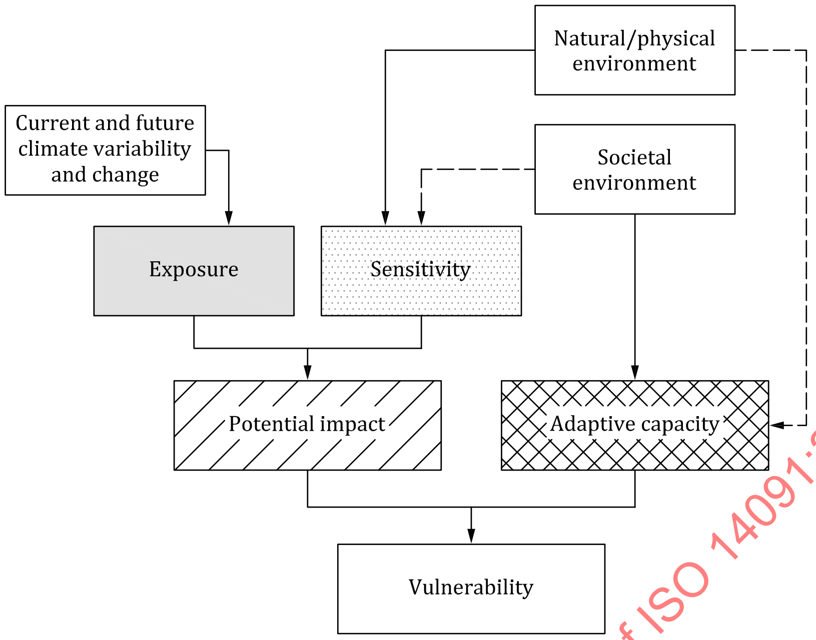
The IPCC AR5 is highly influenced by the Special Report on Extreme Events (SREX)[18], which links climate change adaptation and disaster risk reduction approaches.

In 2007, the IPCC AR4 described vulnerability as a function of the character, magnitude, and rate of climate change and variation to which a system – ecosystem, economic or social system – is exposed, its sensitivity, and its adaptive capacity. In the IPCC AR5 methodological framework, instead of vulnerability, the risk of climate change impacts is the end factor being assessed[14][17][21]. Table A.1 maps the AR4 approach to the AR5 framework.

Table A.1 — Comparison between vulnerability (AR4) and risk concept (AR5)

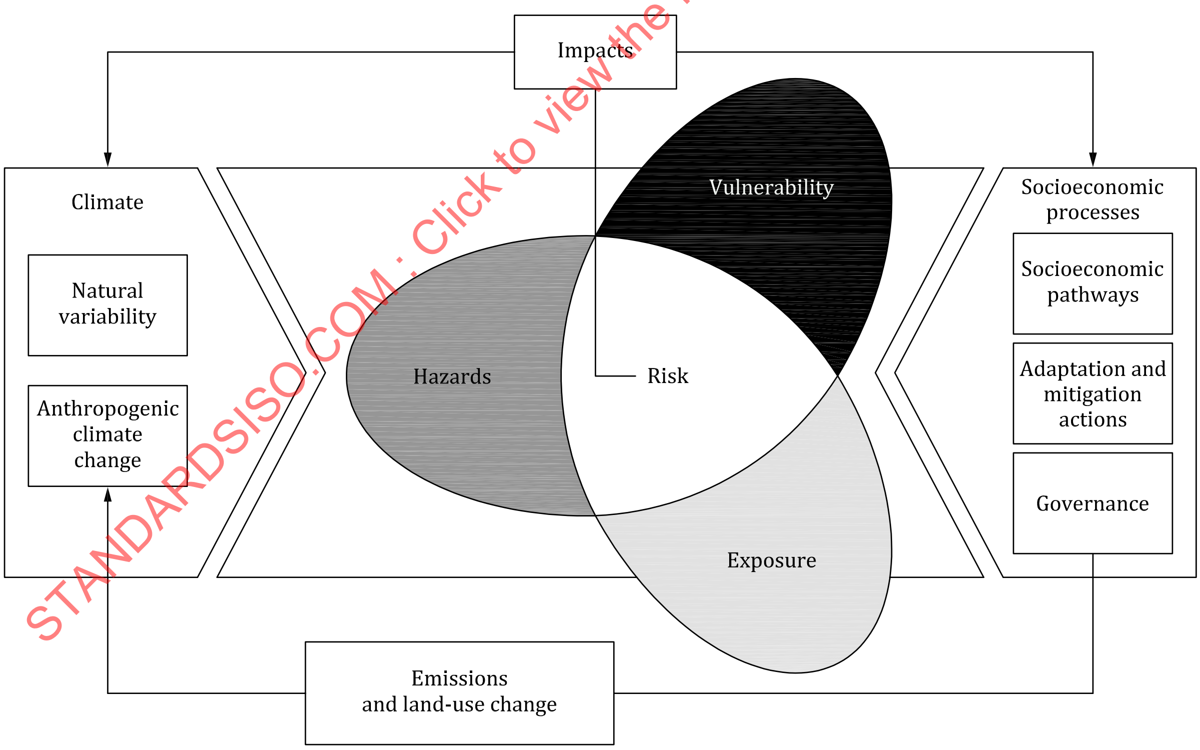
	(AR4) Concept: vulnerability	**(AR5) Concept: risk**
Source	AR4, IPCC 2007[17], *Vulnerability Sourcebook*[12]	AR5, IPCC 2014[19][20]
Main variable	Vulnerability (V)	Risk (R)
Key components	Exposure (E), sensitivity (S), adaptive capacity (AC)	Hazard (H), exposure (E), vulnerability (V)
Function	V = f (E, S, AC)	R = f (H, E, V) V = f (S, AC)
Short definition	Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity[17].	Risk results from the interaction of vulnerability, exposure, and hazard. In AR5, the term risk primarily refers to the risk of climate change impacts[19][20]. Vulnerability includes sensitivity or susceptibility to harm and lack of capacity to cope and adapt[19][20].
Conceptual differences	Climate related signal = exposure (based on the *Vulnerability Sourcebook* interpretation of IPCC 2007)	Climate related signal + direct physical impact = hazard[19][20]
	Exposure = climate-related signal (based on the *Vulnerability Sourcebook* interpretation of IPCC 2007)	Exposure = the presence in settings that could be adversely affected (+ spatial consideration) [19][20]
	Sensitivity = the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli[17]	Sensitivity same as in AR4
	Adaptive capacity = ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences[17]	Adaptive capacity same as in AR4

NOTE Following the IPCC AR5 concept, the term “risk assessment” in this document is understood slightly differently from ISO 14090:2019.



SOURCE Based on the *Vulnerability Sourcebook*[12].

Figure A.2 — Illustration of the core concept of vulnerability (AR4)



SOURCE Based on IPCC AR5[19].

Figure A.3 — Illustration of the core concept of risk (AR5)

Annex B
(informative)

Risk assessment and uncertainty — Climate and non-climatic scenarios

Future changes in climatic or socioeconomic factors, and the effect they will have on societies, cannot be predicted. This is why climate scientists usually make use of climate change scenarios and corresponding climate projections instead of predictions. The same applies for socioeconomic factors and related scenario development methodologies. These are used to project the dynamic nature of risk and vulnerability and their changes over time and space.

Any assessment of climate change impacts and vulnerabilities is uncertain for reasons such as the following.

— The magnitude of climate change depends on future greenhouse gas emissions, which are unknown. Climate models are usually driven by more than one emission scenario, which leads to multiple results. Different climate models produce different results. While all models agree that average global temperatures will increase, their projections for precipitation trends or the geographical distribution of changes often diverge.

— Climate extremes, which are often highly relevant for climate change impact assessments, are more difficult to project than slow onset and long-term trends. Projections of the frequency and severity of extreme events (heavy rain, storms, hail), are particularly subject to uncertainty.

— Models used for impact assessments, such as changes in crop yields, encompass additional uncertainties.

— Developing estimates about future adaptation capacities is challenging.

As a conclusion, addressing these uncertainties is crucial when designing, planning and conducting a risk assessment. However, uncertainties in scenarios should not serve as an argument for inaction[9][12].

Different approaches exist for addressing and reducing these uncertainties. One approach is to use different (climate) scenarios as the basis for assessing future climate change impacts. In addition to climate scenarios, adaptation scenarios can be used, if available, outlining scenarios with additional adaptation compared to no additional adaptation. Furthermore, different socioeconomic scenarios such as variations of population growth or economic development[14] can be used. Uncertainties can be further minimized by consulting a wide range of experts. In addition, conducting multiple rounds of consultation with feedback loops between the experts to enable a comparison and active exchange of expertise can help mitigate uncertainties. Another option is to combine different methodological approaches, e.g. complementing qualitative expert assessments with quantitative models.

An important element is to ensure a high quality of data for the risk assessment. Validating the representativeness of indicators is another significant step to reduce uncertainties.

However, it will never be possible to eliminate the uncertainties in a climate change risk assessment. It is therefore essential to clearly state at which points of the risk assessment uncertainties exist. This includes being explicit on different dimensions of uncertainties, e.g. clearly stating on the one hand the degree to which various expert opinions diverge and to state on the other hand how confident the various experts are about their respective assertions.

Annex C
(informative)

Examples of impact chains and dos and don’ts when developing impact chains

C.1 General

There are different ways to develop impact chains. It is easiest to start with the potential impacts (e.g. decrease in agricultural productivity, see Figure C.1) from the screening exercise in 6.1.1 when designing impact chains. During this first step, a broad overview of the relevant climate change impacts should be gained. If more than one sector is included in the assessment, climate change impacts should be collected for each sector separately. Useful questions for identifying these impacts include how climate signals have impacted the system concerned in the past and whether any new trends or change in recent weather events have been observed[14].

In more complex cases, clustering the impacts by related or similar topics to form groups of impacts is the next step. These clusters are helpful for prioritizing the key impacts/clusters that will be analysed in greater depth in the assessment. The focus should be on those impacts that exercise the most influence on the system.

From the impact, it is easy to follow a bottom-up direction, identifying related intermediate impacts (e.g. reduced water availability) related to the climate change impacts collected above and lastly the hazard (e.g. less precipitation). Each relevant climate change impact should be linked to its climatic causes (i.e. the hazard: less precipitation).

For each impact, the other risk components, i.e. exposure and sensitivity, should be considered as well. Also, the adaptive capacity (e.g. potential for irrigation) that influences the risk to the affected system (see 6.5) can be considered. As far as possible, one or several risk factors for each risk component should be determined (see Table C.1). Afterwards, indicators that can be quantitatively or qualitatively estimated are selected for these risk factors.

In considering the sensitivity of a system, it is helpful to look at the attributes that influence its susceptibility to potential negative impacts (e.g. the crop type cultivated). To identify the exposure factor(s) of a system, the project team should identify the key elements that are present in the system that can potentially be affected by the hazard (e.g. the location of smallholders)[14].

Table C.1 — Examples of relevant risk factors and indicators for different risk components

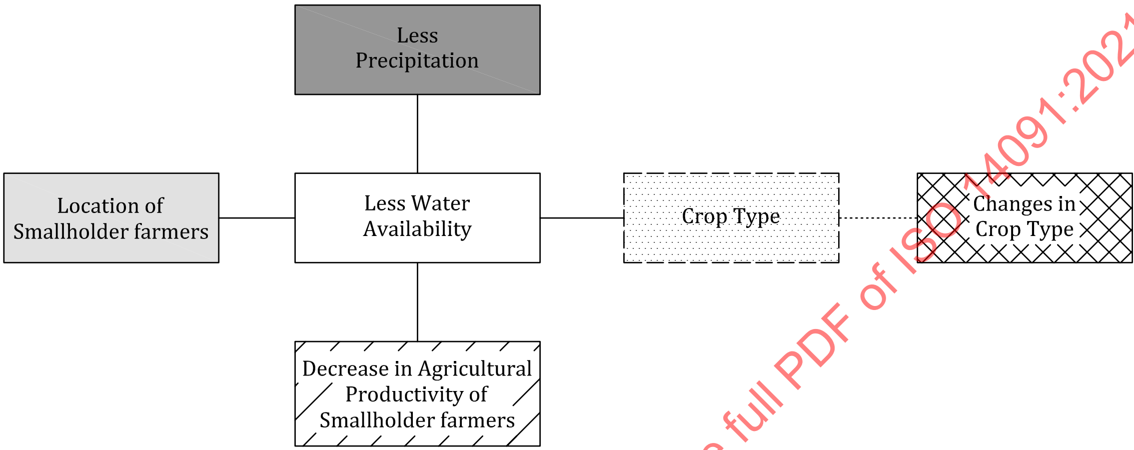
Risk component	Risk factor (example)	Indicator (example)
Hazard	Precipitation	Sum of rainfall over three consecutive months
Exposure	Location of smallholders (incidence)	Number of smallholders in a given area
Sensitivity	Crop type	Percentage of area cultivated with drought sensitive crops
Adaptive capacity	Capacity to switch to resilient crops	Percentage of income available for investment into new crop types

Exposure factors can be identified by answering the following questions: “who or what is potentially exposed to the hazard and the related impacts?” and “which spatial factors contribute to the degree of exposure?” Normally fewer factors are needed to express the exposure component of a risk assessment than is the case for hazard or sensitivity components.

Sensitivity factors can be approached like exposure factors. The guiding question is: “what are the characteristics/existing attributes of the system that make it susceptible to adverse effects of the changing hazards identified in the previous step?”. These characteristics or attributes can be bio-physical, socioeconomic or other (e.g. regulatory, administrative). The task is to identify attributes or properties that influence the extent of the potential impacts.

The following three examples (see Figures C.1, C.2 and C.3) show impact chains for the agriculture sector for different complexities (low, medium, high).

C.2 Examples of impact chains for agriculture



Key

hazard

exposure

sensitivity

adaptive capacity

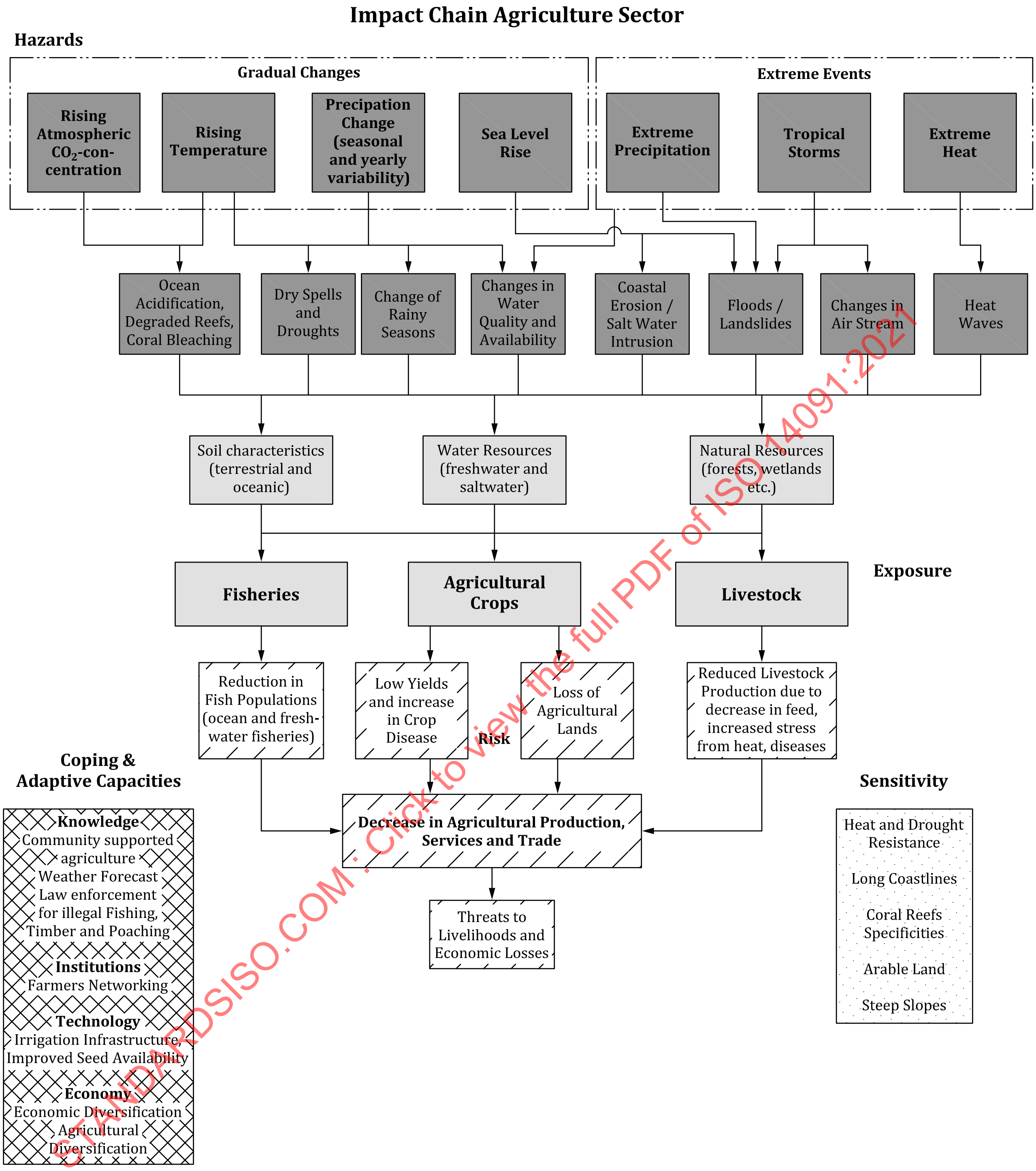
risk without adaptation

intermediate impact

NOTE The dotted line means that adaptation actions have been implemented.

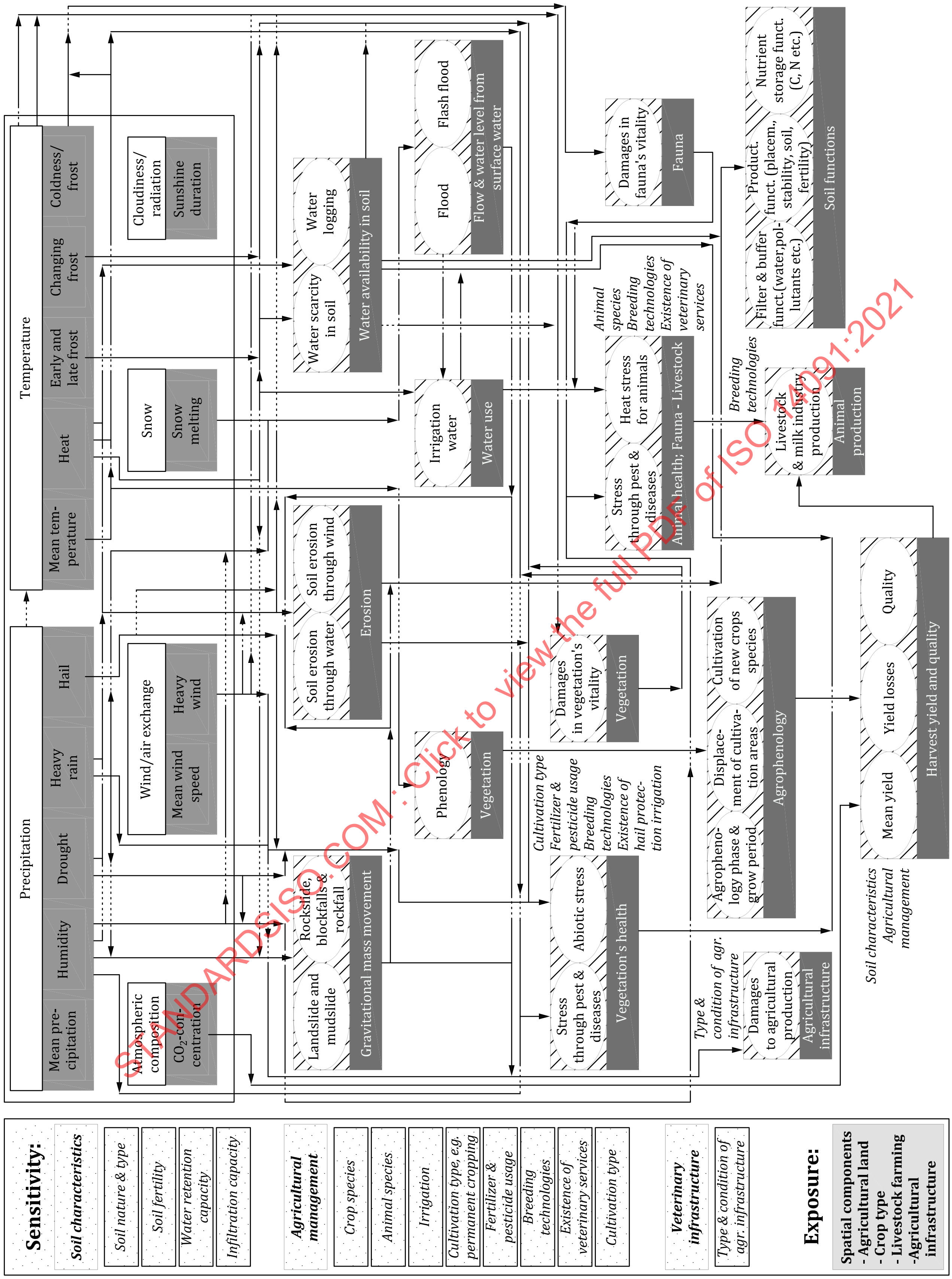
SOURCE Based on Reference [8].

Figure C.1 — Low complexity impact chain



SOURCE Based on Reference [8].

Figure C.2 — Medium complexity impact chain



SOURCE Based on Reference [11].

Figure C.3 — High complexity impact chain

C.3 Dos and Don'ts — What is important when developing impact chains?

Impact chains can serve a variety of objectives. In the field of vulnerability and risk assessments and planning processes aimed at adaptation to climate change, impact chains have the following characteristics:

— an effective tool to better understand and systemize the factors that drive risk and vulnerability in a given system (cause-and-effect relationship);

— a basis for adaptation planning, by identifying indicators and concrete measures;

— a representation of how potential climate change risks can affect a system via direct and indirect impacts.

Some practical hints on what is important to consider (dos) and what should be avoided (don'ts) for warranting a smooth and efficient way of developing impact chains include:

— Dos.

  — Be realistic: Try to elaborate an authentic picture of your system at risk.

  — Be pragmatic: Identify direct impacts and relevant risk factors first.

  — Be focused: Concentrate on the most important relationships between risk factors.

  — Be clear about components: Differentiate between hazard, exposure, sensitivity and adaptive capacity.

  — Do background research: Base your assumptions on scientific literature and expert opinions.

— Don'ts.

  — Don't duplicate sensitivity and adaptive/coping capacities.

  — Don't attempt to capture all aspects of reality in all its details and interconnections.

  — Don't try to visualize all possible interactions between risk factors (try to distinguish between direct and indirect relations).

  — Don't restrict your impact chain to match limited data availability[8].

Annex D
(informative)

Example of a screening matrix

Table D.1 — Example of a screening matrix[15]

LNG facility: system at risk	Physical risk									
	Acute	**Chronic or slow onset**						**Average**	**Max.**	Min.
System elements at risk	Increased severity of extreme events	Changes in precipitation patterns	Changes in temperature	Changes in wind patterns, direction and intensity	Changes in the jet stream and “blocking” weather patterns	Rising sea levels (from all causes)	Ocean acidification			
Organization	3	1	2	1	2	3	0	1,7	3	**0**
Suppliers of raw materials: upstream gas producers, wells, gas plants, compressor stations and their service providers	3	3	3	3	3	0	0	2,1	3	**0**
Suppliers of energy: electricity	3	4	3	2	2	0	0	2,0	4	**0**
Suppliers of transportation from gas producers in collector pipelines	2	2	2	1	1	0	0	1,1	2	**0**
Suppliers of transportation: shipping gas to LNG facility	2	2	2	1	1	0	0	1,1	2	**0**
Suppliers of transportation from LNG ships	3	1	2	2	2	2	0	1,7	3	**0**
LNG terminals in markets	3	1	3	1	1	3	0	1,7	3	**0**
Customers’ use of products	3	3	3	3	3	2	2	2,7	3	**2**
NOTE “1” refers to low risk, “5” refers to high risk.										

Table D.2 — Example of a screening matrix with comments

LNG facility: system at risk	Physical risk						
	Acute	Chronic or slow onset					
System elements at risk	Increased severity of extreme events	Changes in precipitation patterns	Changes in temperature	Changes in wind patterns, direction and intensity	Changes in the jet stream and "blocking" weather patterns	Rising sea levels (from all causes)	**Ocean acidification**
Organization	Could impact operations	Minor impact	Could impact storage tanks and cooling needed	Minor impact	Could impact operations on occasion	Yes depending on where it is built	**No direct impact known**
Suppliers of raw materials: upstream gas producers, wells, gas plants, compressor stations and their service providers	Could impact operations	Could impact operations	Could impact operations	Could impact operations	Could impact operations	No direct impact known	**No direct impact known**
Suppliers of energy: electricity	Could impact operations	Could impact generation capacity	Could impact operations	Could impact operations on occasion	Could impact operations on occasion	No direct impact known	**No direct impact known**
Suppliers of transportation from gas producers in collector pipelines	Could impact operations on occasion	Could impact operations on occasion	Could impact operations on occasion	Minor impact	Minor impact	No direct impact known	**No direct impact known**
Suppliers of transportation: shipping gas to LNG facility	Could impact operations on occasion	Could impact operations on occasion	Could impact operations on occasion	Minor impact	Minor impact	No direct impact known	**No direct impact known**
Suppliers of transportation from LNG ships	Could impact operations	Minor impact	Could impact operations on occasion	Could impact operations on occasion	Could impact operations on occasion	Could impact operations on occasion	**No direct impact known**
LNG terminals in markets	Could impact operations	Minor impact	Minor impact	Minor impact	Minor impact	Could impact operations on occasion	**No direct impact known**
Customers' use of products	**Could impact operations**	**Could impact operations**	**Could impact operations**	**Could impact operations**	**Could impact operations**	**Could impact operations on occasion**	**Could impact operations on occasion**

Annex E
(informative)

Examples of indicators for risk and vulnerability assessments

Table E.1 — Examples of indicators for risk assessments

Risk component	Example risk factor	Example indicator	Possible data source
Hazard	Temperature	Number of nights with T(min) above 25 °C	Meteorological offices
	Precipitation	Number of months with rainfall below 50 mm	Meteorological offices
	Wind	Increase in average wind speed Number of storms above a certain wind speed	Meteorological offices
Exposure	Location of infrastructure	Distribution of traffic infrastructure in flood-prone areas	Planning agencies Local governments
	Exposure of smallholder farming	Percentage of area cultivated by smallholder farmers/total area Percentage of farmer population	Statistical office Planning agencies
	Exposure of eco-systems	Location of habitats in areas affected by sea level rise Location of habitats affected by serious mean temperature rise	Office for nature protection
	Exposure of industry	Percentage of certain vulnerable business types in different regions Area of industrial complexes affected by sea level rise or cyclones	Statistical office Industry association Economic development agency
Sensitivity	Water demand	Water demand (in m^3 per ha) per growing period	Statistical office
	Soil conditions	Water retention capacity of soil	Statistical office/geodetic institutes
	Industrial production	Existence of early warning systems	Office for civil defence
	Vulnerable group (population)	Percentage of population that is vulnerable (e.g. young or old people or people who work outdoors)	Statistical office
Adaptive capacity	Financial capacity	Percentage of income available for investment into new crop types	Statistical office/experts
	Technical capacity	Availability of suitable technologies (e.g. irrigation system)	Industry associations
	Organizational capability	Assessment of training needs for addressing climate change	Experts/managers
		Resourced climate change adaptation plan of action	Experts/financiers/managers

NOTE Adapted from Reference [14].

Annex F
(informative)

Aggregating indicators and risk components

This annex is mostly relevant for risk assessments that aggregate indicators within one risk component (i.e. hazard, exposure, sensitivity and adaptive capacity) or that aggregate risk components.

The method can be different at different levels of aggregation. Higher levels of aggregation usually take qualitative approaches. Some methods separate aggregation from interpretation and evaluation of the results, while others combine these aspects.

Qualitative or semi-quantitative methods are the simplest to apply. One approach is to use a rating scale consisting of one to three or one to five steps (the scale format should be specific for each case). The grading on the rating scale should be informed by the best knowledge available (from existing literature, expert knowledge or any other reliable source). Qualitative information (expert judgements) can be collected using the scale. Approaches in which a rating scale is used as a summary for each climate change impact, rather than for each indicator, are even easier. If aggregation of indicators for one climate change impact proves too difficult, an alternative is to give a narrative summary, perhaps along with maps.

Sometimes, quantitative approaches normalize all data to allow aggregation for each climate change impact. Normalized indicators need to be combined with threshold values for critical risks in the system under consideration (see 6.6).

NOTE The term "normalization" refers to the transformation of indicator values measured on different scales and in different units into unitless values on a common scale. A standard value range from 0 to 1 is often used in risk assessments.

Risk factors usually do not have equal influence on the respective risk component. Therefore, weights should be applied to the indicators which quantify the risk factors. In some cases, there can be valid reasons for assigning equal weights to all indicators (e.g. lack of information, consensus or resources for defining different weights). Neither participatory nor statistical processes provide a completely objective way of defining weights. Consequently, weights should be defined as value judgements. Participatory and transparent approaches should be used as a practical way of applying weighting. As well as other documents, ISO 14033 provides various methods for weighting and aggregating that should be consulted and applied depending on the available resources for the risk assessment.

If potential impacts and adaptive capacities are integrated into one risk composite, the following considerations should be kept in mind.

— Weighting of climate change impact and adaptive capacity: A high adaptive capacity can have the potential to largely offset a high impact. Consequently, the overall result from the risk assessment will be low risk, despite a high potential impact.

— Visual overlay of climate change impact and adaptive capacity: Depending on the focus of the assessment, a composite risk value is not always required. In some cases, the identification of areas of high climate change impact and low adaptive capacity ("hotspots"/"red flags") can be enough for the objective of the risk assessment. A visual overlay of climate change impact and adaptive capacity on the map of a particular geographic area is one option.

— Making individual indicators and risk components visible: A transparent approach should be followed for displaying how underlying factors of risk influence the overall risk. This can be achieved, for example, by using pie charts to illustrate the influence of single indicators on risk components.

Different risks can be further aggregated stepwise into one single, overall risk value where the risk assessment covers different risks in one or several sector(s), region(s), etc. It is important to remember that such an overall risk value represents highly aggregated information and provides no clear information on the influence of the underlying indicators and risk components. Intermediate results of the assessment should be included in the presentation of the final results of the risk assessment to make best use of the underlying information and to provide transparency. Presenting the results in a radar chart is one way to keep detailed inner information in the aggregation process of a risk assessment.

The results of aggregation of several climate change impacts can be presented in comparison charts or comparative maps (with or without overlay) and narrative descriptions of “hotspots”. For a better understanding of the assessment results, the final report should always contain the individual assessment components and not only the aggregated results (see 7.1).

Further details and practical examples can be found in the methods described in ISO 13065. See Reference [14] for issues related to defining, collecting, processing, interpreting and presenting quantitative environmental information, including normalization and aggregation.

