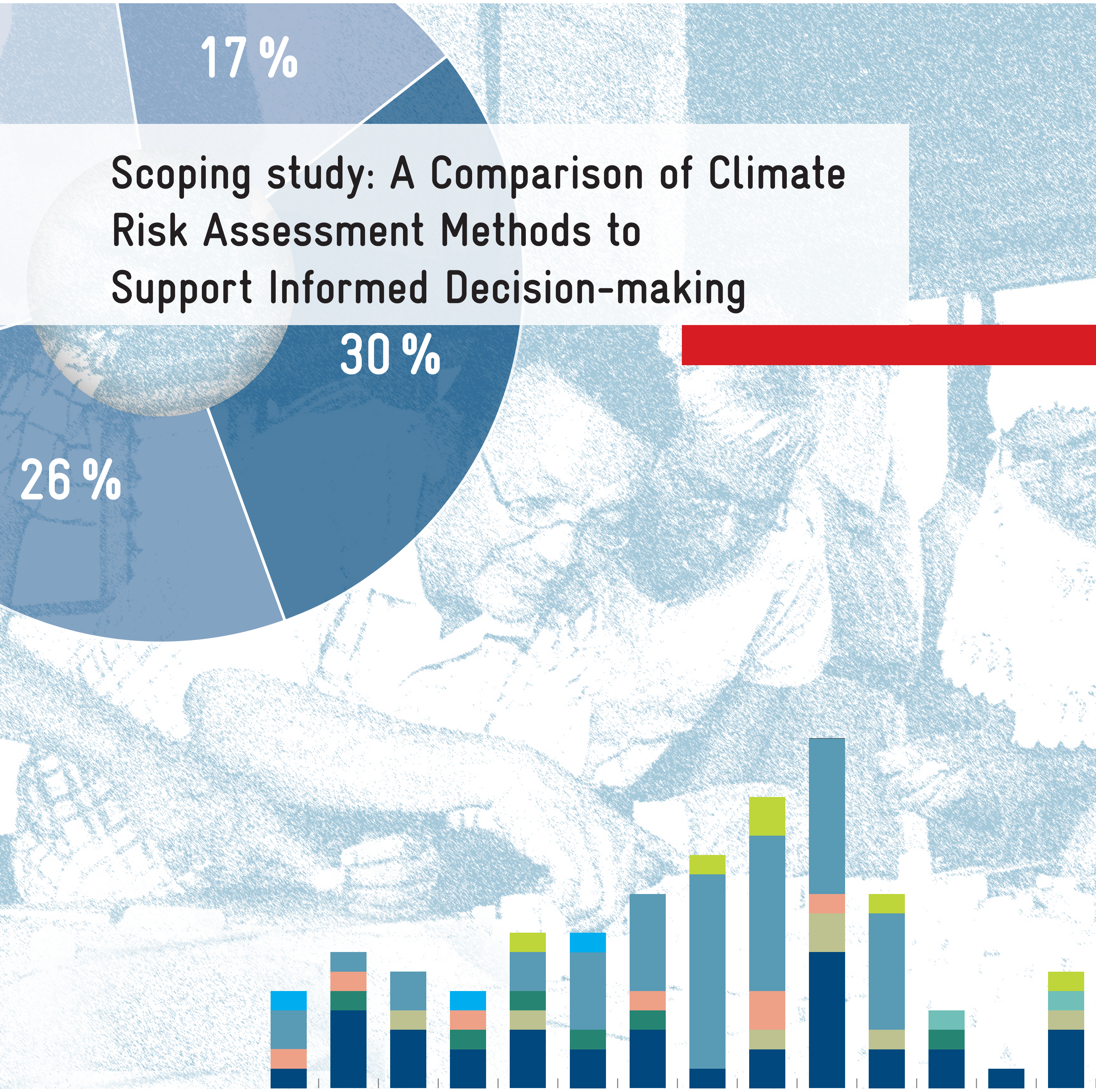
Scoping study: A Comparison of Climate Risk Assessment Methods to Support Informed Decision-making



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Summary and key messages

The negative impacts of climate change are increasing in intensity and severity (EEA, 2017). The current increase in the global average temperature, of 1.2°C above pre-industrial levels (WMO, 2021), results in more than 24,000 deaths and 190 million affected people per year on average (CRED et al., 2021). It is evident that climate change is threatening not only assets, livelihoods and ecosystems, but also our ability to achieve the United Nations' Sustainable Development Goals. In particular, extreme weather events (EWEs) and slow onset processes (SOPs)[1] are increasing. This causes, among other things, a loss of natural resources and biodiversity, which can reduce agricultural and fishing yields and, in so doing, contribute to food insecurity and poverty (WMO, 2021). Risks therefore impact several socio-economic systems and should be addressed and considered in future planning at all levels – from individual to national – and in all policy fields.

A foundation of sustainable development is laid by an effective climate risk management which, in turn, is based upon a context-specific climate risk assessment (CRA). However, practitioners interested in implementing a CRA face the challenge of either spending a great amount of time developing a suitable new methodology or identifying one that fits best with their objectives, available resources, geographical context and other defining criteria from a variety of existing approaches. Methods published in scientific journals or developed by international development and non-governmental organisations are clearly distinguished from those formulated by asset managers to secure their own portfolio, but both are worthy for consideration.

To facilitate the identification of suitable context-specific CRA approaches, and to provide an overview of the state of the art of existing methods, the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) Global Programme on Risk Assessment and Management for Adaptation to Climate Change (Loss and Damage) has compiled a database consisting of 120 CRA methods structured according to 36 different criteria, with specific emphasis on aspects which are relevant to challenges in the context of losses and damages. This database includes methods that were developed in different regions of the world (primarily in Europe and North America) – some as early as 1998 but with the majority published during or after 2014. It represents (to the authors' knowledge) the first endeavour to collect and summarise a wide range of publicly available CRA methods in one database. The collection of all 120 methods has been transferred into an online search engine to facilitate the identification and development of context specific CRAs and is publicly available here.

This scoping study aims to increase understanding of recent innovations, and of remaining methodological challenges to future innovation in CRA. It is based on a large sample of very diverse approaches originating from academia, the private sector (such as insurance or banks), public utility management and development cooperation. The study does not aim to evaluate or rank the various methodologies but instead provides a description of the state of the art and a criteria-based in-depth analysis for selected dimensions.

Six dimensions relevant to the challenges of CRA in the context of climate-related losses and damages are evaluated in detail: consideration of the entire spectrum of risks; recognition of the interdependencies between risks; inclusion of future socio-economic dynamics; inclusion of non-economic Loss and Damage (NELD); involvement of stakeholders; and assessment of adaptation options.

The results of this study can benefit the future development of methods and approaches by enabling practitioners to learn from past experiences and to foster progress. Experts from the related fields, decision-makers, and practitioners who are interested to learn more about climate risk assessment can make use of extensive information in the database about existing methodologies and approaches.

1 In this paper, the term 'slow onset processes' is used instead of 'slow onset events' (following GIZ & IIASA, 2021).

The **key messages** of this study are:

- The study is based on a database of CRA approaches that were developed as early as 1998, with the majority published during or after 2014. Only a few methods provide **concrete information on financial expenditure. Time and cost intensiveness are rarely stated** in the available method description; where they are, the time required varies from a measure of minutes to several years, and open software can cost up to nearly USD 1 million – depending on the approach's scope and objectives. 80 % of all methods have been developed either by academia or development cooperation actors and public authorities. And while most methods (72 %) have been developed in Europe or North America, half of them claim to be applicable worldwide.

- Extreme weather events currently receive more attention than SOPs in CRAs; however, almost half of the approaches (47 %) cover **both EWEs and SOPs**. To address the methodological challenges arising when considering SOPs, tools such as index development or index use, participatory approaches, scenario modelling and quantitative or probabilistic models are often applied.

- **Interdependencies of risks,** which are understood as the complex interlinkages between distinct hazards and impacts and their drivers and processes, and eventually between distinct types of risk (compound, cascading and systemic), are only considered by about a quarter of the methods in the database sample. 57 % of the methods in the sample consider these aspects at least partly. Since interdependencies with human, geographical, economic, political, and social and physical systems can also lead to complex mechanisms and can cause further consequences up to the malfunctioning of entire systems, their recognition is useful in a CRA.

- The consideration of **socio-economic scenarios** (complementing the almost always promoted usage of climate scenarios) is becoming more frequent in CRAs. Projections of socio-economic changes are frequently used by the methods represented in the sample in a quantitative way, in order to better estimate future vulnerabilities and losses. Thereby, socio-economic changes are identified as the most important drivers of overall increase in the exposure of both populations and assets to the risks of climate change (especially in coastal zones). The use of scenarios can be considered as an emerging trend for integrated CRA methods.

- Some of the current methodological challenges of CRAs relate to the inclusion of **non-economic Loss and Damage (NELD)**[2] and consideration of **the entire spectrum of climate-related hazards and impacts**. Accounting for NELD in CRAs is difficult because it presents at least three sets of challenges: conceptual and ethical, empirical, and those of communication and decision-making. This study provides an overview of the most common classifications of NELD in CRAs included in the database.

- For many crucial aspects of CRA, a common understanding and **terminology is lacking.** This is very evident for the term NELD but it also includes other terms such as 'hazard' versus 'impact', or 'risk interdependencies'. This lack of terminology makes it hard to compare the CRA methods.

- **Including stakeholders in CRAs** is crucial as it significantly raises the effectiveness and sustainability of decision-making processes by ensuring that adaptation options are sensitive to local contexts and broadly accepted. However, almost half of the analysed methods (46 %) do not involve stakeholder participation. From 'information only' (online tools and low-cost rapid assessments) to 'self-mobilisation' (stakeholders initiate and control the process of assessment), stakeholder participation could be used more strategically to develop a sense of responsibility and ownership, and empower vulnerable groups through CRAs.

- **Limits to adaptation** are still an underrepresented aspect in CRA methods: they are discussed in only eight methods in the sample. In general, adaptation and its effectiveness are influenced not only by climate change but also by economic development, demographic change, ecosystem alteration and technological innovation. It is inevitable, then, that multiple challenges arise when limits to adaptation beyond adaptation options are subject to investigation through a CRA. However, against a background of increasing climate-related risks, it is useful to develop methodologies for assessing the potential of adaptation options further; in the case of nature-based solutions, for instance, it cannot be ruled out that limits to adaptation will occur.

2 In accordance with the distinction between "Loss and Damage" and "losses and damages" (see box 2), the term "Non-economic losses and damages" would actually be more accurate in this context. However, the authors decided to use "Non-economic Loss and Damage", as this term is more established, also within the UNFCCC context.

Acknowledgements

The Federal Ministry for Economic Corporation and Development (BMZ) commissioned Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) in 2013 to carry out the Global Programme "Risk Assessment and Management for Adaptation to Climate Change (Loss and Damage)". The objective of the programme is to develop tried-and-tested guidelines, innovative concepts and practical instruments for climate risk assessment and management as applied by German Development Cooperation and its international partners in the United Nations Framework Convention on Climate Change (UNFCCC). This scoping study on the comparison of climate risk assessment methods to support informed decision-making is one resulting product of the project. The project team would like to thank all colleagues who have contributed to the establishment of the database and/or to the analysis of the 120 methods therein collected (as of end 2020) that form the basis of this study. In particular, the programme would like to thank members of the Community of Practice on Climate Risk (CoP CR)[3] who contributed via the provision of material (for example, literature and comparison studies) and provided comments throughout the work in progress. Special thanks is dedicated to colleagues from the United Nations University Institute for Environment and Human Security (UNU-EHS) for scientifically revising the study in its final stage.

3 CoP CR aims to promote exchange and innovation among experts around state-of-the-art and practically useful climate risk and vulnerability assessments within the GIZ and with external experts and service providers.

Acronyms

AR	Assessment Report
BMZ	German Federal Ministry for Economic Corporation and Development
CoP CR	Community of Practice on Climate Risk
CRA	climate risk assessment
EWE	extreme weather event
GIS	geographic information system
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
IPCC	Intergovernmental Panel on Climate Change
ISO	Organization for Standardization
L&D	Loss and Damage
NELD	non-economic Loss and Damage
RCCI	Regional Climate Change Index
SOP	slow onset process
SPM	Summary for Policy Makers
UNDRR	United Nations Office for Disaster Risk Reduction
UNFCCC	United Nations Framework Convention on Climate Change
UNU-EHS	United Nations University Institute for Environment and Human Security

1. Introduction

1.1 The context for climate risk assessments

Already, with an increase in the global average temperature of 1.2°C above pre-industrial levels (WMO, 2021) and a 40 % chance of at least one year being 1.5°C warmer than the pre-industrial level by 2025, the world is experiencing negative impacts of climate change that have become more severe and intense (IPCC, 2014; EEA, 2017). Within the last 10 years, weather-related events have resulted in more than 24,000 deaths and 190 million affected people on average per year (CRED et al., 2021). In 2020, natural catastrophe events caused economic losses of USD 190 billion (Swiss Re Institute, 2021). These impacts are triggered by so-called extreme weather events (EWEs) as well as slow onset processes (SOPs) and are likely to increase further with continuous climate change.

Irrespective of ongoing efforts to strengthen climate policy, some residual risk from the impacts of climate change remains in all countries and for all plausible mitigation Pscenarios (IPCC, 2014). These risks are defined as potential negative impacts after all feasible mitigation and adaptation measures have been implemented. Over the course of this century, tipping points such as losing the Amazon rainforest or the West Antarctic ice sheet could be reached, resulting in cascading effects with catastrophic impacts including loss of livelihoods for millions of people depending on ecosystem services, or a sea-level rise above three metres, endangering coastal megacities, communities and assets (Lenton et al., 2019). It is evident that climate risks have the potential to threaten the sustainability of development gains, such as poverty alleviation, global prosperity, or the sustainable use of ecosystems and marine resources. The respective United Nations report from 2019 states that climate change threat-

Box 1: Extreme weather events and slow onset Processes in development cooperation

Climate change is exacerbating EWEs such as intense cyclones, increasingly longer heatwaves or heavy precipitation events, whose immediate and often visible impacts attract widespread attention. But climate change also manifests through SOPs such as sea-level rise, ocean acidification or land degradation, whose rate of impact is slower and appears less destructive than that of EWEs (Matias, 2017). While EWEs can have dramatic impacts in a relatively short period of time (in some cases, only a couple of hours), SOPs can result in long-term, irreversible changes to current (natural) systems – also known as non-manageable tipping points (Lenton et al. 2019). See section 3 for further information on the spectrum of hazards and impacts, and interdependences between EWEs and SOPs.

Box 2: Loss and Damage versus losses and damages

Loss and Damage (L&D) has emerged as a key area in international climate policy. However, the notion of L&D is viewed and interpreted differently by the large variety of stakeholder groups. In this study, Loss and Damage (capitalised letters) is used in reference to political debate on the topic under the UNFCCC. This links particularly to the Warsaw Mechanism on Loss and Damage under the UNFCCC, established in 2013, that addresses "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" (IPCC, 2018). The term 'losses and damages' (plural, lower case letters) is used in reference to harm from (observed) impacts and (projected) risks (IPCC, 2018).

ens progress across the Sustainable Development Goals (UN, 2019). Therefore, climate risks need to be addressed and considered in future planning at all levels, from individuals to national stakeholders and decision-makers, as well as in all policy fields.

Climate risk assessment (CRA) assess the extent to which climate-related risk impacts on people, assets, value chains, infrastructure, and ecosystems. This leads to a better understanding of climate risk, and the initiation of effective action. Obviously, CRAs are increasingly important for ensuring that development is climate-resilient and sustainable. They form the basis for more targeted risk management, including risk-informed decision-making and planning in the context of climate change. Decision-makers choose from a variety of available CRA methods that which is most appropriate for their specific context in terms of available resources, capacities and objectives.

The explicit inclusion of, or focus on, climate-related risk is increasingly taken into account in international processes and mechanisms, such as the working plan of the Technical Expert Group on Comprehensive Risk Management under the UNFCCC's Warsaw International Mechanism for Loss and Damage associated with Climate Change Impacts or the Sendai Framework for Disaster Risk Reduction, specifically in its target E.[4] A forthcoming technical guidance developed by the United Nations Office for Disaster Risk Reduction (UNDRR) and GIZ discusses in more detail the needs and potential of a comprehensive risk assessment and planning approach in the context of climate change.[5] Global efforts aim to establish standards for conducting risk assessments in order to allow easier comparability. Overall, risk assessments should be as comprehensive as possible, accounting for multiple hazards and cascading effects, and covering different sectors and disciplines of thought. In the following text, some ongoing processes are briefly described in order to highlight progress so far.

Initiated by UNDRR, a working group was founded in 2018 to enhance knowledge and management of risks for common metrics and understanding. The aim was to develop a global framework which can be tailored for use according to specific contexts. This Global Risk Assessment Framework is supported by the German government via technical and financial means. The results will allow different stakeholders to find information according to specific spatial and temporal scales, systems of interest and risk components relevant to their work.

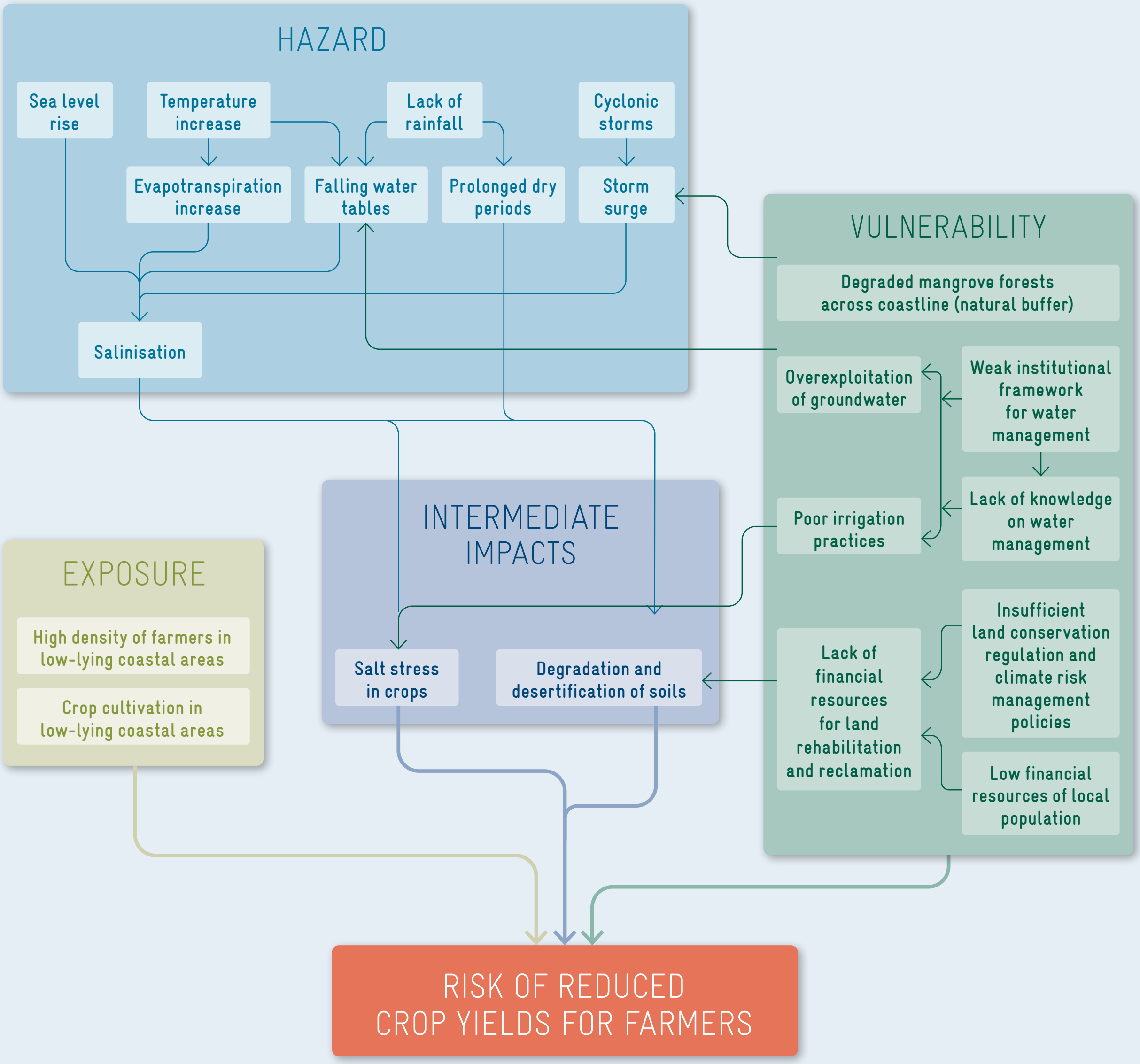
The International Organization for Standardization's ISO 14090 on climate change adaptation and

4 Target E Sendai Framework: Substantially increase the number of countries with national and local disaster risk reduction strategies by 2020.
5 The guidance will be available online at www.undrr.org

ISO 14091 on climate change risk assessment establish systematic standards for climate risk management. While the standard on adaptation was published in 2019, the assessment standard was only published recently in 2021. This second standard emphasises screening assessments to provide a first pre-assessment of *"a straight forward system at risk"*, and assessments in contexts of limited time and other resources. Additionally, impact chains are described and standardised (ISO, 2021). These two methodological approaches, which accentuates participation and inclusion, and combine quantitative and qualitative methods, are considered important elements for standardised climate risk assessments that also contribute to planning processes with regards to disaster risk reduction. In addition, information included in Intergovernmental Panel on Climate Change (IPCC) reports and the vulnerability sourcebook with its risk supplement published by GIZ are shaping the standard with regards to impact chains and the other methodological aspects.

Box 3: Impact chains

Impact chains, a conceptual systemic model come with several opportunities. Structured as co-developed and participatory approach it integrates the knowledge of experts and stake-holders and is strongly recommended as tool to comprehensively analyse risk (compare UNDRR, 2022).



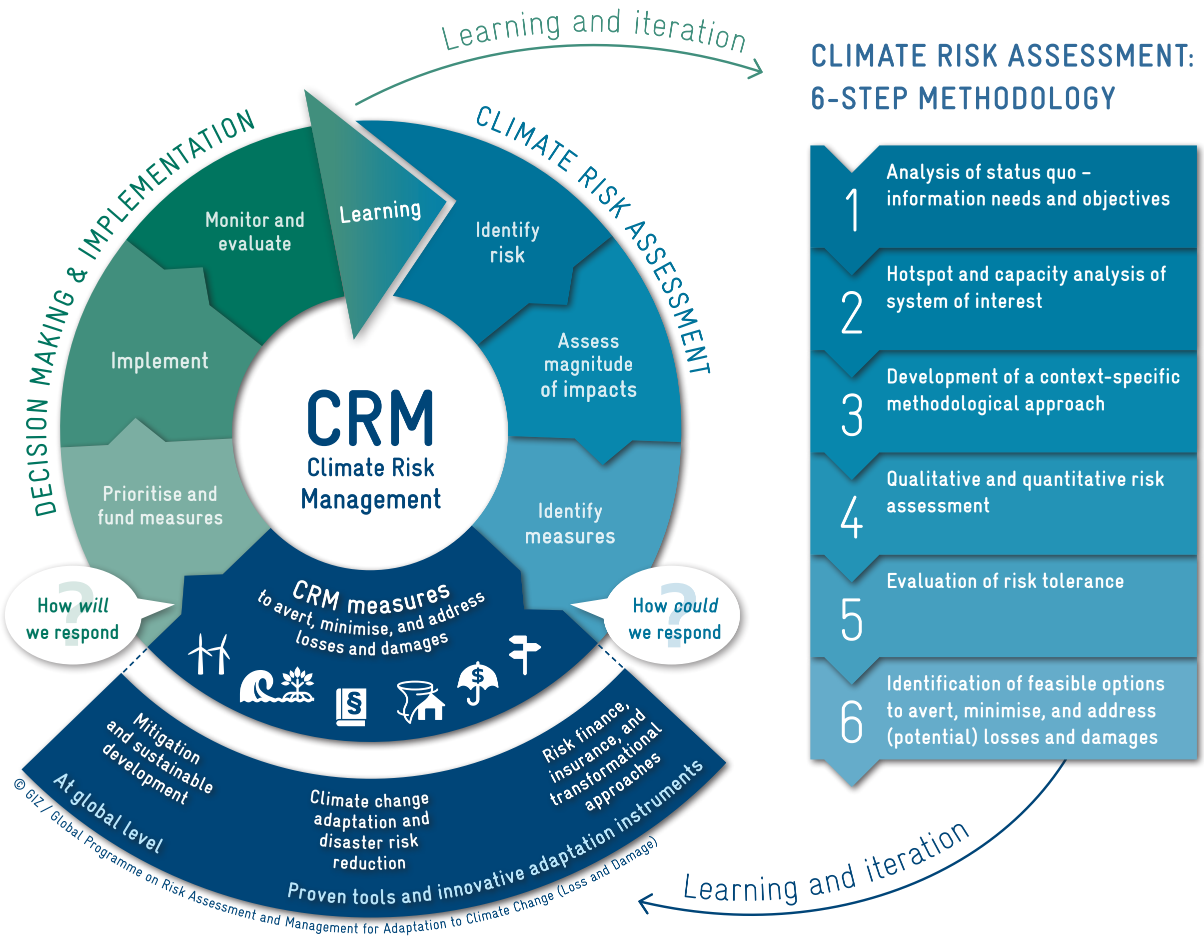


Figure 1: GIZ's 6-step methodology for climate risk assessment
Note: For step-by-step guidance see: here. The methodology has so far been implemented in two partner countries, Tanzania and India.

A number of existing initiatives have led to the development of databases of approaches and tools for climate risk assessment, climate risk management or specific adaptation measures accessible via online platforms or portals. Some contain publicly available datasets which can be used in assessments. Examples include the Climate-Smart Planning Platform, the Climate Change Knowledge Portal and the Inter-Sectoral Impact Model Intercomparison Project.

In comparison to these platforms, the established database and scoping study presented here have a narrower focus, concentrating on methods for the assessment of climate-related risks. The aim was to only include methods which provide practical information on the different steps of CRA so that experts are enabled to implement assessments based on the available descriptions (see section 2 for more details on the selection process). Furthermore, a detailed insight into different aspects was deemed useful for practitioners who benefit from an overview of existing approaches, especially in relation to climate-related losses and damages. The database described in this scoping study allows the user to get a more detailed overview on the challenges identified in existing methodologies, such as how to include non-economic Loss and Damage (NELD) and how to cover a wide spectrum of climate hazards and impacts. It also details innovations, such as community-centred vulnerability assessments, index development and scenario modelling.

GIZ has developed a conceptual framework for climate risk management that includes a 6-step methodology for the assessment of climate risk (GIZ 2021). This methodology is considered helpful guidance which recognises the aspects discussed in this study and combines easily with more concrete methods from the database. The approach is explained further in Figure 1 below. This 6-step methodology has not been included in the database of CRA methods as it represents a wider framework for different steps of climate risk management; it is not part of the analysed sample.

Ultimately, the **decision whether or not to apply a CRA** is the result of a political, economic and social process. Climate risk assessment can, in the broadest sense, contribute to securing development achievements, achieving continuity in business, and enabling the functionality of adaptation and risk management strategies. However, in many cases, assessments can be costly and time intensive as well. If carried out repeatedly, CRA can provide suggestions for the adjustment of procedures and strategies and also justify the risk of intervening with previously applied strategies. Experience shows that costly decisions that anticipate potential climate- induced disasters require political, social and financial persuasion.

1.2 Objectives of the study

To facilitate the identification of suitable context-specific CRA methods, the GIZ Global Programme on Risk Assessment and Management for Adaptation to Climate Change (Loss and Damage) commissioned by BMZ developed a database containing 120 CRA approaches. Based on this database, the scoping study for experts and practitioners was developed with the aim of describing existing approaches as well as good practices and to analyse them in the context of climate-related losses and damages according to pre-selected specific criteria. The database includes diverse approaches developed by scientific institutes, the private sector (such as insurance companies or banks), public utility management agencies, and development cooperation experts. This wide range of sources distinguishes this study from other publications and allows for a comprehensive assessment of current state-of-the-art methodologies used and applied for CRA.

This scoping study also highlights current gaps and challenges in order to inform further development of methods and approaches. Additionally, an online CRA method search engine (CRAMSE) has been developed, enabling decision-makers to quickly identify and access suitable CRA methods for specific contexts and objectives.

Following this introduction, this scoping study explains the methodology that was applied in describing and analysing the approaches included in the database. It continues with a presentation of findings from the analysis: a description of the meta data; information on the geographical and sectoral origin of the CRA methods and how these methods are implemented; and a description of the six key findings relevant to losses and damages. These findings relate to the degree to which methods consider of the full spectrum of climate hazards and impacts, interdependencies of risks, future socio-economic dynamics, NELD, forms of stakeholder involvement, and adaptation options and limits to adaptation. The study ends with some conclusive remarks and suggestions for the way forward.

GIZ / Thomas Imo

2. Description of database and methodology of analysis

This work has been carried out within the BMZ-funded GIZ Global Programme on Risk Assessment and Management for Adaptation to Climate Change (Loss and Damage) and is based on the previously mentioned extensive database on CRA approaches.

Aligned to the approach applied in developing the database on CRA methods, this investigation is based on existing methods in the context of climate risk management and on pre-selected criteria that are deemed relevant to this context. It should be noted that neither the database nor this study intends to 'evaluate' the quality of the different methods or to establish a ranking. The investigation simply follows the objective of cataloguing existing methods in the context of climate risk management and providing findings to inform stakeholders and future progress.

For all content provided in this study, information from the specific method descriptions of each CRA provided by the respective developers has been used as a primary source. To further contextualise the dimensions discussed, examples from scientific literature have been used to understand current methodological discussions and challenges. Throughout the study, individual methods are identified by ID numbers which are provided with the respective authors in the Annex table. This table contains all methods of the database included in this study and summarises the aspects that were considered in the in-depth analyses.

The methodology leading to the findings of this study includes **three main working steps.** (see Figure 2).

A. Identification and selection of existing approaches and screening based on pre-defined criteria.
B. Investigation of the meta-data, which aim to provide an overview on organisational and methodological aspects such as the institutional and geographical origin of methods or their sectoral and geographic coverage.
C. Investigation of dimensions (explained below) that are deemed relevant in the context of losses and damages for an in-depth analysis to identify general trends and innovative approaches.

The steps in more detail:

A. The first sample document contains 204 CRA approaches mainly found in five different sources and published between 1998 and 2020.[6] From the initial sample, 120 methods were selected based on four criteria. Only if all criteria were met was a method taken into account.

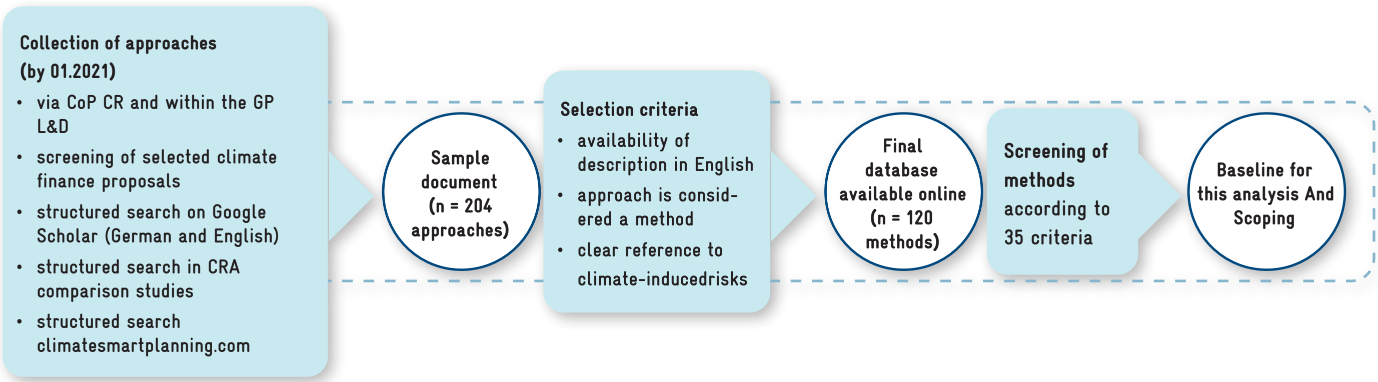


Figure 2: Workflow and sources of database[7]

6 Sampling was mostly conducted in late 2019 and early 2020; therefore, not all methodologies published in 2020 and 2021 are taken into consideration.

7 Note: CoP CR = Community of Practice on Climate Risk; GP L&D = Global Programme on Risk Assessment and Management for Adaptation to Climate Change (Loss and Damage); CRA = climate risk assessment

	FRAMEWORK	METHOD
DEFINITION	"A basic structure underlying a system, concept or text" (Creswell, 1998)	"A particular procedure for accomplishing and approaching something especially a systematic or established one" (Green, 2013)
KEY POINTS	• Loose and generic; can be applied to different scenarios, conditions • Based on set of theories, concepts and relationships • Not too detailed or rigid • Offers guidance and rationale/ structure within study	• Constitutes a research tool and instrument with specific rules, procedures, which aid problem-solving • Replicable (possibility of triangulation) and established methods of research
STRUCTURE	Flexible	Prescriptive, according to procedural rules of method
CONTENT	"What to do"	"What, when and how to do"

Table 1: Distinction between method and framework in the database

These criteria were:

1. A clear link to methods that consider climate variability or climate change for the identification of risks or vulnerabilities.
2. Availability of a method description online.
3. Availability of a method description in English.
4. Conformity with a definition of 'method' as distinct from 'framework'. The distinction of 'framework' and 'method' was based on established definitions (see Table 1.)

More flexible, loose and generic frameworks were excluded. The aim was to only include methods which are as concrete as possible in terms of 'what', 'when' and 'how to do?' to provide practical information with specific rules and procedures on the different steps in the CRA. The method should enable experts to understand how to implement the CRA based on the available description.

Figure 2 illustrates the workflow and the various sources that were used in the compilation of the database. The final database was transferred into an online search engine (CRAMSE) that contains the 120 methods and their descriptions, covering 35 characteristics and various filter options. CRAMSE is available via open access here.

The assessment of **methods used in approved proposals to three Climate Finance funds**, the Green Climate Fund (GCF), the Adaptation Fund (AF) and the Global Environmental Facility (GEF) constituted an additional assignment of the analysis. Results can be found in Box 4.

B. The meta-data description provides an overview on the variety of methods included in the database. It intends to present the methods in accordance with the applied criteria; for instance, frequencies in origins of the methods and their methodological focus, as well as temporal and spatial characteristics relevant for application, are shown by applying simple descriptive statistics.

C. Five dimensions were investigated through an in-depth analysis to identify general trends of CRA design, methodological challenges and how these are addressed by different methods, and innovative approaches in the context of climate-related losses and damages. The identification of these dimensions was carried out based on available literature and the feedback of scientists and experts active in the field.

Four key questions guided the investigation:

- What are the main challenges of integrating [topic] into CRA?
- How is [topic] operationalised?
- What type of approaches exist to integrate [topic] into CRA? What are the main similarities and differences between these methodological approaches?
- Which types of methods have proven successful? What approaches are particularly innovative?

Limitations: The study findings are thought to be useful i) for the identification of suitable methods, ii) as additional information for decision-makers and practitioners, and iii) for the enhancement and development of existing and future methods. Readers and users of the study's findings should take into consideration the following methodological constraints:

- The database reflects a snapshot of methods available in 2020; since then, other methods might have been developed and published.
- The in-depth analysis of the database focuses on the six selected dimensions that are found to be most relevant within the context of climate-related losses and damages. Other aspects concerning innovative advancements or methodological gaps are therefore not be presented.
- The way the investigations are carried out is strongly linked to the terminology used in the method's descriptions and guidelines. Hence, some interpretation of results may be skewed by a possible uncommon usage of language in the respective texts.


GIZ / Michael Tsegaye

3. Results

3.1. Description of meta-data

Before diving deeper into an in-depth analysis of aspects of the database particularly relevant to L&D, this brief analysis of meta-data provides an overview of the methods collated.

3.1.1. Origin of the methods included in the sample

The date of publication for each method ranges from 1998 to 2020, **with almost 60 % of all methods published in or after 2014** (see Figure 3). This might relate to the timeline of climate negotiations (the Paris Agreement was reached in 2015) as well as to the publication dates of IPCC Assessment Reports (ARs): AR 4 was published in 2007, AR 5 in 2014.

As the process of screening CRA methods had already started in 2019, the drop in publications in 2019 and 2020 should be understood with care. The authors cannot guarantee that every method published in these two years was included in the database.

Concerning the **sector of origin,** almost half of the methods were developed in an academic context, while one third are attributable to states or actors in development cooperation. The private sector and non-governmental organisations contributed to 11 % of all methods, and 8 % were developed by a partnership among the aforementioned sectors (Figure 3).

In comparing methods for **geographic distributions of origin and coverage**, it becomes apparent that most methods were developed in Europe (46 %) or North America (27 %), while only few originated in Australia and Oceania (3 %), Asia (3 %), Africa (3 %) or South America including the Caribbean (2 %) (see Figure 4). A considerable percentage of methods (17 %) were developed through intercontinental cooperation. However, the majority of methods were developed for the use worldwide (50 %). The rest of the methods were either developed for, or were initially applied in, Europe (13 %), North America 11 %), Asia (12 %) and Africa (8 %), Australia and Oceania (3%) or South America (4 %).

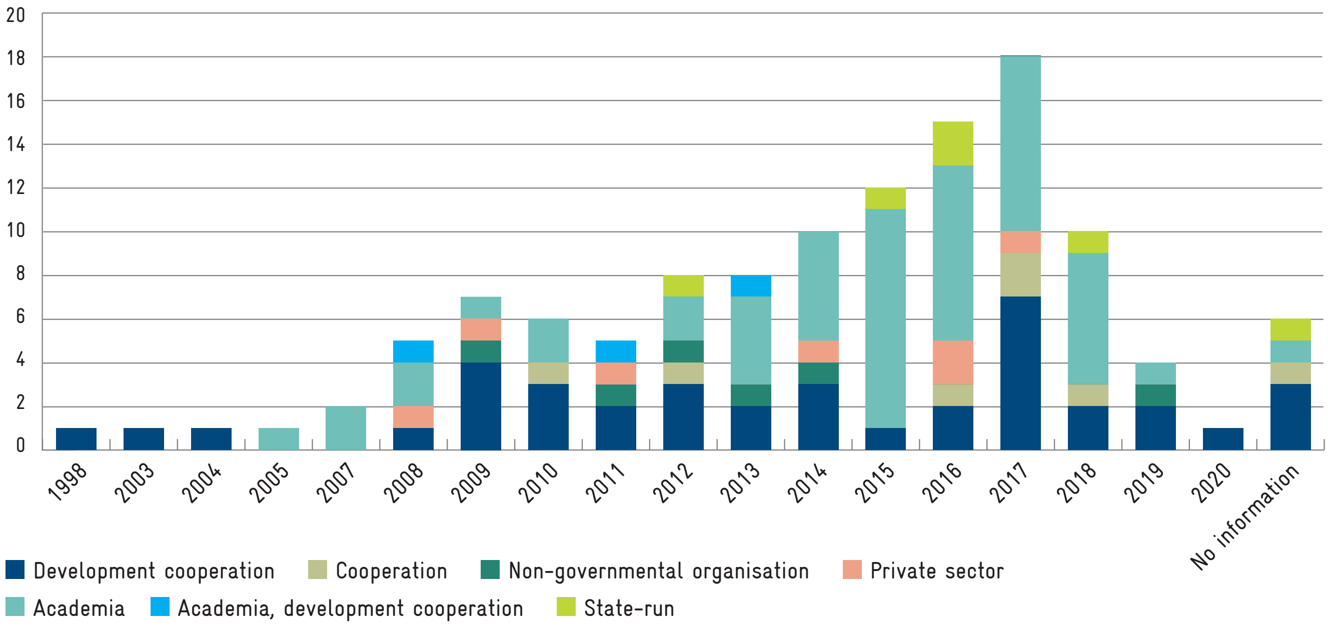


Figure 3: Date of publication and sector of origin for methods of climate risk assessment included in the database

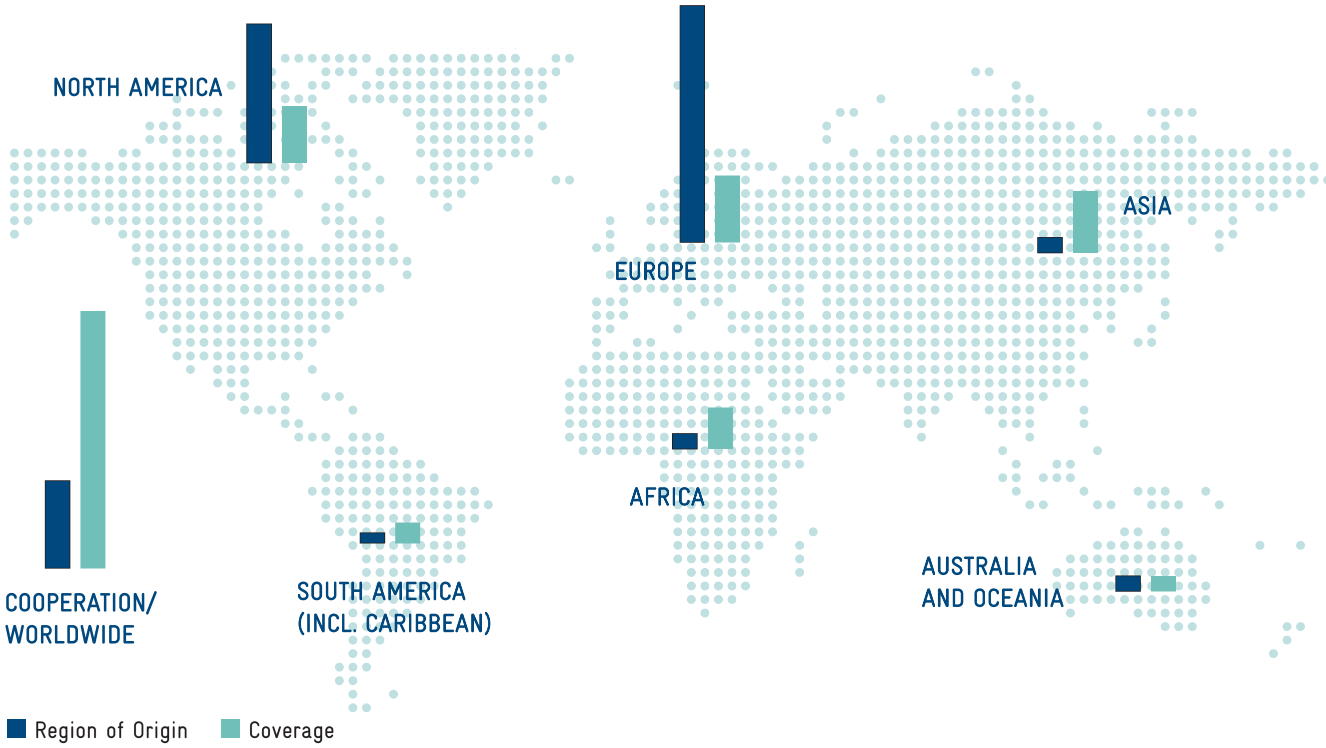


Figure 4: Geographic origin and coverage for climate risk assessment methods included in the database

Box 4: Climate risk assessment in project proposals to main climate funds

A separate part of the study relates to the analysis of recent project proposals to main climate funds (Adaptation Fund, Global Environmental Facility and Green Climate Fund). It identifies those methods that have been used most frequently in the development of project proposals. In 126 project proposals approved by the funds in the last two years, only 11 methods could be identified. Different levels of use of CRA methods were applied: from project proposals including CRA as one of the main planned activities, to proposals which had been developed to include a CRA, and proposals including CRA-relevant references. All reviewed funding proposals included multiple references to existing policy documents, studies or assessments conducted by other authors. These include global studies, the UNFCCC-related reports, regional assessments, and country-specific documents such as national communications, National Adaptation Plans or Nationally Determined Contributions. No general preference could be detected but 18 proposals were found to explicitly mention that a dedicated risk and/or vulnerability assessment was conducted as part of the proposal preparation. However, no specific methods were mentioned as this level of detail is usually included in annexes, which are normally not publicly available. Of the 62 proposals that included CRA as project activities, only a few explicitly identified the method to be applied. This indicates that there is not yet a standardised way of including CRAs in project proposals to main climate funds. Further mainstreaming of CRAs in these processes might be helpful to increase comparability and transparency of project proposals of main climate funds. Further details can be found in the Method factsheet in CRAMSE in the category 'Usefulness for political purposes'.

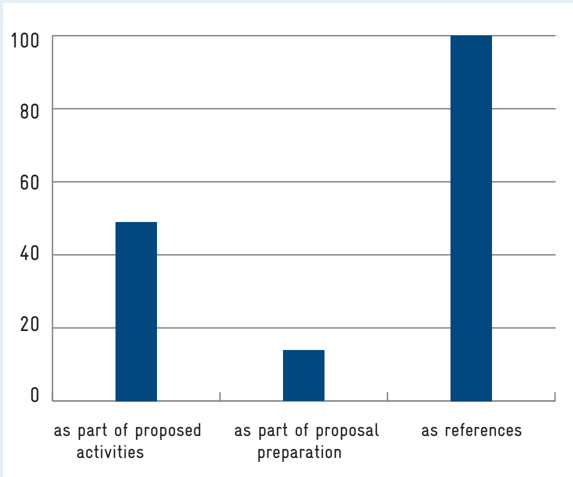


Figure 5: Percentage of proposals mentioning specific climate risk methods

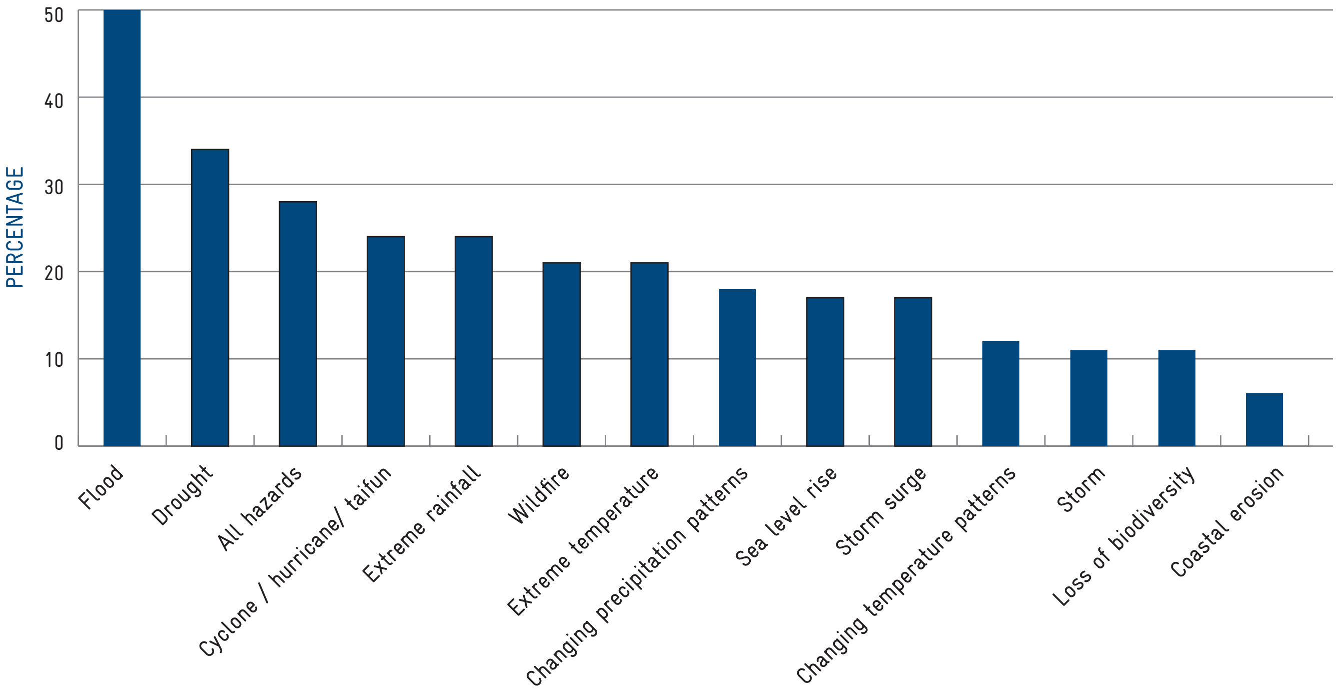


Figure 6: Hazards and impacts considered in climate risk assessment

Looking at the **different hazards which are assessed**, it becomes clear that floods are considered explicitly the most – in 50 % of the methods in the database (see Figure 6). Droughts are specifically mentioned in 34 % of the methods, and cyclones (including hurricanes and typhoons) in 24 %. Changing precipitation patterns (18 %) and sea-level rise (17 %) are the most prominent SOP; however, these are considered less than EWEs. About a quarter of the methods (28 %) claim to be applicable to all kinds of hazards or any hazards that relate to their context. In almost all methods, several hazards are mentioned.

3.2. Implementation of methods

Most of the methods imply extensive use of experts, computational resources or the organisation of workshops and/or stakeholder surveys. Time and cost intensiveness are rarely stated in the available method description. However, the time taken to implement a method tends to vary from some minutes to several years. Only a few methods provide concrete information on financial expenditure. The range of estimated costs is wide and extends from open-source methodologies which use publicly available data sources to methods requiring up to estimated USD 900,000 (Warren et al., 2018 [ID 14]).[7] This is not least because of diverse origins of different methods, as shown in Figure 7. Papers published in scientific journals, or methods developed by organisations of international development cooperation and non-governmental organisations, are clearly distinguishable from methods for risk assessment developed by asset managers to secure their own portfolio. Accordingly, the extent of financial and human resources required for the implementation of different methods varies strongly within the sample. For example, 76 of the CRA methods rely on secondary data, which means that only immediately available data is used, while 44 require either primary or primary and secondary data, which means that data collection is involved. Data collections will substantially increase the duration and cost of the assessment but can also mean that an assessment is much more detailed and context specific.

While risk-screening methods can be used by individuals to obtain a first overview on relevant risks in a few seconds, extensive expert knowledge and stakeholder consultations including organisational learning processes may lead to implementation that lasts several years. Likewise, stakeholder participation, which features in 43 of the methods analysed, is also connected to higher costs but at the same time to better results, and increased awareness and ownership of results among the group responsible for developing the method (see also section 3.3.5).

8 Methods of the database are referred to by their identification digits (IDs) and listed in the Annex. For more information on the selection process, see chapter 2. Methods, which are directly or indirectly cited are named as in-text citation in accordance with Harvard style.

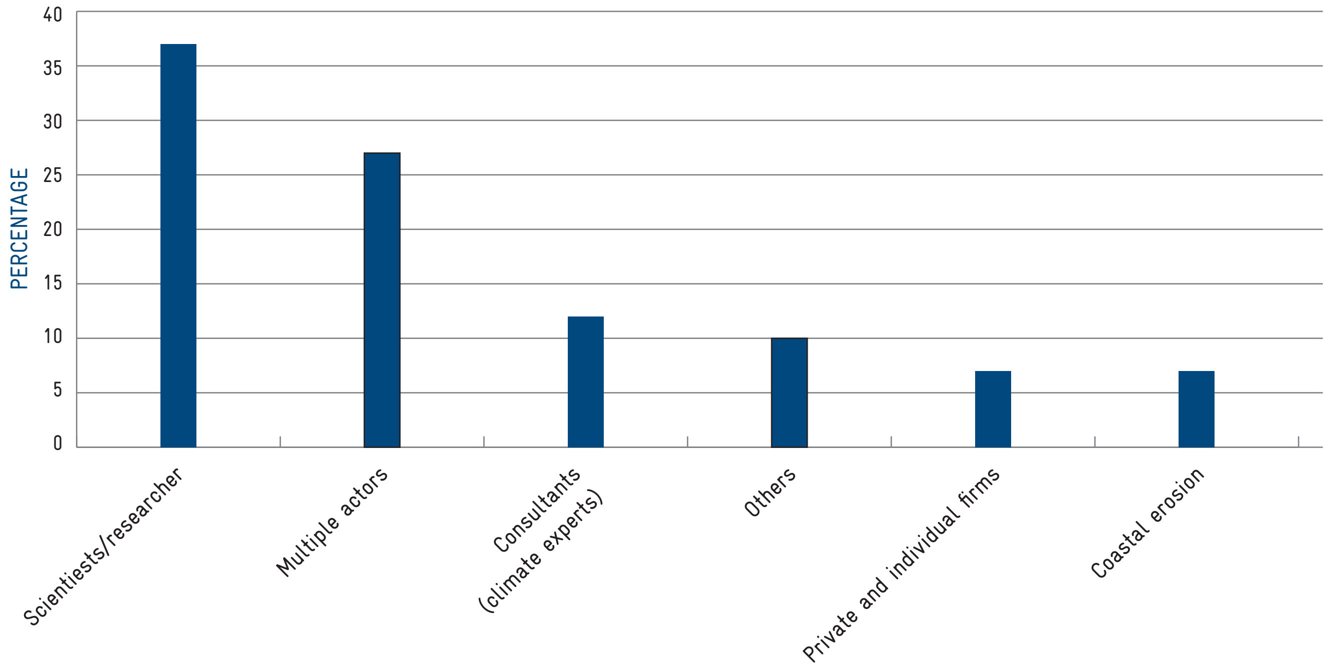


Figure 7: Different sectors developing methods for climate risk assessments

3.3. Analysis: scoping of aspects relevant to losses and damages

The following section will introduce the latest developments and key findings for the main aspects that have been considered relevant to methodological development and for technical discussions on risk assessments in the context of climate-related losses and damages.

3.3.1. Considering the full spectrum of climate-related hazards and impacts at the outset

Hazards and impacts that are climate-related range from extreme weather events to more gradual slow onset processes. Most regions in the world experience compound and interacting EWEs and SOPs, causing cascading effects (see also section 3.3.2). It is therefore necessary to consider the entire spectrum of hazards and corresponding risks (Figure 8) when first embarking on a holistic climate risk

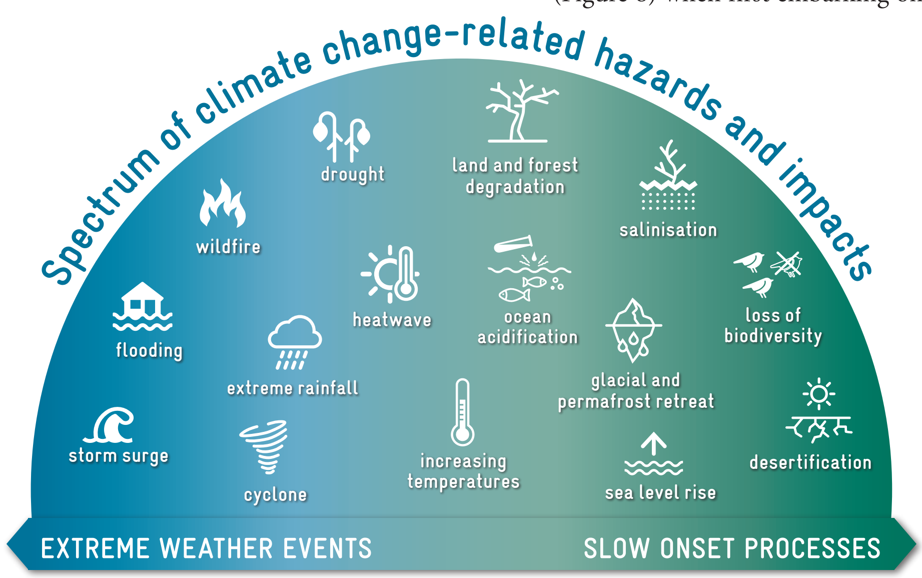


Figure 8: GIZ Global Programme on Risk Assessment and Management for Adaptation to Climate Change (Loss and Damage) model for the spectrum of climate change-related hazards and impacts[8]

9 Figure 8 distinguishes between hazards, such as extreme rainfall, and impacts like landslides. Climate-related hazards are directly exacerbated by rising concentrations of greenhouse gases in the atmosphere; impacts represent subsequent effects and are often the result of multiple drivers, some of which are non-climatic (e.g. land use change, invasive species, pollution), and are linked to exposure and vulnerabilities that influence a determined system. Climate risk management that targets the impact of the hazard can therefore prevent cascading effects and reduce the risk of a system collapsing.

assessment. Depending on the specific context, some hazards can be defined specifically as EWEs or SOEs. However, some hazards such as droughts feature characteristics of both types of events.

Research, implementation and prioritisation of climate adaptation measures have so far seem to have focused on EWEs. This is evident in recent work of the UNFCCC Adaptation Committee in which countries ranked climate hazards according to their relative importance in the respective national contexts (UNFCCC Adaptation Committee, 2020). Nevertheless, accounting for SOPs is also important: although their impacts manifest at a slower rate, they are not necessarily less severe than those of EWEs. ID 60, for example, describes gradual changes as 'Achilles' heel' vulnerabilities which might significantly outweigh other stressors and undermine adaptation.

In general, out of the 120 methods analysed, 47 % consider both EWEs and SOPs when assessing climate-related risk, or put differently: 47 % methods appear applicable for analysing the entire spectrum of hazards, whereas 17 % cover it to some extent and 30 % only apply to a selected type of hazard (see Figure 9). For 6 % of methods, no information was available.

However, only roughly half of the methods which consider the full spectrum explain how the distinction between EWEs and SOPs is made, how the challenges mentioned above are addressed and how the spectrum is covered in detail. In addition, of the methodologies that integrate both EWEs and SOPs, 11 apply mixed approaches and 12 apply one single approach.

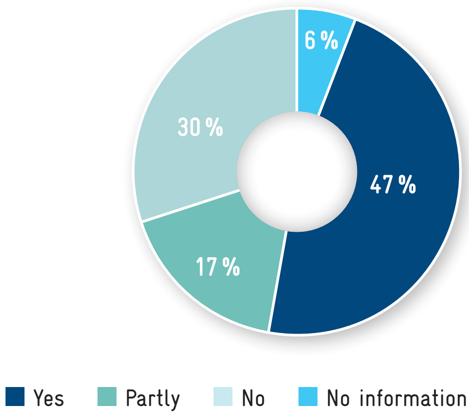


Figure 9: Climate risk assessment methods considering the entire spectrum of climate-related hazards and impacts

Challenges when considering the entire spectrum of hazards and impacts

Taking both SOPs and EWEs into account is a major challenge for methodological approaches. Firstly, the **different timescales** of EWEs and SOPs result in diverse data needs, and it can be difficult to forecast future changes for a specific time period. Models which aim to accurately represent gradual changes may need global data collected over longer timescales; however, the resolution of such datasets may not be sufficient to represent extreme events when the data is analysed through standard deviation or variance.

The difference in timescales for EWEs and SOPs also leads to difficulties in achieving consistent projections or measurements: while EWEs, in most cases, last for a precisely definable time span and occur in an **identifiable spatial extent**, impacts of SOPs are less quantifiable regarding both aspects. One solution discussed in section 3.3.1 is the definition of critical threshold values specific to the system under analysis. In this case, the spatial extent and timescale are adapted to the needs of the target system.

Since both types of events interact, it is important to consider whether **changes in frequency or intensity of EWEs** occur as SOPs arise. This is particularly challenging when using probabilistic approaches: present-day probability density functions for climate variables will not necessarily hold true under future conditions, so there is not always a clear or consistent distinction between an SOP and an EWE. In this section, we therefore refer to the distinction made by the authors of the respective method description – if such a distinction is available.

A particular challenge for participatory methods is the **imperceptibility of gradual changes**. While extreme events often have drastic impacts and stay in collective memory, the gradual changes of, for example, temperature or precipitation patterns, cannot be perceived directly and must be assessed by indirect methods (for further information, see Adamo et al., 2021).

Instruments and innovations for considering the entire spectrum of hazards and impacts

Despite the challenges mentioned, numerous methods have a found a variety of ways in which to consider the entire risk spectrum; some of these involve innovative approaches. Common instruments include index development or index use, participatory approaches, scenario modelling and quantitative or probabilistic models.

Five of the methods have developed an index or make use of an already existing index (ID 42, ID 46, ID 69, ID 127, ID 154). Torres et al. (2012 [ID 127]), for example, uses the Regional Climate Change Index (RCCI), which can synthesise a large number of climate model projections for climate analysis. RCCI is based on the temperature change in a specific region relative to changes in mean global temperature, mean regional precipitation, and interannual variability of temperature and precipitation, all of which are calculated separately for austral summer and winter. ID 42 makes use of historical datasets to create a composite index for SOP and EWE in which the gradual changes are normalised as a number of standard deviations for precipitation and temperature in each decade from mean values calculated for the overall time period. This is combined with a measure of frequency of selected EWEs (defined with threshold values) per year in order to create the composite index.

Out of the methods analysed in order to identify how the risk spectrum is incorporated, eight of the methods are participatory, or have participatory elements (ID 151, ID 13, ID 66, ID 60, ID 138, ID 57, ID 153, ID 205). Bennett et al. (2015 [ID 60]), for example, suggests community-centred vulnerability assessments with a focus on local perspectives and experiences. Each category of drivers in the framework considering both EWEs and SOPs can be explored through qualitative interviews, or results emerging from interviews can be compared with or coded against the framework. Interviewing can also be used to examine local perceptions on the presence or absence of specific exposures to both types of hazards. Different exposures can be ranked by importance or rated (e.g. on a Likert scale of 1 to 5) to determine the relative severity of the exposure or the sensitivity of communities, households or groups. In this method, exposure is differentiated between acute, such as the 2004 tsunami in Southeast Asia, and chronic, such as the steadily increasing impacts of sea-level rise for communities that are situated in low-lying coastal areas.

A further approach applied by methods covering the entire spectrum of hazards is scenario modelling (ID 40, ID 66, ID 74/75,[9] ID 129, ID 180, ID 185). Preston, B. et al. (2007, [ID 129]), for example, applies an impact assessment which relies upon quantitative scenarios of climate change, including projections of changes in average temperature, rainfall, evaporation and humidity in 2030 and 2070. Additional modelling is conducted to generate scenarios of changes in extreme rainfall events and storm surge events across the analysed region.

Moreover, most of the methods analysed have quantitative or probabilistic elements (ID 4, ID 15, ID 66, ID 78, ID 60, ID 118, ID 40, ID 74/75, ID 154). ID 40, for example, uses pertinent climate data, which is divided into three categories: temperature and precipitation changes, sea-level rise, and incidence of hurricanes and tropical storms. Specific hazard models are constructed which incorporate sea-level rise as the main relevant slow onset change.

As a further example, Holsten and Kropp (2012 [ID 15]) applies exposure variables as proxies for extreme events and for slower climatic changes. Identified relevant climatic stimuli are transferred to exposure variables prior to the aggregation of impacts. To express the direction of change, absolute exposure variables are between minus 1 (decrease in climatic stimuli) and 1 (increase), based on the maximum absolute change in either direction for the whole regional data range.

As already mentioned, most of the methods analysed make use of more than one approach and combine different elements. CARE International (2010 [ID 138]), for example, suggests a combination of climate data – especially that which relates to long-term trends and future projections – with local observation and knowledge. This approach can address the challenge of dealing with biased perceptions of gradual changes: climate data can reduce distortions caused by the fact that gradual changes could be perceived as less severe and can complement qualitative data obtained through participatory approaches. As another example, Preston et al. (2007 [ID 129]) combine impact analysis, which applies a scenario modelling approach as described above, with a vulnerability analysis. The latter is operationalised by identifying indicators of exposure, sensitivity and adaptive capacity for five potential climate change impacts.

10 Here, the same method was published in two different publications.

3.3.2. Recognising interdependencies between risks

Various interdependencies exist between distinct climate hazards and their impacts, drivers and processes, and ultimately between distinct types of risk. Systems in general interlink with each other and interact, and this holds true for the impacts of climate change as *"the multiplicity of climatic variables, the spatial scale over which they manifest and their many points of interaction with human and physical systems inevitably leads to a range of complex interactions"* (Dawson, 2015, p. 1080). Examples of how interdependencies manifest include compound risks, cascading risks, and systemic risks (see Box 5 for definitions).

Interdependencies can significantly change the nature and extent of risk. They also affect how risks are perceived and defined, which in turn influences the way in which risk is analysed. As the definition of risk might have serious implications for how risk is managed, and decisions are made (Aven, 2016), interdependencies and interaction require in-depth consideration when conducting a climate risk assessment.

In the study sample, 26 % of the methods fully consider interdependencies of risks and 27 % consider them partly; 30 % of methods do not consider them at all (see Figure 10).

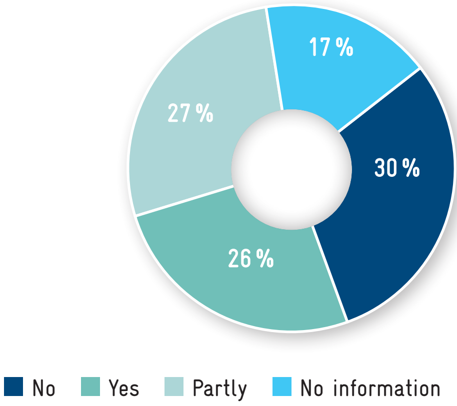


Figure 10: Climate risk assessment methods considering interdependencies of hazards, impacts and risks

Instruments and innovations for considering interdependencies between risks

Recognising **compound risks**, Asare-Kyei et al. (2017 [ID 69]) explicitly considers the combined effects of floods and droughts, which are among the most problematic hazards in West Africa (UNU-EHS, 2017). The approach therefore constructed a multi-hazard index integrating flood and drought hazards, and drew on the strengths of a simple hydrological model and statistical methods integrated using geographic information systems (GIS) to develop a Flood Hazard Index to an acceptable level of accuracy.

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Box 5: Compound, cascading and systemic risks

Compound risks refers to concurrent or successive extreme events and can be associated with multiple, otherwise unrelated, hazards interacting (Pescaroli and Alexander, 2018). Classifications made in climate science extend this classification to "combinations of extreme events with underlying conditions that amplify the impact of the events and combinations of events that are not themselves extremes but lead to an extreme event or impact when combined" (IPCC, 2012, p. 118). Compound risks are understood not as new risks but as those for which the likelihood, type and impact is affected when climate change alters the distribution of climate variables and their spatial and temporal dependencies (Zscheischler et al., 2020). An example is that coastal floods which are predicted to occur every 100 years can become yearly events (in the high-emissions 'business-as-usual' RCP8.5 scenario) because of an overall rising sea level (Church et al., 2013).

Cascading risks are risks "that develop due to a hazard and its impacts in situ to the systems affected, flowing out to other domains" (Lawrence et al. 2020, p. 2). In practice, climate change can cause cascading risks such as a drought which causes ground movement which then affects the integrity of pipe systems responsible for supplying water. This is referred to as a cascading impact (Lawrence et al., 2020, p. 7). Usually, a resulting impact following cascading effects is significantly larger than the initial impact (IPCC, 2019).

Systemic risks can result from the interdependencies of events or effects, eventually leading to system malfunction or collapse. For example, the loss of infrastructure and crops caused by compounding droughts and floods in Mozambique in the mid-2000s had a substantial adverse domino effect on key socio-economic outcomes such as housing, jobs, education and social cohesion, and can therefore be described as system malfunction (GIZ and IIASA, 2021). The contribution of the IPCC Working Group II to the Fifth Assessment Report identified systemic risks as key risks across sectors and regions (IPCC, 2014).

The index was validated with participatory GIS techniques using information provided by local disaster managers and historical data.

In a similar fashion, the Climate and Development Knowledge Network (2013 [ID 153]) highlights the importance of identifying correlations between the impacts of climate-related hazards, and climate parameters. The method suggests two procedures that can be applied to define the degree of correlation between the two. *"Either process begins with assembling databases covering climate-related hazard impacts (e.g. flood disaster damage or crop losses due to long term reductions in precipitation) and climate parameters, most often precipitation and temperature, linked to the nature of the hazard being considered"* (Climate and Development Knowledge Network, 2013, p. 33f. [ID 153]).

Aiming to account for **cascading as well as systemic risks**, **United Nations Office for Disaster Risk Reduction** (2017 [**ID 70**]) presents ten essential steps for making cities resilient. It advises that local governments should identify and understand risk scenarios and use this knowledge to inform decision-making. Risk scenarios should identify hazards, exposures and vulnerabilities in at least the 'most probable' and 'most severe' ('worst-case') scenarios, paying particular attention to the consequent risk of cascading failures from one asset system to another. *"The 'failure chains' between different elements of a city's infrastructure (for example, where an energy system failure triggers loss of water treatment) can be a critical vulnerability – and one that may be hidden unless specifically identified, and thus come as an unwelcome shock when responding to a disaster"* (United Nations Office for Disaster Risk Reduction 2017, p.16 [ID 70]).

All in all, a range of methods have found ways of accounting for interdependencies of risks. However, such interdependencies, especially cascading effects which can lead to system failure with potentially catastrophic impacts, need to be taken into account more systematically to provide a comprehensive and thorough picture of climate risks.

3.3.3. Including socio-economic dynamics in future scenarios

It is standard for climate change-related studies to use climate scenarios in order to appraise future hazards and identify related risks. However, future potential losses and damages are strongly influenced by the exposure and vulnerabilities of the social-ecological system at risk. Therefore, it is pivotal to consider not only the future development of climate parameters, but also the social and economic characteristics of the systems at stake. Unfortunately, the respective models are often not available at all or only available in limited ways – for example as population/demographic scenarios.

By combining scenarios on climate change with socio-economic scenarios that include assumptions on the future trends of demography and economic growth as well as patterns of international trade, governance and institutional development, it is possible to assess how climate change impacts across different sectors. In turn, an improved understanding of future risks and the vulnerabilities of livelihoods, infrastructure and societies to climate change can enable the adoption of more informed risk management strategies that better consider uncertainties (Berkhout et al., 2014).

Instruments and innovations for considering socio-economic dynamics

Projections of socio-economic changes are frequently used by the methods represented in the sample in a quantitative way, in order to better estimate future vulnerabilities and losses (compare ID 4, ID 53, ID 60, ID 127, ID 28, ID 85, ID 160, ID 74/75, ID 190).

Essentially, future socio-economic dynamics are looked at from two angles: firstly, as a driver of climate risks, which increase vulnerability and sensitivity; and secondly, as a consequence of climate change-related development pathways. The role of socio-economic dynamics as a potential driver of vulnerability (ID 118, ID 60, ID 53, ID 28, ID 39, ID 85) relates in particular to coastal zones or cities. Thereby, socio-economic changes are the most important driver of an overall increase in the exposure of both population and assets to climate change. Urbanisation, rising populations, increasing asset values, migration and changes in water supply are the most frequently observed factors that can increase exposure. However, the whole range of exposures associated to socio-economic changes contains many more aspects, as shown in the following table provided in Figure 11.

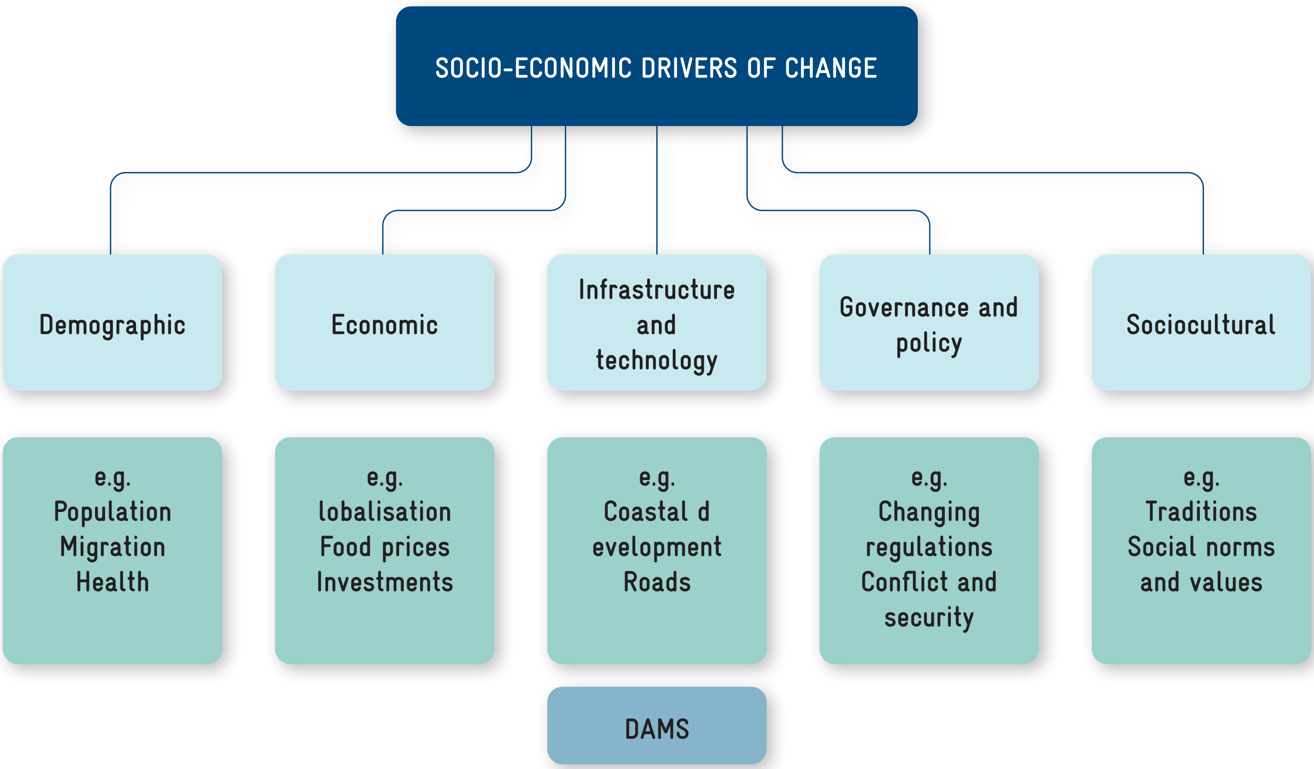

Figure 11: Socio-economic drivers of change that influence exposure to climate change (Source: (Bennett et al., 2015 [ID 60])

When looking at socio-economic vulnerabilities as a consequence of climatic changes (ID 66, ID 57, ID 157, ID 4, ID 15, ID 127, ID 88, ID 184, ID 185), CRA covers a broad range of factors, such as health (ID 157, ID 88), infrastructure (ID 4, ID 157) or education (ID 127). In this regard, CARE International's participatory and community-based CRA methods (2012 [ID 66]; 2019 [ID 57]) pay special attention to the influence of gender, poverty and other local socio-economic characteristics influencing climate resilience.

Another approach for including future socio-economic dynamics in CRA methods is to demonstrate, based on economic projections, the cost-effectiveness of investments in climate risk management measures for increasing the resilience of critical infrastructure (Pan American Health Organization, 1998 [ID 157]; Brown et al., 2018 [ID 4]). This includes information on future economic developments, investment decisions, inflation, building costs, maintenance costs, clean-up costs and savings in relation to deferring a project. In the context of losses and damages in the private and business sector, risks related to climate change are expected to lead to business interruption due to flooding, an increase in supply chain disruption as a result of extreme events or loss of staff hours due to high internal building temperatures (Adapting to Climate Change Programme UK, 2012 [ID 41]; United States Environmental Protection Agency, 2016 [ID 180]).

To sum up, the consideration of socio-economic scenarios (in the almost always promoted climate scenarios) is becoming more frequent and is an emerging trend for integrated CRAs. Thereby, socio-economic changes are

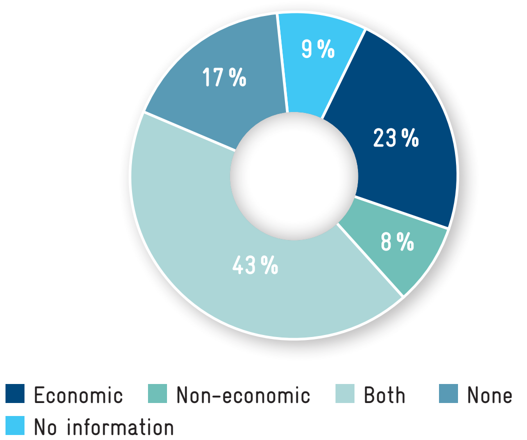

Figure 12: Climate risk assessments methods considering non-economic Loss and Damage

identified as the most important driver for an overall increase in the exposure of both population and assets to climate change.

3.3.4. Including non-economic Loss and Damage

Losses and damages discussed in the contribution of the IPCC Working Group II to the Fifth Assessment Report are primarily of an economic nature and include damage to property or infrastructure and income losses. Non-economic Loss and Damage, such as a loss of biodiversity, identity, livelihoods or health, has received significantly less attention (Van der Geest and Warner, 2020). Therefore, this section takes a closer look at the challenging task of assessing these non-economic types of losses and damages by analysing to what extent and how NELD is recognised by existing CRA methods.

Due to great variation in the conceptualisation and actual use of the terms 'non-economic losses and damages' and 'Loss and Damage' in the CRA methods, the term is defined as follows: NELD can be either material or non-material and can have value in itself (intrinsic value, e.g. health) or constitute a way to achieve a valuable item (instrumental value, e.g. food to maintain health) (Fankhauser et al., 2014). Only one method (Economics of Climate Adaptation [ID 74/75]) explicitly makes use of the exact wording *"non-economic losses"*. The authors acknowledge that considering both non-economic losses (e.g. social and environmental impacts), as well as non-economic benefits of adaptation measures increases the usefulness of cost–benefit analyses, but does not further the focus on NELD. In other method descriptions, the terms *"non-economic costs and economic and/or quantifiable costs"* (Swiss Agency for Development Cooperation, 2009, p.9 [ID 162]), *"loss of non-monetary cultural resources and value"* (European Topic Centre on Climate Change Impacts, Vulnerability and Adaptation, 2011, p. 9 [ID 149]), *"nonmonetary [...] effects of climate change on natural and human systems"* (Asian Development Bank, 2012: xii [ID 184]), *"non-monetary costs"* (Warren et al., 2018, p. 9 [ID 14]), or *"fewer tangible issues"* (CARE International, 2019, p.35 [ID 57]) were employed and imply a reference to NELD.

Findings indicate that more than half of the methods (51 %) include an assessment of non-economic losses and damages (see Figure 12). 43% of methods include both economic and non-economic L&D, whereas 8 % methods exclusively focus on NELD. 23 % of methods focus entirely on economic

Box 6: Non-Economic Loss and Damage under the United Nations Framework Convention on Climate Change

The topic of **non-economic Loss and Damage** is gaining increased attention in negotiations under the UNFCCC over the last decade (Serdeczny et al., 2016a). Focusing on the negative impacts of climate change that are difficult to quantify or measure in monetary terms (Serdeczny et al., 2016a; Serdeczny, 2018), NELD are understood by the UNFCCC as losses "that are not commonly traded in markets" (UNFCCC 2013a, p. 3). Given that NELD constituted a selected topic in the workplan of the Warsaw International Mechanism for Loss and Damage associated with Climate Change Impacts, an expert group was formed to "develop inputs and recommendations to enhance data on and knowledge of reducing the risk of and addressing non-economic losses" (UNFCCC Secretariat 2014).

L&D. Following the trend for variations in the way 'NELD' is conceptualised and used, further differences exist between 'economic' and 'non-economic' losses and damages.

The most common approach in CRA is to differentiate between environmental or biophysical losses and damages – i.e. climate and other environmental changes – and socio-economic losses and damages – i.e. economic, technological, sociocultural, demographic and political change (ID 47, ID 60, ID 152, ID 158, ID 135, ID 102, ID 184, ID 118, ID 42, ID 166) or between social, economic and environmental drivers, exposures, impacts, risks and damages (ID 14, ID 27, ID 41, ID 83, ID 87, ID 128, ID 151, ID 5, ID 115). For some methods, the built environment (ID 160, ID 92, ID 117, ID 161, ID 113), ecosystem services and biodiversity (ID 160, ID 113) as well as cultural (ID 92, ID 175, ID 138, ID 205), demographic (ID 175) and political (ID 161, ID 113, ID 36, ID 138, ID 153) factors are added as separate dimensions to further differentiate the context in which losses and damages occur. Lastly, another approach is the assessment of sector-specific impacts which may entail both economic and non-economic losses and damages; these include impacts on food/agriculture, water, health, fish stocks, cultural heritage, education, government, and peace and security (ID 66, ID 69, ID 15, ID 32, ID 33, ID 76, ID 54, ID 100, ID 148, ID 200, ID 203).

This lack of a clear differentiation and common terminology makes it difficult to draw attention to NELD and impedes comparability between CRA methods. Accordingly, this study takes a closer look at the **range of NELD indicators** considered in the 61 identified CRA methods is and considers possible options for classification. Even though the majority of methods underline the non-exhaustive nature of their selection of indicators (compare those methods listed in the paragraph above), findings of the study's indicator assessment (Figure 13) show a clear pattern of the types of NELD most commonly considered.

Instruments and innovations for considering non-economic Loss and Damage

The approaches most commonly applied in the methods reviewing NELD are quantitative (21) and mixed-method (22) alongside other (9) approaches often including participatory, self-rated or spatial elements. Some methods are based on scenario mapping (6), while purely qualitative (3) approaches occur relatively rarely.

In terms of assessment methodology, development of indices (12) or models (7) are common quantitative approaches to assess non-economic losses and damages in addition to those of an economic nature. Climate and Development Knowledge Network (2013 [ID 153]), for example, provides detailed instructions for integrating the impact of each selected climate hazard on human, financial, social, natural and political livelihoods into a composite impact score. Mixed-methods studies tend to complement secondary or observational data sources with participatory methods (ID 100, ID 57, ID 45, ID 151, ID 152, ID 5, ID 205), or other qualitative methods such as interviews or perception-based assessments (ID 109, ID 153, ID 102, ID 151, ID 135, ID 47) or literature reviews (ID 41, ID 165, ID 47). Swiss Agency for Development Cooperation (2009 [ID 161]) introduces a detailed assessment methodology which integrates climate change, disaster risk reduction and environment at the strategic level: the basis for identifying potential risks and suitable measures is here laid by an in-depth context analysis of primary and secondary data – such as official policies, strategies and plans at national and sub-national levels. After relevant actor groups are mapped out for all levels, a participatory workshop

Material & Intrinsic

- Biodiversity (12)
- Biodiversity loss (8)
- Species distribution (4) & composition (2)
- Vegetation health (2)
- Animal health (4)
- Loss of life (3)
- Poor health (4)
- Poor living conditions (1)

- Places (2)
- Loss of public spaces (2)

- Artefacts (3)
- Cultural heritage (3)

Material & Instrumental

- Land egradation (6)
- Soil (2) & water (6) quality
- Habitat destruction (3)
- Environmental degradation (2)

- Ecosystem Services (4)

Non-material & Intrinsic

- Intrinsic values (9)
- Mental and emotional health (5)
- Life expectancy (2)
- Well-being (2)
- Recreation (1)
- Loss of irreplaceable memorabilia (1)

Non-material & Instrumental

- Agency (22)
- Conflict and security (9)
- Government function (7)
- Migration (5) and displacement (7)
- Policies & plans (4)
- Education (5)
- Public participation (3)
- Human rights (3)
- Social cohesion (3) and social institutions (2)
- Safety (2)

- Identity (12)
- Norms and values (7)
- Social networks (5)
- Gender relations (5)
- Loss of traditional knowledge (1)

Figure 13: Types of non-economic Loss and Damage indicators most commonly considered in climate risk assessment. Numbers in brackets indicate how often the respective indicators were mentioned in the 61 methods identified (categories taken from Serdeczny et. al, 2016a)

Box 7: Spectrum of NELD indicators - The example of health in NELD

Particularly useful resources for a broad overview of material, non-material, intrinsic and instrumental NELD indicators are Tapia et al. (2017 [ID 113]), which review categories of indicators found in the literature, and Bennett et al. (2015 [ID 60]), which present a conceptual framework for integrating multiple exposures into vulnerability analysis and adaptation planning. Bennett et al. (2015 [ID 60]) provide examples in the realms of demographics (e.g. migration, chronic or acute diseases, injuries, disabilities, mental health), governance and policy (e.g. decision-making structures, legitimacy, networks, capacity and resourcing, changes in tenure and rights, natural resource management, conflicts and security), sociocultural change (e.g. shifting traditions, knowledge and values, shifting family relationships and gender roles, organisational networks and bridging social capital) and the environment – demonstrating the need to integrate a broad spectrum of NELD indicators.

Aspects of human health as examples of material, intrinsic indicators are acknowledged in 24 methods. In this sample, methods tend to focus on loss of life or damage to physical health, including injuries and hospitalisation, sometimes with special attention to vulnerable groups such as children and elderly people (ID 100, ID 32) or indigenous populations (ID 88). CARE International (2019 [ID 57]) highlights gender equality as a key topic to consider as research has shown that non-monetary losses and damages often affect women in developing countries more directly than men, particularly in the domains of mortality, health, food security, human mobility and gender-based violence (Von Ritter Figueres, 2013; GIZ, 2020).

Based on the available methods, it is assumed that the selection of health indicators seems to depend on the target audience or geographical coverage of CRA methods. USAID (2017 [ID 54]), addressing development organisations and humanitarian actors, also measures vector-borne and waterborne diseases and nutrition, while adding psycho-social stress caused by loss of livelihoods, malnutrition, disease, seasonal or permanent migration, and social conflict. In its assessments of climate risks in European cities, Tapia et al. (2017 [ID 113]) include life expectancy, age dependency ratios, fertility rates, population growth, family and household structure, nutrition and population in special needs as health indicators. These two methods reflect demographic and epidemiological transitions from high mortality rates, with mortality primarily due to infectious diseases, to lower mortality rates, with mortality primarily caused by chronic diseases, as development proceeds. Only a few methods take into account the impact of climate change on well-being (ID 100, ID 32) or mental and emotional health (ID 60, ID 92, ID 48, ID 54, ID 205), including through the fear, shock, devastation and stress associated with the occurrence of extreme weather events and cleaning up or loss of irreplaceable memorabilia of sentimental value (Lindley et al. (Joseph Rowntree Foundation), 2011 [ID 48]).

serves to qualitatively assess vulnerabilities and the likelihood of hazards and risks with a risk matrix.

To sum up, accounting for NELD in CRAs is challenging for several reasons. At the conceptual level, for which a focus on NELD needs to be based on normative questions, the concept of NELD is based on symbolic and personal values, and human perceptions of risks and their importance, which, in turn, vary from culture to culture (Serdeczny et al., 2016b). Thus, a triple challenge of defining indicators, weighing their importance and assessing their value in a context-tailored manner (Serdeczny et al., 2016b) poses several empirical challenges. In addition, many NELD are not only context-specific and dynamic, but also incommensurable, meaning that their value is often intangible and cannot be expressed through a standardised unit (Serdeczny et al., 2016b). This means that most financial instruments are not suitable for the assessment of NELD (Schäfer & Balogun, 2015), making it hard to aggregate NELD in climate risk assessments (Serdeczny et al., 2016b). Also, assessing NELD often requires both substantial technical capacity/expertise (e.g. modelling expertise) and large amounts of data that cannot be considered as given in any context.

Yet, there are some approaches to climate risk management which demonstrate the strong benefits of recognising NELD in the context of CRA. Bennett et al. (2015 [ID 60]) provide an overview of assessment methodologies with examples ranging from quantitative rankings and cost–benefit analyses to qualitative interviews, arts-based methods or mental models, and spatial approaches.

3.3.5. Involving stakeholders

Including stakeholders' perspectives in climate risk assessments is crucial since these individuals or groups will be most "[…] *affected by climate change or by the actions taken to manage anticipated climate risks*" (Carter et al., 2007, p. 141f.). As stated in Asian Development Bank (2013 [ID 185]), uncertainties associated with future climate-related losses and damages require participatory CRA approaches not only to develop a more thorough understanding of the local context, but also to address all stakeholders' concerns, facilitate an exchange of information and increase awareness, skills and cooperation (Gardner et al., 2009; Carter et al., 2007).

In the study database, 46 % of the methods do not foresee involving stakeholders, 35 % of the methods include participatory elements such as workshops, focus group discussions and others and 17 % are categorised as partly participatory which means that stakeholders are selectively involved at certain stages of the CRA (see Figure 14).

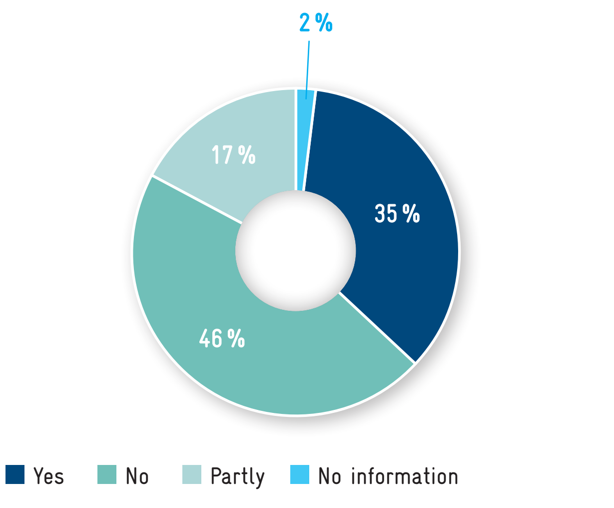

Figure 14: Climate risk assessment methods with participatory elements

Whereas some methods can be conducted either without or through stakeholder engagement (ID 33, ID 54, ID 74/75, ID 165) or generally propose a multi-stakeholder engagement process (ID 69, ID 14, ID 117, ID 161, ID 162, ID 143), others put stakeholders at the heart of the decision-making process. Drawing on examples included in the database, the following text considers **how** to involve stakeholders, **who** should be involved and **at which stage** of the process.

Participative climate risk assessments: Instruments and innovations for stakeholder identification

As a first step for a participative CRA, **relevant stakeholders (who?)** have to be identified in line with the assessment's scope, objectives, focus and spatial scale (Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Eurac Research, 2017 [ID 158]). ID 158 and ID 175 propose a set of guiding questions and describe how mapping responsibilities and relationships (stakeholder mapping) can help identify whom to involve, why, how and when. Ten of the participatory methods are expert driven, e.g. through consultation with businesses, programme managers, non-governmental organisations or disciplinary experts during data analysis (ID 46, ID 137, ID 81, ID 5, ID 45, ID 100, ID 160, ID 48, ID 193, ID 109), whereas only a few methods exclusively involve community members, including women and ethnic groups (ID 102, ID 47, ID 27, ID 182, ID 199, ID 200).

Community knowledge is often complemented by policy-based approaches through the additional inclusion of local government representatives, local institutions and authorities (ID 167, ID 57, ID 151, ID 73, ID 200), and ministries (ID 51). Almost one third of all participatory methods (17) proposes a wide range of policy- and expert-based stakeholders from community members (including farmers and marginalised groups such as women and the elderly), municipal authorities, governments at all levels, ministries, city planners, the private sector, industry, service providers, sectoral experts, non-governmental organisations (ID 66, ID 70, ID 2, ID 135, ID 28, ID 158) and research organisations (ID 20, ID 146, ID 130, ID 92, ID 86, ID 88, ID 175, ID 185, ID 184, ID 153, ID 163), as illustrated in Figure 15. While involving local institutions and experts helps to increase the quality of assessment through local knowledge and access to data sources, community knowledge is crucial for making CRAs relevant locally, ensuring local support and empowering af-

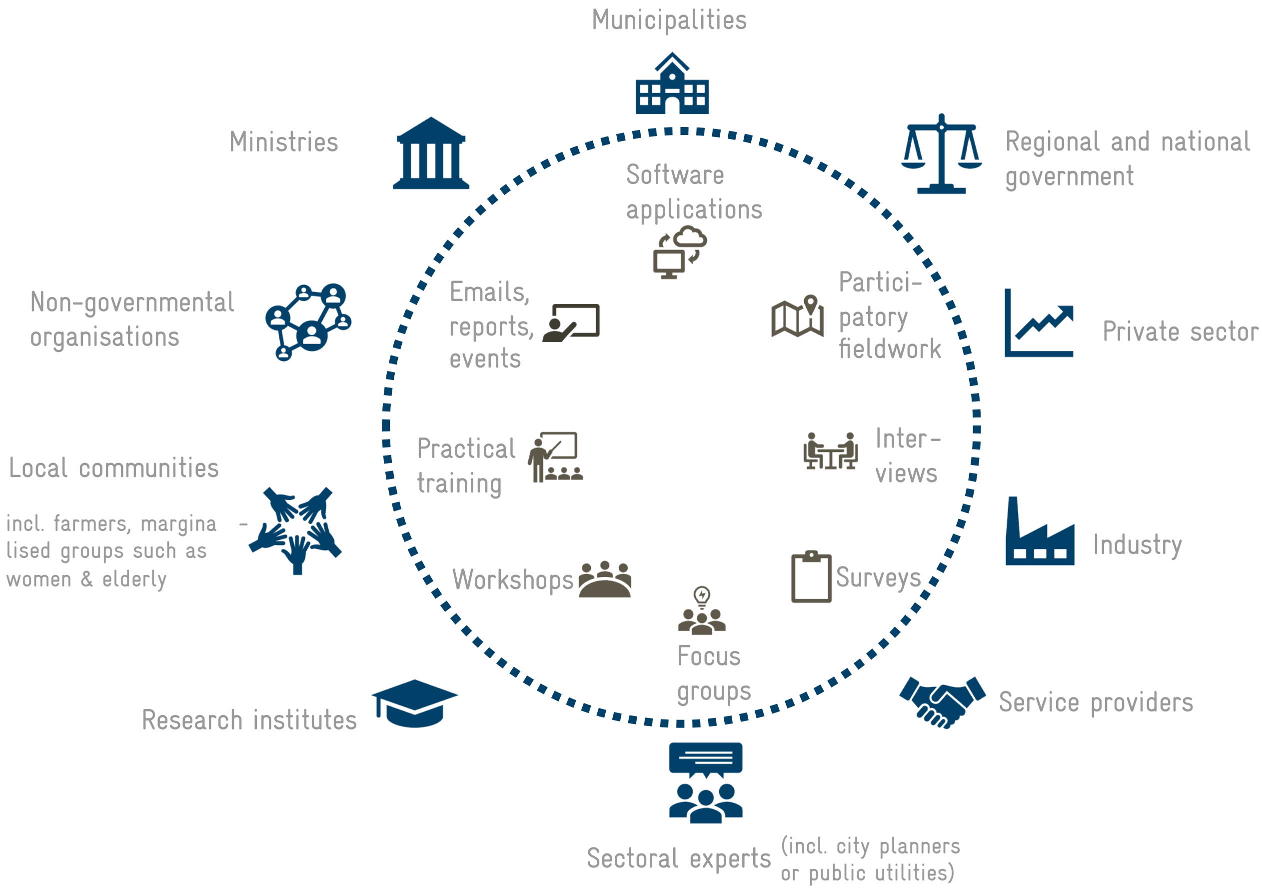

Figure 15: Stakeholders (blue) engaged in the participatory processes of climate risk assessments, and the processes through which they are involved (grey)

fected people (CARE International, 2012 [ID 66]; Climate and Development Knowledge Network, 2013 [ID 153]). Involving local institutions can facilitate political decision-making through promoting acceptance as well as the uptake and scaling-up of identified measures for managing risks (Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Eurac Research, 2017 [ID 158]).

With regards to the **form of stakeholder involvement (how?, at which stage?)**, the process can – based on the study sample of methods – take from two hours to four months depending on the type and variety of participatory methods applied in a CRA. Common methods are qualitative interviews (ID 163, ID 102, ID 130, ID 48, ID 74/75, ID 73, ID 158, ID 135, ID 143), sometimes complemented by quantitative information from households (ID 101, ID 47, ID 167) or community surveys (ID 143, ID 153, ID 5, ID 158). A few methods build on participatory fieldwork (ID 32, ID 51, ID 102, ID 138) or provide scenario-driven software applications and hands-on practical training for users (ID 123, ID 128, ID 160); others include information sharing through emails and reports (ID 143) or national and regional dissemination events (ID 28).

The majority of participatory CRA methods involves stakeholders through workshops (24) or focus group discussions (10), applying tools such as participatory (scenario) planning (ID 66, ID 45, ID 146), historical timelines (ID 60, ID 32, ID 57), seasonal calendars (ID 32, ID 151, ID 57), community mapping (ID 60, ID 32, ID 151, ID 57, ID 2), storytelling/poetry (ID 32) or participant observation (ID 102). Tools such as daily clocks for instance, serve to identify gender differences in division of labour, participation in household and public decision-making, control of productive assets, access to public spaces and services as well as control over one's body, violence and restorative justice and aspirations for oneself.

The choice of participatory method also depends on the **degree of stakeholder involvement**. The IPCC proposes five stages of stakeholder engagement, varying from passive interactions where stakeholders are involved in data collection to a level where stakeholders are empowered to initiate and design CRAs themselves (Figure 16) (Carter et al., 2007).

Engaging stakeholders in the stage of collecting **information** often involves the selection and prioritisation of indicators (e.g. ID 5, ID 46, ID 69, ID 137, ID 130, ID 101) to establish a common understanding and ensure that risk estimates are sensitive to the local context. Ellison (2014 [ID 143]) describes how the **participation** of stakeholders during scoping and information sharing can help strengthen the local context, improve policies and enable the identification of management priorities to promote adaptation measures in a process driven by a third party. Building on a collaborative execution of a CRA in **partnership** with stakeholders, the World Bank (2010 [ID 86]) continuously involves a range of actors in the identification of objectives and indicators, the assessment of risks, and the identification and prioritisation of options as well as implementation and monitoring. Putting "*local governments and urban stakeholders in the driver's seat of urban resilience planning from Day 1*", Disaster Risk Management, Sustainability and Urban Resilience (2018, p. 6f. [ID 146]) is an example of a **self-mobilisation** approach. External trainers initialise and support the process, but a small team is trained to lead the data collection and analysis, actively engage with communities during every step and collectively draft a City Resilience Framework for Action. Thereby, on-the-job training courses and trainings of trainers serve to build and strengthen capacities of communities and decision-makers. Lastly, CARE International (2019 [ID 57]) can be highlighted as a rather innovative method: not only does it facilitate a dialogue between stakeholders in order to understand their experiences and perspectives on climate change impacts in their community, and gathers feedback on the draft analysis which is then used to adapt the assessment process, but it also advise that data is collected separately from focus groups of women and men in order to reveal gender-specific vulnerabilities and needs.

To sum up, there is a consensus that, depending on the scope and objective of the assessment, mobilising stakeholders is essential for identifying needs and measures sensitive to uncertain future risks (e.g. CARE International (2012 [ID 66]). Beyond that, local and indigenous knowledge has been recognised as a particularly valuable information source, as locally adapted solutions have already proven successful for some challenges. Ultimately, stakeholder involvement has the potential to raise the effectiveness and sustainability of decision-making processes by ensuring that adaptation options are sensitive to local practices, habits and attitudes – appropriately planned and broadly accepted.

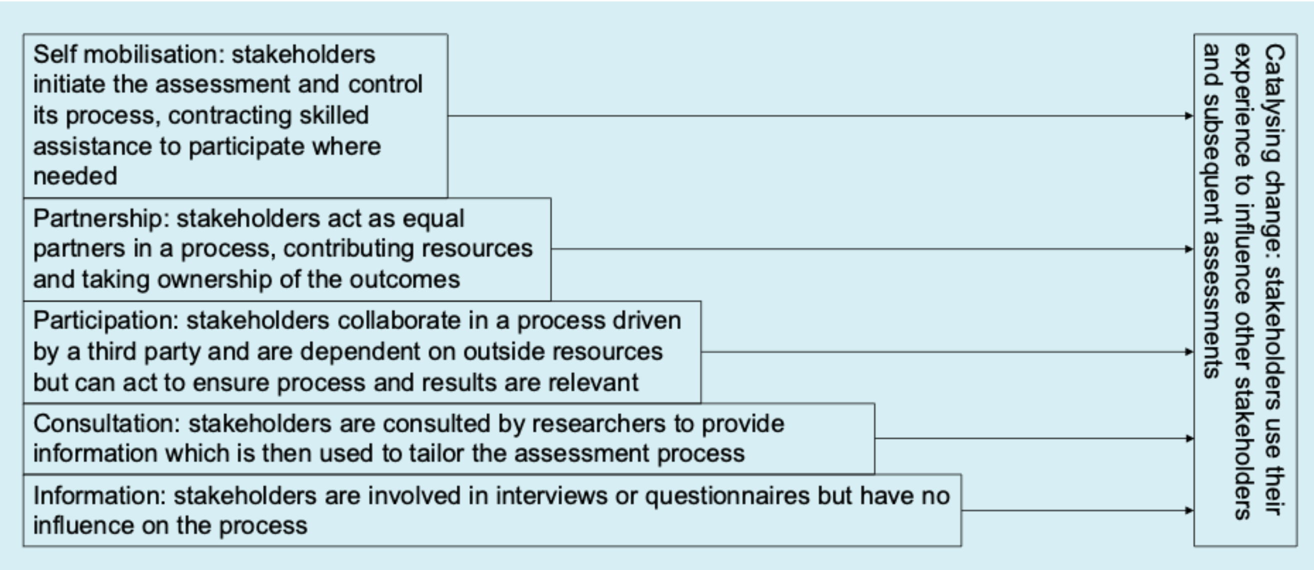

Figure 16: Ladder of stakeholder participation *(Source: Carter et al., 2007, p. 142)*

3.3.6. Assessing adaptation options and considering limits to adaptation

The assessment of adaptation options can provide information beyond the identification of likely impacts, exposure or vulnerability, and can further identify potential limits to adaptation. An appropriate adaptation option can then be chosen to address the results arising from risk assessments in order to bring the negative or adverse impacts of climate change down to an acceptable level (Climate ADAPT, 2021).

In general, adaptation and its effectiveness are not only influenced by climate change but also by economic development, demographic change, ecosystem alteration, and technological innovation (IPCC, 2014). Under certain context-specific circumstances, the limits of adaptation can be reached; what is perceived as an adaptation limit in one context does not necessarily have to be an adaptation limit in another context. For further details von adaptation options and limits to adaptation please refer to box 8.

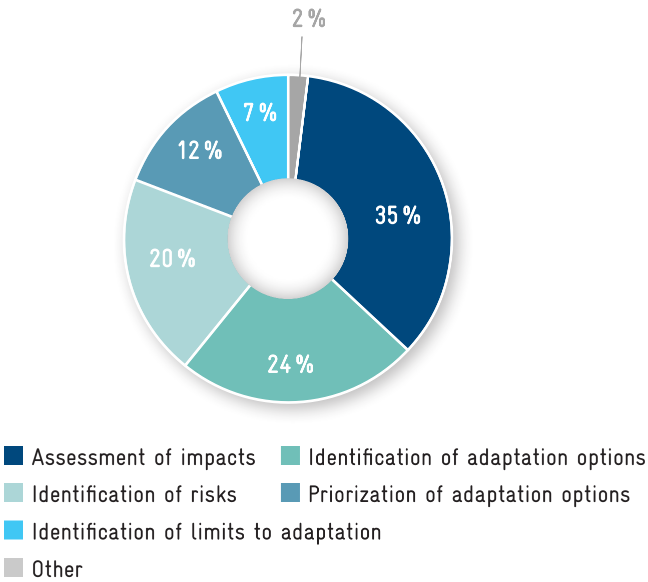

Figure 17: Climate risk assessment methods considering limits to adaptation

Following the information given in each method description, from the 120 methods analysed, 35 % conduct an assessment of impacts, 24 % identify adaptation options, 20 % identify risks, 12 % prioritise adaptation options, 7 %

methods discuss limits to adaptation and 2 % seem to refer to limits by applying other categories (see Figure 17). The logic and design of each climate (change) risk assessment can have different entry points and emphasis and can – depending on the objective – cover differential scopes.

Instruments applied considering adaptation options and limits to adaptation

The **identification of adaptation options** is either an integral part of or an addition to the actual risk assessment and is integrated as a subsequent step. In the case of UK Climate Impacts Programme, University of Oxford (2013 [ID 13]) for instance, the intended output is an adaptation strategy as well as an implementation plan including monitoring and evaluation which build upon results from assessing current and projected climate conditions, in this case referred to as vulnerabilities. Of all the methods, beyond those identifying options, 15 methods prioritise adaptation options as part of the assessment (ID 13, ID 14, ID 30, ID 54, ID 55, ID 66, ID 68, ID 73, ID 74/75, ID 86, ID 88, ID 118, ID 162, ID 180, ID 203). The objective then is to understand the suitability of options in order to recommend the best option for planning and implementation. As a 'hands-on adaptation toolkit' for the energy sector, The Energy Sector Management Assistance Program, World Bank (2010 [ID 86]) is designed to help countries carry out a stakeholder-based, semi-quantified risk assessment of climate vulnerabilities and adaptation options for the entire energy supply-use chain. It can help address questions such as "*How can a country best manage its future security of energy supply in the face of a changing climate*?". Just recently, GIZ and Climate Analytics (forthcoming) looked into options for assessing the impacts of climate risks and the potentials of measures to address these risks using a software-based approach.[10]

Box 8: Adaptation options and limits to adaptation

In this report, limits to adaptation follow the definition of the IPCC.

Adaptation options

Adaptation options can range from actions that build adaptive capacity (e.g. creating knowledge and sharing information, developing supportive institutional frameworks or establishing management systems and supportive mechanisms such as better land management planning and insurance policies) to adaptation actions implemented on the ground (e.g. physical or ecosystem-based measures).

Limits to adaptation

Natural and social systems often have the capacity to adapt; this includes the potential in social systems for transformative adaptation in response to climate-related risks. But although opportunities for adaptation exist, the capacity of both systems to adapt not only to extreme weather events, but also to gradual changes can be limited (e.g. Adger et al., 2009; Dow et al., 2013a,b; IPCC, 2014; Sainz de Murieta et al., 2021). According to the 2018 IPCC Special Report on Global Warming of 1.5°C (SR1.5), limits to adaptation are understood as the point at which an actor's objective (or system needs) cannot be secured from intolerable risks through adaptive actions. More explicitly, it means that, for the particular actor, system or planning horizon of interest, no adaptation options exist, or an unacceptable measure of adaptive effort is required, to maintain societal objectives or the sustainability of a natural system. The Summary for Policymakers (SPM) of the contribution of IPCC Working Group II to the Fifth Assessment Report recognised the existence of potential residual risk: "Under all assessed scenarios for adaptation and mitigation, some risk from adverse impacts remains (very high confidence)" (IPCC, 2014). Similarly, the SPM of the SR1.5 provides the IPCC's first synthesis of limits in natural and social systems with medium confidence: "There are limits to adaptation and adaptive capacity for some human and natural systems at a global warming of 1.5°C, with associated losses to a medium confidence" (IPCC, 2018).

Some methods included in this study do not directly refer to limits to adaptation as understood by the IPCC, but rather consider residual and unmanageable risks.

11 This study will be published shortly and will be available at Climate Risk Assessment & Management – Adaptation Community

Of those methods that consider or prioritise adaptation options, eight methods discuss limits to adaptation explicitly (ID 2, ID 3, ID 14, ID 27, ID 32, ID 48, ID 128, ID 205). For this sample, it can be assumed that only a few methods directly address adaptation limits. This is because multiple challenges arise when limits to adaptation are investigated beyond adaptation options through a climate risk assessment.

Regarding the concepts put forward by the IPCC, it appears useful and methodologically relevant to distinguish between socio-economic and natural systems. In the case of social limits to adaptation, participatory approaches and context-specific aspects seem indispensable. The perception of risk and the extent to which an individual or a community can adapt is subjective and depends on a variety of determining conditions. In the case of Lindley et al. (Joseph Rowntree Foundation) (2011 [ID 48]) for instance, the adaptive capacities of house owners in flood-prone areas are restricted by the external factor of fear of an increased risk of burglary when floodgates are installed that obscure back doors and decrease visibility. This example stresses the subjectivity of adaptive capacity and reveals that, in some cases, adaptation depends on whether individuals or communities are willing to adapt or willing to make contributions to adaptation. An additional, significant factor is the risk tolerance of affected populations and individuals, which is closely connected to the local context. Intolerable risk potentially leads to losses and damages. However, there is as yet no method for clearly and objectively defining at which point a risk becomes intolerable (for more information on the evaluation of risk tolerance see GIZ's 6-step methodology to assess climate-related risks).

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By contrast, for natural systems objective indicators can be constructed since, in most cases, irreversible thresholds such as intolerable conditions in the case of a plant species can be defined. A common example is changing sea water conditions (in temperature and pH value) that can drive corals to become extinct (e.g. Hughes et al., 2017). Applying a qualitative approach estimating the adaptive capacity of tree species, Thorne et al. (2016 [ID 3]) addresses limits to adaptation of natural systems. Individual species are scored based on their adaptive capacity to withstand fire, their mode and level of recruitment of new individuals, and seed longevity. Scores are also derived from relevant literature and expert opinions, and provide a series of hypotheses about how individual species may respond to climate change. Adaptive capacity can therefore refer to estimates of the degree to which different species can use their life history characteristics to moderate impacts from changing climate.

For both social and natural systems, the benefits of identifying either adaptation options or limits to adaptation should be made clear in order to ensure adequate integration of the results. In the case of CEDRA (2009, p. 38 [ID 32]), unmanageable risks are understood in the following sense: "*the impacts of climate change and environmental degradation are likely to be so substantial that they become unmanageable in some locations. [...] If addressing risks through adapting existing projects proves too costly, impractical or undesirable, a development agency may want to stop the project(s) or design a new project that meets the same objectives.*" Climate-related risks impacting projects can be identified as unmanageable due to political reasons or lack of resources. For example, the risk of a coastal agricultural project failing due to flooding from sea-level rise could be unmanageable if the cost of constructing a sea wall is so high that there available financial resources are insufficient or there is not enough willingness to pay.

4. Conclusion and way forward

This scoping study, and the database on which it is based, cover a broad range of available methods to assess climate risks. These compiled methods reflect current trends in terms of methodological approaches or tools dealing with a variety of challenges. The findings presented here may serve as source of information for practitioners and decision-makers. Beyond that, they may function as a basis for further research and to advance the current state of the art in risk assessment methodologies.

A meta-analysis highlights that 120 evaluated CRA methods were developed by academia, and that most originate in Europe and North America but claim to be applicable worldwide. The publication dates range from 1998 to 2020 and most of the methods were developed by academia or within development cooperation.

Zooming deeper into the five identified dimensions related to assessing the risk of climate-related losses and damages, the in-depth analysis concludes the following:

Considering the full spectrum of climate hazards and impacts at the outset of the assessment is important in CRA because different types of hazards – usually categorised as extreme weather events or slow onset processes – are often compound and interlinked, causing cascading effects. 47 % of the analysed methods cover EWE- and SOP-related hazards; yet, EWEs receive more attention in risk management, dialogues and planning, while assessment of SOPs is lacking due to methodological challenges. These challenges include data requirements arising from long time scales and the imperceptibility of gradual changes. Approaches applied to assess risks triggered by SOPs – and which are seen promising – are physical and probabilistic models, scenario modelling, and indicators and indices development, as well as participatory approaches such as expert and stakeholder interviews. A combination of different elements from several of these processes can help to mitigate the weaknesses of a single approach.

Various interdependencies exist between distinct hazards and events, their drivers and processes, and ultimately between distinct types of risk. In many cases, these interdependencies of risk are only partially understood and considered; in only about a quarter (26 %) of the methods are they taken into account fully. If the dynamics of highly interconnected and complex systems are not considered comprehensively, miscalculations could occur, leading to misinterpretations and unsuitable and ineffective decisions could result. The small number of approaches that do embrace the assessment of interdependencies for various risks and their components may indicate that respective methods are available, but not yet widely used.

By integrating into assessments socio-economic scenarios that comprise, among other things, projections on demography and economic growth, patterns of international trade, governance and institutional development, or risk management strategies, it is possible to assess climate change impacts and vulnerabilities across different sectors. Essentially, socio-economic dynamics in the future can be looked at from two angles: firstly, as drivers of climate risks, which increase vulnerability and sensitivity, and secondly, as a consequence of climate change-related development pathways. Thereby, socio-economic changes are the most important driver of an overall increase in the exposure of both populations and assets to climate change. However, while some CRA methods consider various aspects of socio-economic developments in the future, this appears not to be common practice yet. Nevertheless, the use of socio-economic scenarios can be considered a general trend in the development of integrated CRA methods.

While more than half of all methods investigated include or refer to non-economic Loss and Damage, understanding of how to differentiate between economic and non-economic L&D varies, with socio-economic, environmental, economic and sector-specific impacts all playing a part. Rather than explicitly referring to it, many methods apply indicators for assessing the risks of NELD. Overall, the lack of clear differentiation and common terminology complicates awareness of NELD and hinders comparability between CRA methods; methodologies therefore need to be developed further to incorporate this highly relevant dimension.

Risk is perceived differently by each individual, group and sector, and the effectiveness of risk management strategies as well as their acceptance strongly depend on the involvement of all stakeholders. Furthermore, **stakeholder involvement** can raise the effectiveness and sustainability of decision-making processes by ensuring that adaptation options are sensitive to local contexts and broadly accepted; thus, **it is seen as a crucial part of** CRAs. However, almost half of the methods (46 %) do not involve stakeholder participation. But some of these methods are online tools and rapid assessments, which aim to gain an overview of relevant climate risks at low cost and function more as pre-assessments than as baselines of decision-making processes. Nevertheless, empowering vulnerable groups is particularly important in addressing, minimising, and averting current and future L&D and shifting unequal power relations (GIZ, 2020).

The scope and objective of a CRA determines whether a method assesses **adaptation options and** takes **limits to adaptation** into account. Only 7 % consider adaptation limits explicitly and even then, these factors are often touched upon only briefly and not analysed systematically. This is partially due to the challenge of determining limits but it is also because of previously applied concepts and objectives.

Against a background of increasing climate-related risks, it is useful to develop methodologies that do not necessarily take limits to adaptation into account but do allow for the assessment of adaptation options and risk tolerance as critical dimensions in the context of losses and damages.

To sum up, the database compiled by the Global Programme on Risk Assessment and Management for Adaptation to Climate Change (Loss and Damage) represents the first extensive collection of CRA methods and, together with this scoping study, constitutes a helpful resource for practitioners and other stakeholders. It is the first in-depth analysis of methods available for conducting CRAs, and aims to provide decision-makers and practitioners with information that helps them successfully scope for a suitable method. For further investigation, practitioners can take a look at the methods first hand in order to review details relating to contexts, results, encountered challenges and further experiences; all sources are provided in the annex of this study. Further research might be useful for aligning the recommendations made by method developers with the needs and constraints encountered by users, and providing guidance for future applications.

Lastly, the study attempts to be useful for technical experts, especially in the context of developing countries which aim to conduct a risk assessment in a specific context or with a specific objective. This study, as well as the database, can enable such experts to make informed decisions and to use available resources in the most effective way.

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5. References

Adamo, S., Djalante, R., Chakrabarti, P., Renaud, F. G., Yalew, A. W., Stabinsky, D. and Zommers, Z. (2021). **Slow Onset Events related to Climate Change.** Current Opinion in Environmental Sustainability, 50, 1–8.

Adger, W.N., Dessai, S., Goulden, M. et al. (2009). **Are there social limits to adaptation to climate change?** Climatic Change 93, 335–354.

Aven, T. (2016). **Risk Assessment and Risk Management: Review of Recent Advances on Their Foundation.** European Journal of Operational Research, 253 (1), 1-13.

Berkhout, F., van den Hurk, B., Bessembinder, J., de Boer, J., Bregman, B. and van Drunen, M. (2014). **Framing climate uncertainty: socio-economic and climate scenarios in vulnerability and adaptation assessments.** Regional Environmental Change, 14(3), 879–893.

Carter, T.R., R.N. Jones, X. Lu, S. Bhadwal, C. Conde, L.O. Mearns, B.C. O'Neill, M.D.A. Rounsevell and M.B. Zurek. (2007). **New Assessment Methods and the Characterisation of Future Conditions.** In: M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, [Eds.]. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge, 133-171.

Church, J. A., Clark, P. U., Cazenave, A., Gregory, J. M., Jevrejeva, S., Levermann, A., Merrifield, M. A., Milne, G. A., Nerem, R. S., Nunn, P. D., Payne, A. J., Pfeffer, W. T., Stammer, D. & Unnikrishnan, A. S. (2013). **Sea Level Change.** In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge.

Climate ADAPT (2021). **The Adaptation Support Tool - Identifying adaptation options.** Available online at: https://climate-adapt.eea.europa.eu/knowledge/tools/adaptation-support-tool/step-3-0.

CRED, UNDRR, USAID & UCLouvain (2021). 2020. **The Non-COVID year in disasters.** Global trends and perspectives. Reliefweb. Available online at: https://reliefweb.int/report/world/2020-non-covid-year-disasters-global-trends-and-perspectives.

Dawson, R. J. (2015) **Handling Interdependencies in Climate Change Risk Assessment.** Climate 2015 (3), 1079–1096.

Dow, K., Berkhout, F., Preston, B. L., Klein, R. J., Midgley, G. & Shaw, M. R. (2013a). **Limits to adaptation.** Nature Climate Change, 3(4), 305–307.

European Environment Agency (EEA) (2017). **Climate change, impacts and vulnerability in Europe 2016.** An indicator-based report. European Environment Agency. Available online at: https://www.eea.europa.eu/publications/climate-change-impacts-and-vulnerability-2016.

Fankhauser, S., Dietz, S., and Gradwell, P. (2014). **Non-economic losses in the context of the UNFCCC work programme on loss and damage (policy paper).** London: London School of Economics – Centre for Climate Change Economics and Policy, Grantham Research Institute on Climate Change and the Environment.

Gardner, J., Dowd, A.-M.., Mason, C. & Ashworth, P. (2009): **A framework for stakeholder engagement on climate adaptation.** CSIRO Climate Adaptation Flagship Working Paper No.3. Available online at: http://www.csiro.au/resources/CAF-working-papers.html.

GIZ (2020): **Diving into the Gap: Gender dimensions of Climate Risk Management.** Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH Global Programme on Risk Assessment and Management for Adaptation to Climate Change (Loss and Damage), Bonn and Eschborn. Available online at: https://www.adaptation-community.net/wp-content/uploads/2020/11/GIZ_Gender_CRM_Study_FINAL.pdf.

GIZ (2021). **Assessment of climate-related risks.** A 6-step methodology. Available online at: https://www.adaptation-community.net/publications/a-6-step-methodology-to-assess-climate-related-risks/

GIZ and IIASA (2021). **Integrating slow onset processes into climate risk management: An urgent agenda to build resilience to climate change (forthcoming).**

Hughes, T., Barnes, M., Bellwood, D. et al. (2017). **Coral reefs in the Anthropocene.** Nature, 546, 82–90.

IPCC (2012). **Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation.** A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. Cambridge and New York. Available online at: https://www.ipcc.ch/report/managing-the-risks-of-extreme-events-and-disasters-to-advance-climate-change-adaptation/.

IPCC, 2014. Fifth Assessment Report, Jurgilevich, A., Räsänen, A., Groundstroem, F., Juhola, S. (2017): **A systematic review of dynamics in climate risk and vulnerability assessments.** Environmental Research Letters, 12(1), 3.

IPCC (2018). **Global Warming of 1.5°C.** An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. Available online at: https://www.ipcc.ch/sr15/.

IPCC (2019). **Special Report on the Ocean and Cryosphere in a Changing Climate** [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. Available online at: https://www.ipcc.ch/srocc/.

ISO (2021) ISO 14091:2021, **Adaptation to climate change – Guidelines on vulnerability, impacts and risk assessment.** International Organization for Standardization. Available online at: https://www.iso.org/obp/ui/#iso:std:iso:14091:ed-1:v1:en.

Lawrence, J., Blackett, P., Cradock-Henry, N.A. (2020). **Cascading climate change impacts and implications.** Climate Risk Management, 29. Available online at: https://www.sciencedirect.com/science/article/pii/S2212096320300243.

Lenton, T. M., Rockström, J., Gaffney, O., Rahmstorf, S., Richardson, K., Steffen, W., Schellnhuber, H. J. (2019). **Climate tipping points – too risky to bet against, Nature,** 575, 592-595.

Matias, D. M. (2017). **Slow onset climate change impacts: global trends and the role of science-policy partnerships (No. 24/2017).** German Development Institute. Discussion Paper. Available online at: https://www.die-gdi.de/en/discussion-paper/article/slow-onset-climate-change-impacts-global-trends-and-the-role-of-science-policy-partnerships/.

Pescaroli, G., Alexander, D. (2018). **Understanding Compound, Interconnected, Interacting, and Cascading Risks: A Holistic Framework.** Risk Analysis, 38 (11).

Sainz de Murieta, E., Galarraga, I. and Olazabal, M. (2021). **How well do climate adaptation policies align with risk-based approaches?** An assessment framework for cities. Cities, 109 (103018).

Schäfer, L. and Balogun, K. (2015). **Stocktaking of climate risk assessment approaches related to loss and damage.** UNUEHS Working Paper, No. 20. Bonn: United Nations University Institute of Environment and Human Security. Available online at: https://pdfs.semanticscholar.org/81c0/4e76c7271040a4d868a4ed65d4f329f76908.pdf.

Serdeczny, O., (2018). **Non-economic Loss and Damage and the Warsaw International Mechanism.** In: Mechler R., Bouwer L., Schinko T., Surminski S., Linnerooth-Bayer J. (eds). Loss and Damage from Climate Change. Climate Risk Management, Policy and Governance. Cham.

Serdeczny, O., Waters, E. & S. Chan, (2016a). **Non-economic Loss and Damage: Addressing the Forgotten Side of Climate Change Impacts.** Briefing Paper 3/2016. Available online: https://www.die-gdi.de/uploads/media/BP_3.2016_neu.pdf.

Serdeczny, O., Waters, E. and S. Chan, (2016b). **Non-Economic Loss and Damage in the Context of Climate Change.** Understanding the Challenges. Discussion Paper 3/ 2016. Available online at: https://www.die-gdi.de/uploads/media/DP_3.2016.pdf.

Swiss Re Institute (2021). Natural catastrophes in 2020: **Secondary perils in the spotlight, but don't forget primary-peril risks, sigma 1/2021.** Available online at: https://www.swissre.com/institute/research/sigma-research/sigma-2021-01.html.

UN (2019). **The Sustainable Development Goals Report.** Available online : https://unstats.un.org/sdgs/report/2019/.

UNFCCC Adaptation Committee (2020). **Synthesis report on how developing countries are addressing hazards, focusing on relevant lessons learned and good practices in the context of the recognition of adaptation efforts of developing countries (AC18).** Available online at: https://unfccc.int/sites/default/files/resource/ac18_5d_hazards.pdf.

UNFCCC Secretariat (2014). **Report of the Executive Committee of the Warsaw International Mechanism for Loss and Damage associated with Climate Change Impacts.** Held in Lima from 1 to 6 December 2014. Available online at: http://unfccc.int/resource/docs/2014/sb/eng/04.pdf.

UNFCCC (2013a): **Report of the conference of the parties on its eighteenth session, held in Doha from 26 November to 8 December 2012.** FCCC/CP/2012/8. Available online at: https://unfccc.int/resource/docs/2012/cop18/eng/08a01.pdf.

UNDRR (2022): **Technical Guidance on Comprehensive Risk Assessment and Planning in the Context of Climate Change.** United Nations Office for Disaster Risk Reduction. Available at: www.undrr.org

UNU-EHS (2017). **Risk Assessment in West Africa: A Handbook for Practitioners.** Part II: Scientific and Technical Background. Available online at: http://collections.unu.edu/eserv/UNU:6482/Handbook_Part2.pdf.

Van der Geest, K. and Warner, K. (2020) **Loss and damage in the IPCC Fifth Assessment Report (Working Group II):** a text-mining analysis, Climate Policy, 20 (6), 729-742.

Von Ritter Figueres, N. (2013). Loss and Damage, Women and Men. Applying a gender approach to the emerging loss and damage agenda. Available online at: https://www.preventionweb.net/publication/loss-and-damage-women-and-men-applying-gender-approach-emerging-loss-and-damage-agenda.

WMO (2021). **State of the Global Climate 2020.** World Meteorological Organization. Available online at: https://library.wmo.int/doc_num.php?explnum_id=10618.

Zscheischler, J., Martius, O., Westra, S. et al. (2020). **A typology of compound weather and climate events.** Nature Reviews Earth & Environment 1, 333–347.

Annex

ID	Name	Organisation/Author	Year of publishing	Link
2	Community-based Risk Screening Tool (CRiSTAL)	International Institute for Sustainable Development, International Union for Conservation of Nature, Helvetas, Stockholm Environment Institute	2012	https://www.iisd.org/sites/default/files/publications/cristal_user_manual_v5_2012.pdf
3	A climate change vulnerability assessment of California's terrestrial vegetation	Thorne, J.H. et al.	2016	https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=116208&inline
4	A coastal vulnerability assessment for planning climate resilient infrastructure	Brown, J.M. et al.	2018	https://www.sciencedirect.com/science/article/pii/S0964569118300693
5	A dynamic assessment tool for exploring and communicating vulnerability to floods and climate change	Giupponi, C. et al.	2013	https://www.sciencedirect.com/science/article/pii/S1364815212001594
9	Aware for Projects	Acclimatise	2011	http://www.acclimatise.uk.com/wp-content/uploads/2018/11/Aware_brochure_Nov2018.pdf
13	The UKCIP's Adaptation Wizard v 4.0.	UK Climate Impacts Programme, University of Oxford	2013	https://www.ukcip.org.uk/wizard/
14	Advancing national climate change risk assessment to deliver national adaptation plans (CCRA 2)	Warren, R.F. et al.	2018	https://royalsocietypublishing.org/doi/abs/10.1098/rsta.2017.0295
15	An integrated and transferable climate change vulnerability assessment for regional application	Holsten, A., Kropp, J.P.	2012	https://link.springer.com/article/10.1007/s11069-012-0147-z
17	Assessing climate change vulnerability in Alaska's fishing communities	Himes-Comell, A., Kasperski, S.	2015	https://www.sciencedirect.com/science/article/abs/pii/S016578361400277X
20	Assessment of climate change vulnerability at the local level: a case study on the Dniester river basin (Moldova)	Corobov, R. et al.	2013	http://downloads.hindawi.com/journals/tswj/2013/173794.pdf
27	Caribbean Risk Management Guidelines for Climate Change Adaptation Decision Making	Adapting to Climate Change in the Caribbean Project, Caribbean Community Secretariat, Canadian International Development Agency	2003	http://dms.caribbeanclimate.bz/M-Files/openfile.aspx?objtype=0&docid=2879

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28	Climate Change Adaptation and Natural Disasters Preparedness in the Coastal Cities of North Africa	Marseille Center for Mediterranean Integration, Worldbank, Egis Bceom International, IAU îdF (Paris Region Planning and Development Agency), BRGM (French geological survey)	2011	https://www.cmimarseille.org/sites/default/files/newsite/library/files/en//UD2_ClimChange_FinalReport_EN.pdf
30	CatSIM (Catastrophe Simulation)	International Institute for Applied Systems Analysis	2014	http://pure.iiasa.ac.at/id/eprint/11212/1/XO-14-004.pdf
32	CEDRA (Climate change and Environmental Degradation Risk and Adaptation assessment)	Tearfund	2009	https://www.preventionweb.net/files/11964_CEDRAClimatechangeandEnvironmentalD.pdf
33	Climate, Environment and Disaster Risk Reduction Integration Guidance – Light Rapid Screening	Swiss Agency for Development and Cooperation	2009	https://www.cedrig.org/sites/default/themes/cedrig/img/CEDRIG_Light_EN.pdf
36	Central Appalachians Forest Ecosystem Vulnerability Assessment and Synthesis: A Report from the Central Appalachians Climate Change Response Framework Project	US Forest Service	2015	https://www.fs.fed.us/nrs/pubs/gtr/gtr_nrs146.pdf
38	Climate and Disaster Risk Screening Tool for Agriculture Project	World Bank, International Bank of Reconstruction and Development-International Development Association	No information	https://climatescreeningtools.worldbank.org/agr/agriculture-welcome
39	Climate change and agricultural water resources: A vulnerability assessment of the Black Sea catchment	Bär, R. et al.	2015	https://www.sciencedirect.com/science/article/abs/pii/S1462901114000720
40	Climate Change Data and Risk Assessment Methodologies for the Caribbean	Inter-American Development Bank, Environmental Safeguards Unit	2016	https://publications.iadb.org/en/climate-change-data-and-risk-assessment-methodologies-caribbean
41	Climate Change Risk Assessment (CCRA1) for the Business, Industry and Services Sector	Adapting to Climate Change Programme, Department for Environment, Food and Rural Affairs, UK	2012	http://randd.defra.gov.uk/Default.aspx?Module=More&Location=None&ProjectID=15747
42	Climate change vulnerability assessment in Georgia	Binita, K.C. et al.	2015	https://www.sciencedirect.com/science/article/abs/pii/S0143622815000909
44	Climate Change Vulnerability Assessment of Aquatic and Terrestrial Ecosystems in the U.S. Forest Service Rocky Mountain Region	U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station	2018	https://www.fs.fed.us/rm/pubs_series/rmrs/gtr/rmrs_gtr376.pdf
45	Climate change vulnerability assessment of the urban forest in three Canadian cities	Ordóñez, C., Duniker, P.N.	2015	https://link.springer.com/article/10.1007/s10584-015-1394-2

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46	Climate Change Vulnerability Mapping for Southeast Asia	Economy and Environment Program for Southeast Asia, International Development Research Centre, Swedish International Development Cooperation Agency, Canadian International Development Agency	2009	https://www.preventionweb.net/files/7865_12324196651MappingReport1.pdf
47	Climate change vulnerability, adaptation and risk perceptions at farm level in Punjab, Pakistan	Abid, M. et al.	2016	https://www.sciencedirect.com/science/article/pii/S0048969715311086
48	Climate change, Justice and Vulnerability	Lindley, S. et al. (Joseph Rowntree Foundation)	2011	https://www.jrf.org.uk/report/climate-change-justice-and-vulnerability
51	Climate Proofing ADB Investment in the Transport Sector	Asian Development Bank	2014	https://www.adb.org/sites/default/files/publication/152434/climate-proofing-adb-investment-transport.pdf
53	Climate Risk Assessment under Uncertainty: An Application to Main European Coastal Cities	Abadie, L.M. et al.	2016	https://www.frontiersin.org/articles/10.3389/fmars.2016.00265/full
54	Climate Risk Screening and Management Tool for Strategy Design	USAID	2017	https://www.climatelinks.org/sites/default/files/Strategy Tool %2B Sector Annexes.pdf
55	Climate Safeguards System: Climate Screening and Adaptation Review & Evaluation Procedures Booklet	African Development Bank Group	2012	https://www.afdb.org/fileadmin/uploads/afdb/Documents/Generic-Documents/CSS%20Basics-En_def.pdf
57	Climate Vulnerability and Capacity Analysis Handbook	CARE International	2019	https://careclimatechange.org/cvca/
60	Communities and change in the Anthropocene: understanding social-ecological vulnerability and planning adaptations to multiple interacting exposures	Bennett, N.J. et al.	2015	https://link.springer.com/article/10.1007/s10113-015-0839-5
66	Decision-making for climate resilient livelihoods and risk reduction: A participatory scenario planning approach	CARE International	2012	https://care.org/wp-content/uploads/2020/05/CC-2011-ALP_PSP_Brief.pdf
68	Decision-Scaling: A Decision Framework for DoD Climate Risk Assessment and Adaptation Planning (climate stress test)	University of Massachusetts, U.S. Army Engineer Research and Development Center, National Center for Atmospheric Research	2016	https://apps.dtic.mil/sti/pdfs/AD1024405.pdf
69	Development and validation of risk profiles of West African rural communities facing multiple natural hazards	Asare-Kyei, D. et al.	2017	https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0171921#sec001
70	Disaster Resilience Scorecard for Cities (preliminary and detailed assessment)	United Nations Office for Disaster Risk Reduction	2017	https://www.unisdr.org/campaign/resilientcities/toolkit/article/disaster-resilience-scorecard-for-cities

ID	Name	Organisation/Author	Year of publishing	Link
72	Drought hazard assessment in the context of climate change for South Korea	Nam, W. et al.	2015	https://www.sciencedirect.com/science/article/abs/pii/S0378377415300433
73	Economic Evaluation of Climate Change Adaptation Projects	World Bank	2010	https://openknowledge.worldbank.org/bitstream/handle/10986/27752/554700WP0D-1CC010Box349454B01PUBLIC1.pdf?sequence=1&isAllowed=y
74/ 75	Shaping Climate-Resilient Development: a framework for decision-making	Economics of Climate Adaptation	2009	https://media.swissre.com/documents/rethinking_shaping_climate_resilent_development_en.pdf
76	Ensemble flood risk assessment in Europe under high end climate scenarios	Alfieri, L. et al.	2015	https://www.sciencedirect.com/science/article/pii/S0959378015300406
78	Estimating economic damage from climate change in the United States	Hsiang, S. et al.	2017	https://science.sciencemag.org/content/356/6345/1362/tab-pdf
81	Flood risk and adaptation strategies under climate change and urban expansion: A probabilistic analysis using global data	Muis, S. et al.	2015	https://www.sciencedirect.com/science/article/pii/S0048969715305714
83	GAR Atlas – Global Risk Mode	United Nations Office for Disaster Risk Reduction	2017	https://www.preventionweb.net/files/53086_garatlaslr2.pdf
85	Climate Risks: Impact on natural hazards insurance between now and 2040	Fédération Française de l'Assurance (French Insurance Federation)	2016	https://www.ffa-assurance.fr/en/publications/climate-issues/climate-risks-impact-natural-hazards-insurance-between-now-and-2040
86	Hands-on Energy Adaptation Toolkit	The Energy Sector Management Assistance Program, World Bank	2010	https://www.esmap.org/sites/default/files/esmap-files/HEAT-Brochure.pdf
87	Hazus	Federal Emergency Management Agency, US	2017 (current edition)	https://www.fema.gov/hazus-software
88	Protecting Health from Climate Change – Vulnerability and Adaptation Assessment	World Health Organization	2013	https://apps.who.int/iris/bitstream/handle/10665/104200/9789241564687_eng.pdf?sequence=1&isAllowed=y
90	Hydrology Study and Climate Change Vulnerability Assessment to inform Management Planning of Khijadiya Wildlife Sanctuary in Gujarat	Indo-German Biodiversity Programme, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)	2017	https://snrd-asia.org/wp-content/uploads/2018/04/CMPA-Technical-Report-Series-No.-46.-Hydrology-Study-and-Climate-Change-Vulnerability-Assessment-to-inform-Management-Planning-of-Khijadiya-Wildlife-Sanctuary-in-Gujarat.pdf
91	Improving the interpretability of climate landscape metrics: An ecological risk analysis of Japan's Marine Protected Areas	Molinos, J.G. et al.	2017	https://onlinelibrary.wiley.com/doi/abs/10.1111/gcb.13665

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92	InaSAFE V5.0	Indonesian Government, Australian Government, World Bank, Global Facility for Disaster Reduction and Recovery	2017	http://manual.inasafe.org/en/index.html#overview
94	Incorporating Potential Severity into Vulnerability Assessment of Water Supply Systems under Climate Change Conditions	Goharian, E. et al.	2016	https://ascelibrary.org/doi/full/10.1061/%28ASCE%29WR.1943-5452.0000579
100	Impact and Vulnerability Analysis of Vital Infrastructures and Built-up Areas	Fraunhofer Institute for Intelligent Analysis and Information Systems	2018	http://www.resin-cities.eu/fileadmin/user_upload/Resources/Design_IVAVIA/IVAVIA_Guideline_v3_final__web.compressed.pdf
101	Livelihood vulnerability approach to assessing climate change impacts on mixed agro-livestock smallholders around the Gandaki River Basin in Nepal	Panthi, J. et al.	2016	https://link.springer.com/article/10.1007/s10113-015-0833-y
102	Longitudinal assessment of climate vulnerability: a case study from the Canadian Arctic	Archer, L. et al.	2017	https://link.springer.com/article/10.1007/s11625-016-0401-5
103	Damage, Loss and Needs Assessment: Guidance Notes (DaLA Method)	International Bank of Reconstruction and Development, World Bank	2010	https://reliefweb.int/sites/reliefweb.int/files/resources/TTL%20Vol1_WEB.pdf
106	Mali Climate Vulnerability Mapping	USAID	2014	https://www.usaid.gov/sites/default/files/documents/1860/MALI%20CLIMATE%20VULNERABILITY%20MAPPING.pdf
109	Climate Risk Screening of Development Portfolios and Programmes	Institute of Development Studies, Department for International Development, UK	2008	https://opendocs.ids.ac.uk/opendocs/bitstream/handle/123456789/8190/IDSB_39_4_10.1111-j.1759-5436.2008.tb00481.x.pdf?sequence=1
112	Power-generation system vulnerability and adaptation to changes in climate and water resources	Van Vliet, M. et al.	2016	https://www.nature.com/articles/nclimate2903
113	Profiling urban vulnerabilities to climate change: An indicator-based vulnerability assessment for European cities	Tapia, C. et al.	2017	https://www.sciencedirect.com/science/article/abs/pii/S1470160X17301036
114	Public Health System Resilience – Addendum Scorecard	United Nations Office for Disaster Risk Reduction	2018	https://www.unisdr.org/campaign/resilientcities/assets/toolkit/documents/Disaster%20Resilience%20Scorecard_Public%20Health%20Addendum%20Ver1%20Final_July%202018.pdf
115	Quantifying transnational climate impact exposure: New perspectives on the global distribution of climate risk	Hedlund, J. et al.	2018	https://www.sciencedirect.com/science/article/abs/pii/S0959378017312505

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116	Quantitative Assessment of Climate Change Vulnerability of Irrigation Demands in Mediterranean Europe	Garrote, L. et al	2015	https://link.springer.com/article/10.1007/s11269-014-0736-6
117	Quick Risk Estimation	United Nations Office for Disaster Risk Reduction, Deloitte	No information	https://www.unisdr.org/campaign/resilientcities/toolkit/article/quick-risk-estimation-qre
118	Ranking Port Cities with High Exposure and Vulnerability to Climate Extremes: Exposure Estimates	Organisation for Economic Co-operation and Development	2008	https://www.oecd-ilibrary.org/docserver/011766488208.pdf?expires=1569838422&id=id&accname=guest&checksum=A370DCAE5BF63D555C8D173DCA2D16C7
120	Risk assessment of precipitation and the tourism climate index	Olya, H., Alipour, H.	2015	https://www.sciencedirect.com/science/article/abs/pii/S0261517715000138
121	Risk Management Software Suite	AIR Worldwide	2017 (founded in 1987)	https://www.air-worldwide.com/SiteAssets/Publications/Brochures/documents/about-catastrophe-models
122	RiskScape software	Institute of Geological and Nuclear Science, National Institute of Water and Atmospheric Research, Earthquake Commission	2007	https://wiki.riskscape.org.nz/index.php/Overview
123	RMS(one) platform	Risk Management Solution Inc. (founded at Stanford University)	2014	https://forms2.rms.com/rs/729-DJX-565/images/rms_corporate_brochure.pdf
125	Future risk assessment by estimating historical heatwave trends with projected heat accumulation using SimCLIM climate model in Pakistan	Nasim, W. et al.	2018	https://www.sciencedirect.com/science/article/pii/S0169809517310992
127	Socio-climatic hotspots in Brazil	Torres, R. et al.	2012	https://link.springer.com/article/10.1007/s10584-012-0461-1
128	CAPRA (Probabilistic Risk Assessment) Platform	Universidad de los Andes, Center for Coordination of Natural Disaster Prevention in Central America, UNISDR, the Inter-American Development Bank, World Bank	2008	https://ecapra.org/
129	Spatial approaches for assessing vulnerability and consequences in climate change assessments	Preston, B. et al.	2007	https://www.researchgate.net/publication/253423481_Spatial_Approaches_for_Assessing_Vulnerability_and_Consequences_in_Climate_Change_Assessments
130	Spatial assessment of climate change vulnerability at city scale: A study in Bangalore, India	Kumar, P. et al.	2016	https://www.sciencedirect.com/science/article/abs/pii/S0264837716301363

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132	The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation	Brooks, N. et al.	2005	https://www.sciencedirect.com/science/article/abs/pii/S0959378004000913
134	The impacts of climate change on river flood risk at the global scale	Arnell, N., Gosling, S.	2014	https://link.springer.com/content/pdf/ 10.1007%2Fs10584-014-1084-5.pdf
135	The rains are disappointing us: dynamic vulnerability and adaptation to multiple stressors in the Afram Plains, Ghana	Westerhoff, L., Smit, B.	2008	https://link.springer.com/article/10.1007/s11027-008-9166-1
137	ThinkHazard!	World Bank, Global Facility for Disaster Reduction and Recovery	2017 (2nd version)	https://gfdrr.github.io/thinkhazardmethods/
138	Toolkit for Integrating Climate Change Adaptation into Development Projects	CARE International, Institute for Sustainable Development	2010	https://careclimatechange.org/wp-content/uploads/2019/06/CARE_Integration_Toolkit.pdf
142	Using climate model simulations to assess the current climate risk to maize production	Kent, C. et al.	2017	https://iopscience.iop.org/article/10.1088/1748-9326/aa6cb9/pdf
143	Vulnerability assessment of mangroves to climate change and sea-level rise impacts	Ellison, J.	2014	https://link.springer.com/article/10.1007/s11273-014-9397-8
145	Climate Change Atlas	United States Department of Agriculture, Forest Service	No information	https://www.fs.fed.us/nrs/atlas/models/
146	City Resilience Action Planning Tool	Disaster Risk Management, Sustainability and Urban Resilience	2018	http://dimsur.org/3-cityrap-tool/
147	Climate Adaptation in Rural Development Assessment Tool	International Fund for Agricultural Development	2019	https://www.ifad.org/en/web/knowledge/publication/asset/41085709
148	Notre Dame Global Adaptation Index	University of Notre Dame	2017	https://gain.nd.edu/our-work/country-index/
149	Methods for assessing coastal vulnerability to climate change	European Topic Centre on Climate Change Impacts, Vulnerability and Adaptation	2011	https://www.eionet.europa.eu/etcs/etc-cca/products/etc-cca-reports/1
151	Adapting to A Changing Climate: Guide to Local Early Action Planning and Management Planning	Gombos, M. et al.	2013	https://www.weadapt.org/sites/weadapt.org/files/legacy-new/knowledge-base/files/1344/5342746cc12ea-adapting-to-a-changing-climate-final-dec.-2013.pdf
152	Climagine	Plan Bleu	No information	https://climate-adapt.eea.europa.eu/metadata/case-studies/integrating-climate-change-adaptation-into-coastal-planning-in-sibenik-knin-county-croatia

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153	Climate Risk Assessment Guide – Central Asia	Climate and Development Knowledge Network	2013	https://cdkn.org/resource/climate-risk-assessment-guide-central-asia/?loclang=en_gb
154	Mozambique – Integrated Context Analysis	World Food Programme	2017	https://geonode.wfp.org/maps/8177
156	Soil & Water Assessment Tool	Texas A&M University	No information	https://swat.tamu.edu/
157	Natural Disaster Mitigation in Drinking Water and Sewerage Systems – Guidelines for Vulnerability Analysis	Pan American Health Organization	1998	https://ec.europa.eu/echo/files/evaluation/watsan2005/annex_files/PAHO/PAHO1%20-%20Nat%20mit%20in%20wat%20and%20sewage%20-%20VA.pdf
158	Vulnerability Sourcebook and Risk Supplement	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Eurac Research	2017	https://www.adaptationcommunity.net/news/risk-supplement-vulnerability-sourcebook/
159	The Climate and Disaster Risk Screening Tools	World Bank	2015	https://climatescreeningtools.worldbank.org/sites/default/files/methodology-docs/methodology-national-tool.pdf
160	Rapid Analysis and Spatialisation Of Risk	CIMA Research Foundation	2016	http://www.rasor-project.eu/
161	Climate, Environment and Disaster Risk Reduction Integration Guidance – Strategic	Swiss Agency for Development Cooperation	2009	https://www.cedrig.org/sites/default/themes/cedrig/img/CEDRIG_Strategic_EN.pdf
162	Climate, Environment and Disaster Risk Reduction Integration Guidance – Operational	Swiss Agency for Development Cooperation	2009	https://www.cedrig.org/sites/default/themes/cedrig/img/CEDRIG_Operational_EN.pdf
163	Climate Risk Analysis for Identifying and Weighing Adaptation Strategies in Ghana's Agricultural Sector	Potsdam Institute for Climate Impact Research	2019	https://www.adaptation-community.net/wp-content/uploads/2019/12/Climate-Risk-Analysis-for-Identifying-and-Weighing-Adaptation-Strategies-in-Ghanas-Agricultural-Sector-komprimiert.pdf
165	Temperate	Local Governments for Sustainability USA, Azavea Inc.	2016	https://temperate.io/methodology
166	INFORM (Index for Risk Management)	Marin-Ferrer, M. et al.	2017	https://drmkc.jrc.ec.europa.eu/inform-index/Portals/0/InfoRM/2017/INFORM%20Concept%20and%20Methodology%20Version%202017%20Pdf%20FINAL.pdf?ver=2017-07-11-104935-783
167	Climate and Disaster Exposure Database	United Nations Development Programme, Australian Government, Philippines Climate Change Commission	2014	https://www.preventionweb.net/files/38314_38314bookletjune271.pdf

ID	Name	Organisation/Author	Year of publishing	Link
170	Caliza Version 3.0	Climate Risk Analysis	2014	https://www.climate-risk-analysis.com/software/caliza/caliza-manual.pdf
175	Baltic Climate Toolkit	Academy for Spatial Research and Planning, Environmental Projects Ltd., Centre for Climate Science and Policy Research, Regional Council of Central Finland, Stockholm Environment Institute Tallinn Centre	2014	http://www.balticclimate.org/uploads/files/BalticClimate_Guideline+Report_Support-for-Impacts-and-Vulnerability-Assessment_main-part_and_Appendices_A-B.pdf?ALPHA_SESSION_ID=b7f3828adb0ea95a1ab73b3c821b248c
176	Hydrological impacts of climate change on flood probability in small urban catchments and possibilities of flood risk mitigation	Hellmers, S.	2010	https://tore.tuhh.de/bitstream/11420/1697/4/Wasserbauschrift_Band13_e_TUB.pdf
180	Climate Resilience Evaluation and Awareness Tool Version 3.0	United States Environmental Protection Agency	2016	https://web.archive.org/web/20200319094315/https://www.epa.gov/sites/production/files/2016-05/documents/creat_3_0_methodology_guide_may_2016.pdf
181	Generic framework for meso-scale assessment of climate change hazards in coastal environments	Rosendahl Appelquist, L.	2013	https://link.springer.com/article/10.1007/s11852-012-0218-z
182	District Climate and Energy Plans Preparation Guideline	Alternative Energy Promotion Centre, Stiftung Neue Verantwortung, UK Aid	2011	https://snv.org/cms/sites/default/files/explore/download/dcep.guidelines.pdf
183	Global Information and Early Warning System on Food and Agriculture	Food and Agriculture Organization of the United Nations	2012	http://www.fao.org/giews/earthobservation/asis/index_2.jsp?lang=en
184	Guidelines for Climate Proofing Investment in Agriculture, Rural Development, and Food Security	Asian Development Bank	2012	https://www.adb.org/sites/default/files/institutional-document/33720/files/guidelines-climate-proofing-investment.pdf
185	Guidelines for Climate Proofing Investment in the Energy Sector	Asian Development Bank	2013	https://www.adb.org/sites/default/files/institutional-document/33896/files/guidelines-climate-proofing-investment-energy-sector.pdf
188	A GIS-based vulnerability assessment of coastal natural hazards, state of Pará, Brazil (Composite Vulnerability Index)	Szlafsztein, C., Sterr, H.	2007	https://www.researchgate.net/publication/226839274_A_GIS-based_vulnerability_assessment_of_coastal_natural_hazards_state_of_Para_Brazil
189	A multi-scale coastal vulnerability index: A tool for coastal managers?	McLaughlin, S., Cooper, A.	2010	https://www.researchgate.net/publication/232958368_A_Multi-scale_coastal_vulnerability_index_A_tool_for_coastal_managers

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190	EUROSION project (Living with coastal erosion in Europe: Sediment and Space for Sustainability)	Directorate General Environment European Commission	2004	http://www.eurosion.org/reports-online/part3.pdf
193	Adapting to Climate Change – Canada's First National Engineering Vulnerability Assessment of Public Infrastructure	Canadian Council of Professional Engineers	2008	https://pievc.ca/wp-content/uploads/2020/12/adapting_to_climate_change_report_final.pdf
196	Risk and Readiness for Insurance Solutions Assessment Tool' (InsuRisk Assessment Tool)	United Nations University – Institute for Environment and Human Security	2018	https://www.preventionweb.net/news/insurisk-assessment-tool
198	Opportunity Mapping tool	United Nations Environment Programme and UNEP Global Resource Information Database – Geneva	2020	https://pedrr.org/methodology/
199	Risk and Vulnerability Assessment Methodology Development Project	United Nations Environment Programme , The Planning Institute of Jamaica	2010	https://wedocs.unep.org/handle/20.500.11822/8879
200	Disaster and Climate Change Risk Assessment Methodology for IDB Projects: A Technical Reference Document for IDB Project Teams	Inter-American Development Bank	2019	https://publications.iadb.org/en/disaster-and-climate-change-risk-assessment-methodology-idb-projects-technical-reference-document
201	Climate Risk Informed Decision Analysis: Collaborative Water Resources Planning for an Uncertain Future	United Nations Educational, Scientific and Cultural Organization, International Center for Integrated Water Resources Management	2018	https://en.unesco.org/crida
203	Building the Resilience of WSS Utilities to Climate Change and Other Threats: A Road Map	International Bank for Reconstruction and Development, World Bank	2018	https://www.semanticscholar.org/paper/Building-the-Resilience-of-WSS-Utilities-to-Climate-Bonzanigo-Rozenberg/398cb1c4a4a9caca1b94f813c664ac7297338230?p2df
205	Handbook for assessing loss and damage in vulnerable communities	Van der Geest, K., Schindler, M.	2017	http://collections.unu.edu/eserv/UNU:6032/Online_No_21_Handbook_180430.pdf

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