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Economics of Climate Adaptation (ECA) - Guidebook for Practitioners

A Climate Risk Assessment Approach Supporting Climate Adaptation Investments

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Abstract

There is a growing consensus that climate change impacts should be considered in the development of adaptation strategies by decision makers at all levels. This requires identifying cost-efficient adaptation measures, resulting from a structured risk management approach. The Economics of Climate Adaptation (ECA) approach offers a unique contribution, which combines risk assessment, adaptation measures and risk transfer. Its results allow a flexible identification of cost-effective climate adaptation measures for a variety of projects and sectors.

Recently, KfW decided to implement two pilot studies in Bangladesh and El Salvador using the ECA methodology. The main objectives were to support decision makers in developing their adaptation strategy and to develop a climate adaptation measures investment portfolio. Following the evaluation of these two pilot studies, the need to develop a document for practitioners has arisen.

The **ECA Guidebook** aims at filling this gap while complementing the already existing ECA documentation and tools. This Guidebook is tailored for practitioners of developing projects, which promote resilience in developing countries. It aims also at 1) exploring whether ECA methodology is appropriate to the project's goals and 2) offering step-by-step guidance while using the ECA methodology.

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Introduction and scope

Promoting resilience through the assessment of weather and climate risks and the integration of appropriate climate change adaptation (CCA) measures are essential steps in project development. In the context of international financial and technical cooperation, specific CCA measures are ensuring investments that are more sustainable, while promoting assets and economic activities that are more resilient to the impacts and consequences of current and projected future climatic conditions.

Considering climate change adaptation early on in planning and policymaking sets a clear context for interventions at project level. Climate change impacts should be taken into account in the development of strategies, investment and national adaptation plans (NAPs) by governments, local authorities, communities and businesses. This requires identifying cost-efficient CCA measures, in a transparent and structured manner, to identify which future investments would be sustainable and what residual risk can be covered by risk transfer solutions[1]. Such an approach calls for a comprehensive climate risk management system in order to ensure a climate-resilient development. A plethora of approaches has already been designed to respond to the complexity and the uncertainty of climate change related projects. With regards to the implementation of climate change adaptation strategies, they range from climate vulnerability assessments, risk assessments, economic and/or sustainability impact assessments to decision-making support tools. Among these, none has been fully integrating processes from risk assessment to a feasibility of CCA measures.

The Economics of Climate Adaptation (ECA) approach bridges this gap and offers a unique approach towards the flexible identification of cost-effective CCA measures for a variety of projects and sectors. It addresses in particular the following questions:

1) What is the potential climate-related damage[2] over the coming decades?

1 Please refer to KfW publication of September 2016 "Economics of Adaptation (ECA) in Development Cooperation: A Climate Risk Assessment Approach" https://www.kfw-entwicklungsbank.de/PDF/Download-Center/Materialien/2016_No5_Economics-of-Adaptation_EN.pdf

2 It is essential to differentiate between loss and damage (for definition, please see Glossary in this Guidebook). Since most adaptation measures as dealt with by the ECA Methodology are risk management ones, we shall refer to 'damage' wherever possible in the ECA context

2) How much of that damage can be averted, using what type of CCA measures?

3) What investments will be required to fund those measures - and will the benefits of these investments outweigh the costs?

ECA offers a systematic and transparent approach that fosters trust and initiates in-depth inter-sectoral stakeholder discussions. The methodology can be flexibly applied from the national down to local level to different sectors and different hazards[3]. It also gives guidance on what aspects to focus on during a feasibility study. It provides key information for programme-based approaches, insurance approaches and has potential to support National Adaption Plans' (NAPs) development.

Recently, KfW decided to implement two pilot studies in Bangladesh and El Salvador using the ECA methodology. The main objectives were to support decision makers in developing their adaptation strategy and to develop a CCA measures investment portfolio. Based on the evaluation of these two pilot studies, the need to develop a document for practitioners has arisen. Consequently, the **ECA Guidebook** is designed for practitioners of developing projects that promote resilience in developing countries. It also aims at supporting their efforts in deciding whether the ECA Methodology is appropriate to their goals and while using the ECA methodology, to offer guidance in their endeavours. More specifically, this **ECA Guidebook** is tailored to two main groups: 1) Donors, with Project Managers and Technical experts looking into the potential of ECA for new projects and 2) Partners and Implementing Experts such as technical experts or consultants using the ECA Methodology. As described in more details in sections "*how to use the ECA Guidebook*" (p.14), the **ECA Guidebook** completes already existing tools, manuals and case studies documenting the ECA Approach.

3 ECA has been applied in more than 20 case studies (see www.swissre.com/eca) and the methodology is described in "shaping climate resilient development – a framework for decision making" available at http://media.swissre.com/documents/rethinking_shaping_climate_resilent_development_en.pdf)

Why use the ECA Methodology?

This opening section aims at helping practitioners, and in particular project managers and technical experts developing new projects in deciding if the ECA methodology is relevant for their objectives. We will describe when (and to what purposes) the ECA methodology can be applied, and we will present the minimum requirements for implementing an ECA Assessment. Finally, we will discuss the target audience of this guidebook. So, if you decide to carry out a CCA Assessment, you will have a broader perspective of the associated workload, timespan of the assessment, costs and skills needed to build up your team.

When should the ECA Assessment be applied?

The ECA methodology, and therefore the **ECA Guidebook,** shall be of special interest for practitioners looking into the following aspects of adaptation planning:

- ✓ **Estimating actual and future risks** related to natural catastrophes and climate change in a particular region (scale can vary greatly from local to national)
- ✓ Applying a **multi-hazard approach**
- ✓ **Estimating actual and future costs** due to economic development, climate variability and climate change
- ✓ Identifying and **ranking potential CCA measures**
- ✓ Defining potential **CCA measures for investment** purposes
- ✓ Enabling **multi-stakeholder collaboration** and ensure local involvement in order to create a long-term adaptation strategy
- ✓ Structuring a **transparent approach** towards climate adaptation.

If these aspects are in line with your objectives, the ECA Methodology might be of interest to you. In the next section, we will explore several criteria to determine whether the ECA Methodology is relevant to your project. It is also important to note that the **ECA Methodology is open-source** and consequently free of charge.

Is the ECA methodology relevant for your project?

Project duration, budget, skills for team set-up, and the resolution (i.e. the level of detail required for your study) are the main criteria influencing the decision to undertake a CCA Assessment using the ECA methodology. As depicted in Figure 1, these criteria are interlinked and each of them should be considered when making your decision. The basic skill set required for a CCA Assessment using the ECA Methodology does not vary significantly with regard to the duration, budget and level of detail (resolution) of the CCA Assessment. Indeed, whereas the size of your team might increase, the skills needed to achieve each element of the ECA Methodology shall remain constant. We will review in details what skills are needed later in this section.

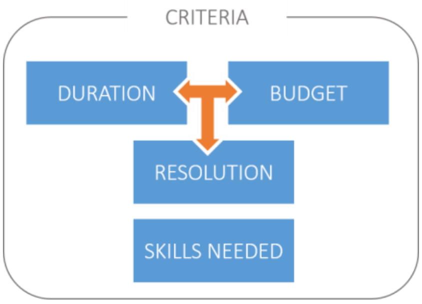


Figure 1 Criteria influencing the undertaking of a CCA Assessment using the ECA methodology

First, we will study the influence of project duration and the resolution of your assessment on the budget required. In most cases, while developing a new project for CCA Assessment, you will have a clear idea about your budget, the time span available to reach your objectives as well as what level of resolution will be required to achieve your objectives. The decision matrix in Figure 2 offers an overview of the interactions between these three criteria. For instance, if you have a short time span available (2 months) and only a limited budget (i.e. for instance €150K[4]), the ECA methodology is suited for assessment at country level, regional level, urban and sub-urban level. However, a higher level of resolution (at local level or considering each building, agricultural field or other assets) is not recommended. If your objective is to develop CCA measures at building level, using the ECA methodology will require a larger budget (between €450K and €600K), a larger team, and longer project duration. Please note that these values are indicative only, and are only meant to give you an order of magnitude in order to facilitate your decision making. As clearly presented in Figure 2, budgets vary largely according to the level of resolution targeted in the study. Best practice is to seek a good trade-off. For instance, to see the potential of certain CCA measures in a region, you might want to start a short assessment with a lower resolution to then focus later on higher resolution in selected areas (iterative approach) than can be up-scaled. This iterative approach has many advantages, as it helps in identifying what areas are most at risk, what categories of assets are most vulnerable and what measures are

[4] *All monetary numbers are given as indicative value only. For values in Euro, a standard rate of 1.2 can be used for USD. This conversion rate is indicative only.*

most effective. In a second stage, building on these outputs, a more detailed CCA Assessment can be carried out in a well-defined region because the ECA methodology and its results are easily scalable from the national level to higher level of resolutions.

PROJECT DURATION

RESOLUTION — € = €150 K	LONG (6-10 months)	MEDIUM (3-6 months)	SHORT (1-2 months)
LOCAL LEVEL	€€€€	€€€	*na*
INTERMEDIATE	€€€	€€	€€
URBAN LEVEL	€€€	€€	€
COUNTY LEVEL	€€	€	€
NATIONAL LEVEL	€€	€	€

Figure 2 Project Decision Matrix for using the ECA Methodology and the ***ECA Guidebook*** *(values are indicative only)*

In Figure 3, we showcase typical types of projects that can be addressed using the ECA methodology with the **ECA Guidebook**. The project duration, budget and resolution are represented for different types of CCA Assessments. As shown in the decision matrix in Figure 2, the duration of the project and the level of detail chosen (or needed) for the purpose of the study shall influence your budget, and will therefore play a role in your decision whether you undertake an ECA-CCA Assessment or not. We have chosen five (5) “typical” projects, which might be of interest:

1. **Long-term investment planning**: In this type of project, you are interested in extending your investment portfolio in a country. Depending on the volume of the investment, a detailed study for CCA measures might be meaningful.
2. **NAPs development**: numerous governments are looking into developing their National Adaptation Plans (NAPs) and your project aims at assisting them in their decision-making process. In this case, the level of detail you will go into depends on the volume of your project and the prospect of an investment in CCA measures.
3. **Risk transfer**: in some cases, you might be interested in completing already existing CCA measures and looking into potential for risk transfer for low-frequency hazards.
4. **Strategic planning**: prospective assessment in order to determine what measures are best adapted to certain conditions in a well determined

area. The level of detail is moderate but goes beyond the country level. Ideally, after such a project a more detailed assessment is carried out if deemed meaningful.

5. **Pre-feasibility**: prospective CCA Assessment in order to identify efficient measures and areas most at risk. This kind of project is ideally embedded in an iterative assessment prospect if deemed meaningful.

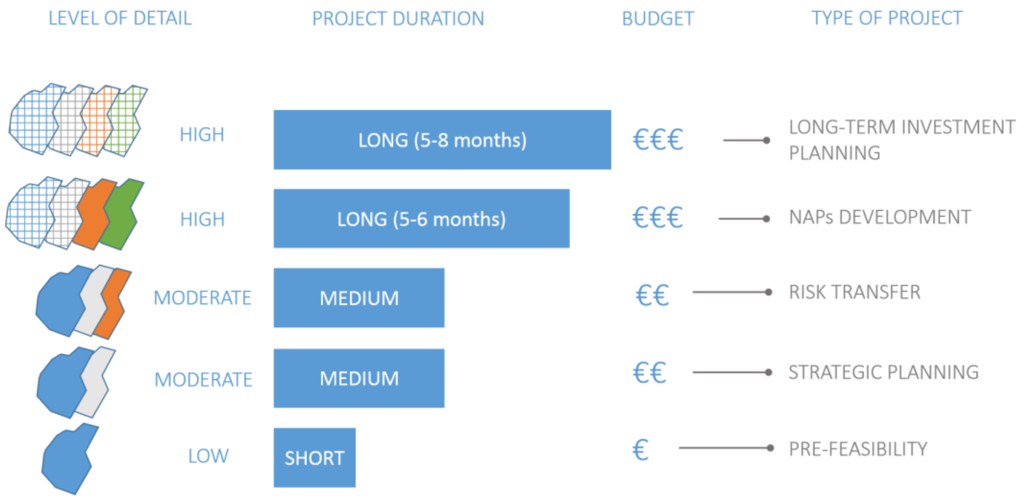


Figure 3 Project characteristics according to project type, including indicative budget

What professional skills are necessary?

Users of the **ECA Guidebook** will ideally already have experience in climate variability and climate change and adaptation assessment. Advanced knowledge of the GIS software package and a good command of MATLAB®/Octave is an advantage to handle certain tools presented in this document. However, advanced scientific knowledge and senior expertise in climate adaptation in developing and conducting CCA assessment is not a prerequisite. Users with a basic understanding of the concept and methods of vulnerability should find the **ECA Guidebook** very helpful.

Table 1 provides an overview of what skills are required for an ECA assessment. Please note that not all members of the team should be proficient in all skills to ensure a successful output of your study. These skills are typically represented by the entire project team, consisting of roughly 5 to 15 experts.

Table 1 Level of skills needed by field of expertise

Type of expertise needed	Level of skill needed *(+ basic, ++ medium, +++advanced)*
Multidisciplinary skills	+++
Presentation skills	+++
Workshop/Meeting organisation	+++
Economics	++
GIS	++
Hazard Modelling	++
Intercultural skills	++
MATLAB®/Octave	++
Sector-specific knowledge	++
Socio-economic methods	++
Climate variability and climate change	++
Adaptation	+
Data Management	+
Engineering	+
Finance	+
Insurance / risk transfer	+

Who is the ECA Guidebook's target audience?

The **ECA Guidebook** is of interest to institutions and organisations engaged in climate variability and climate change and sustainable development activities. It is specifically designed to accompany CCA Assessments using the open-source ECA methodology. It is targeted at two main groups:

1) **Donors**: Development cooperation project managers and technical experts in order to decide if the ECA Methodology is relevant for their project. This is intended to assist them in developing Terms of References (ToR) and design their project in more details.
2) **Project partner and implementation team**: consultants, practitioners, technical experts involved in the project as well as project partners and decision makers. It aims at supporting their efforts towards the development and CCA assessment and planning, while using the ECA methodology.

How do you use the ECA Guidebook?

The **ECA Guidebook** shall allow a project team (partner organisations, consultants etc.) to carry out, with limited assistance, an ECA Assessment study, from risk assessment to feasibility study of CCA measures. The **ECA Guidebook** shall also provide technical and practical information about every step necessary in the achievement of a CCA Assessment using the ECA methodology and its associated tools (i.e. climada[5]).

How was the ECA Guidebook developed?

In 2013, KfW started to implement two pilot studies in Bangladesh (Barisal) and El Salvador (San Salvador) testing the ECA approach to prepare CCA measures in urban areas. KfW had identified the ECA methodology as a valuable approach to (1) provide local decision makers with the fact base to develop their own adaptation strategy, (2) foster the development of KfW's CCA portfolio, including more loan and programme-based finance as well as climate risk insurance approaches, not least in the context of (3) the future challenge of National Adaptation Plans (NAPs), and to (4) learn for its climate screening procedure, too[6].

Following these two field studies, KfW identified the potential and limitations of the ECA methodology in developing countries. Based on this evaluation, KfW recognized the need to develop a document offering a hands-on approach to the methodology, accompanying the user step by step through the ECA methodology process.

How should the ECA Guidebook be used?

The **ECA Guidebook** is designed to accompany CCA Assessment using the **open-source** ECA methodology and its associated tools (climada[7], also **open-source**). The **ECA Guidebook** is particularly helpful in cases which require an integrated approach towards the development and planning of specific CCA measures.

[5] *climada is a tool dedicated to the ECA Methodology. It assists the users in many ways and is presented later in this Guidebook.*
[6] *https://www.kfw-entwicklungsbank.de/Internationale-Finanzierung/KfW-Entwicklungsbank/Wer-wir-sind/News/News-Details_232192.html*
[7] *https://github.com/davidnbresch/climada*

Thanks to its flexibility, it is applicable to a wide range of topics and the **ECA Guidebook** is not limited to one sector or spatial level and can be used in various contexts.

The **ECA Guidebook** is particularly helpful in guiding practitioners through the ECA associated tool climada. This tool will be presented further in the following chapters. The **ECA Guidebook** explains in detail, and using examples from field studies, how the tool climada is used, calibrated and validated for the needs of your study. Hence, in addition to the more technical manual of climada (presented in the next chapter), the **ECA Guidebook** offers guidance on how to fully integrate this tool in your CCA Assessment.

The **ECA Guidebook** is part of several elements developed around the ECA Approach (cf. Figure 4): (i) The **ECA Methodology**[8], (ii) the ECA implementation tools grouped into **climada** (see next section), (iii) the **ECA case studies**[9] in various developing countries, and (iv) the **ECA Guidebook**. For readers in need of a more detailed understanding of the ECA approach and vulnerability analysis, we recommend additional reading material developed by the ECA Working Group.

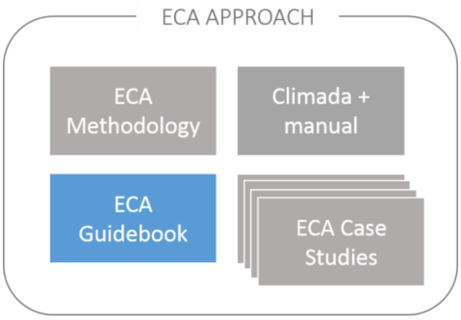


*Figure 4 The **ECA Guidebook** within the ECA Approach*

The **ECA Guidebook** comprises four major parts:

1) The first chapter “Why use the ECA Methodology?” assists Project Managers and Technical Experts in **deciding whether the ECA Methodology is adapted to their needs** for developing new projects.
2) The second chapter "How do you use the ECA Guidebook?” (this chapter) is dedicated to the **outline and scope** of use of this Guidebook.
3) It is followed by a **description of the ECA Conceptual Framework**. The conceptual framework of the ECA approach does not offer in-depth theoretical knowledge, but rather an overview of the methodology, its tools and how it is embedded in practice[10].
4) Further, Phases 1 to 8 provide detailed, **practical instructions for implementing the ECA Methodology**. These instructions will assist the user in using climada (ECA associated tool, explained further in the next chapter) in a step-by-step approach providing the reader with additional

[8] http://media.swissre.com/documents/rethinking_shaping_climate_resilent_development_en.pdf
[9] http://www.swissre.com/eca/eca_case_studies.html
[10] http://www.swissre.com/eca/

information on expected outcomes, necessary inputs and available tools. Each Phase also identifies potential issues the user may encounter during implementation.

In addition, each Phase provides a series of complementary information such as:

- ✓ **Boxes** providing further theoretical background information or showcasing practical examples from pilot studies
- ✓ **Tips** informing the users on best practices and practical shortcuts
- ✓ **Glossary** providing definitions of key terms used throughout the **ECA Guidebook**
- ✓ **Bibliography** of most relevant literature on the topic for further reading
- ✓ **Annexes** providing the practitioners with additional useful information, e.g. data resources and links.

The **ECA Guidebook** was developed, based on a modular structure, easily allowing the addition of complementary Phases. This version constitutes the first version of the **ECA Guidebook** and might be subject to amendments and benefit from further contribution by upcoming assessments.

An overview of the ECA Methodology

Conceptual Framework

The Economics of Climate Adaptation (ECA) methodology was set out to develop a practical framework allowing national and local decision makers to carry out a comprehensive assessment of climate risks facing their economies while minimising the cost of adaptation through cost efficient strategies. Special emphasis was placed on a robust and integrated approach based on sound scientific facts. The methodology as described in Figure 5 proposes three elements:

1) **Climate risk identification**: Conduct an identification of climate risk in a defined region (e.g. urban area), identify areas and people at risk, spanning all significant climate hazards and the full range of possible impacts for different sectors
2) **Climate risk quantification**: Calculate the expected damage across multiple climate and economic scenarios
3) **Identification and prioritisation of CCA measures (using Cost Benefit Analysis of CCA measures)**: Determine strategies including a portfolio of specific CCA measures with detailed cost/benefit assessment.

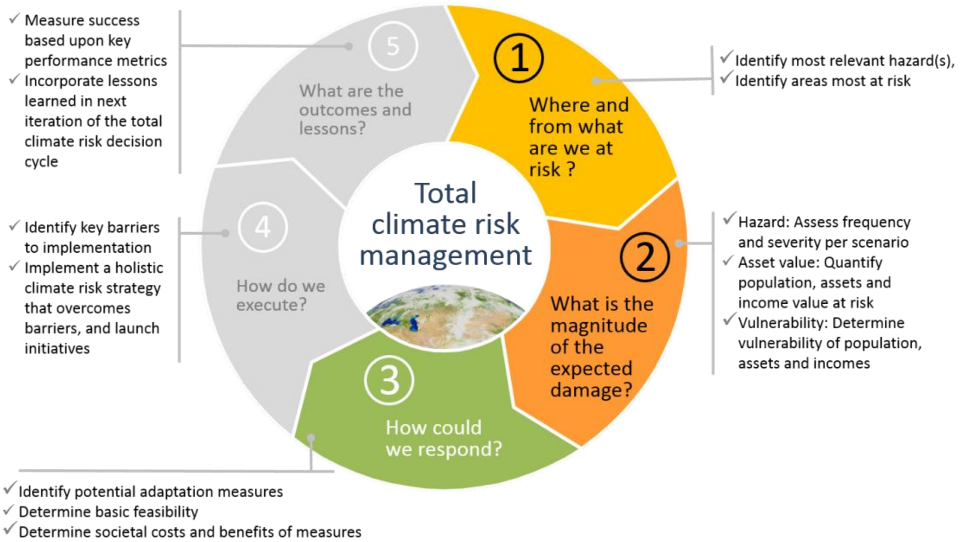


Figure 5 Presentation of the ECA elements (modified from ECA Working Group)

Further elements in the methodology include the implementation of the portfolio of CCA measures and the inclusion of best practices in the next climate risk decision. In this **ECA Guidebook**, only step 1 to 3 shall be considered.

The ECA Framework in eight (8) Phases

This section describes different Phases (1-8), corresponding to each element of the ECA Conceptual Framework. These Phases are concisely presented below. For ease of reading, each Phase shows corresponding ECA colours (cf. Figure 6). The eight (8) Phases described in the following chapters are presented in Figure 6. As depicted below, each Phase builds on one another. Furthermore, recommended tools are depicted such as for element 1 (Phase 1 and 2), mainly carried out using expert knowledge during workshops. For element 2 (Phase 3-6) and element 3 (Phase 7-8), the tool “climada” (description in the next section) offers a fully integrated approach.

Each Phase is constructed to include key questions to guide the user through the implementation. Because of the interaction between Phases, they refer to relevant steps and outcomes of previous Phases, if appropriate. Furthermore, to facilitate the practical application, references are made to more detailed supplementary information or practical tools in the Annex. At the beginning of each Phase, you will find an overview of:

- ✓ **Description of the Phase**: provides a concise description of the Phase, its rationale and purpose.
- ✓ **Key steps**: shows the main tasks to be undertaken guided by key questions.
- ✓ **Input needed**: reviews the necessary inputs needed to undertake each step. This input might be outcomes from previous Phases. It lists all the information needed before starting this Phase.
- ✓ **Expected outputs**: the main outcomes from the Phase, often used as input for the next Phases.
- ✓ **Tools and additional information**: tools, templates, and additional information related to the Phase are included.

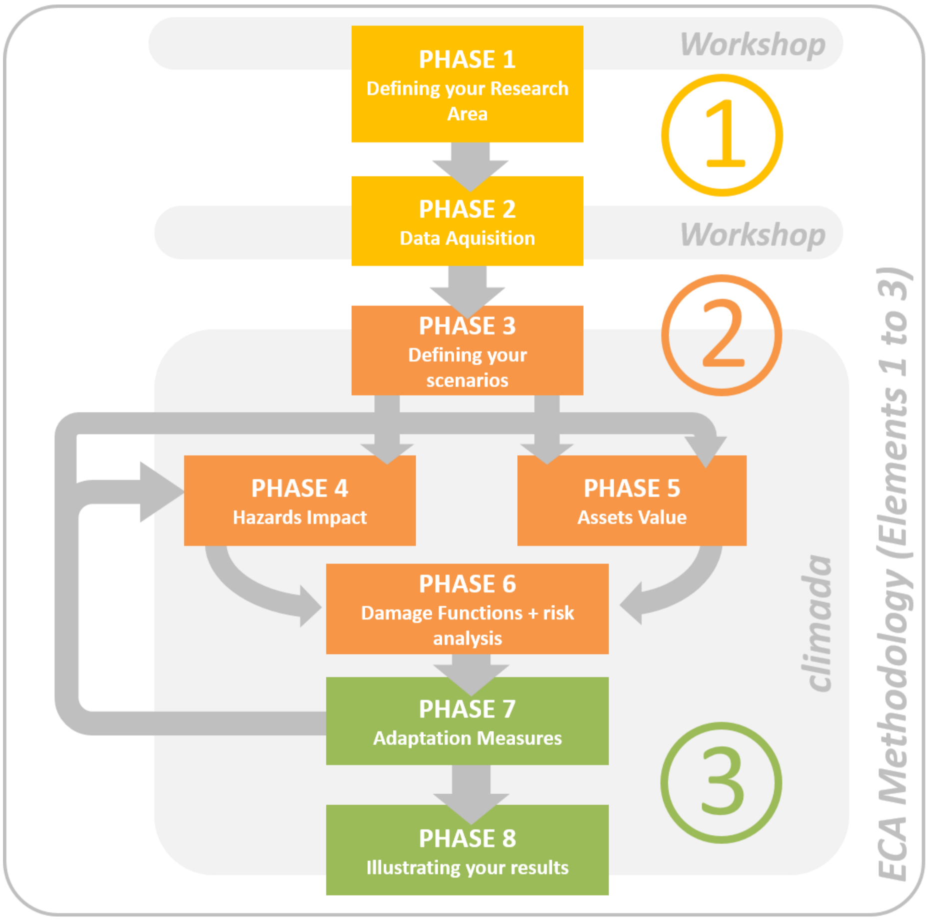


Figure 6 Diagram of every Phase and their interconnection

Phases will be described later in detail. However, for ease of use, an overview of each Phase's content is given below.

Table 2 Overview of the different Phase available in this ***ECA Guidebook***

Phase	What will be achieved in this Phase	Key Tools
PHASE 1: **Defining your Research Area**	*This Phase outlines the essential steps for preparing your CCA assessment. The main output of this Phase will be a specifically defined research area, with its associated risks and assets. It shows how to assess the initial situation of your analysis, define – according to the objectives– what risks should be considered and what assets are relevant (group of people, areas, type of houses, commercial activity, etc.). In addition it offers guidance in integrating stakeholders and decision makers at the earliest stage of the process.*	✓ Hazard pre-selection grid (cf. Table 4) ✓ Template CCA implementation plan (cf. Figure 8)
PHASE 2: **Data Acquisition and Management**	*This Phase outlines the essential steps for identifying what data are needed for your CCA assessment. It shows how to assess what data are available and how to identify the right institutions in a timely manner. It helps define, based on the outcome of Phase 1, what data are of first order and what information remains optional. In addition, it offers guidance in data collection, database construction and storage.*	✓ A checklist with data needed for each Phase (Annex 1) ✓ Template data gathering for asset value (Annex 2)

PHASE 3: **Defining Scenarios**	*This Phase outlines the essential steps for defining your climate and socio-economic scenarios. It shows how to assess the current situation and decide what scenarios are relevant for your objectives. It assists you in defining a time horizon relevant for the CCA measures, hazards and financial/economic scenarios you have considered in Phase 1. In addition, it provides guidance in obtaining and developing scenario relevant information for hazards, assets and economic scenarios.*	✓ Criteria for time horizon selection
PHASE 4: **Modelling Hazards**	*This Phase outlines the essential steps for modelling hazards selected in Phase 1. It will assist you in using the data gathered in Phase 2 and include scenarios developed in Phase 3. In addition, it will provide you with guidance on how to create hazard impact maps using climada for selected hazards.*	✓ climada Hazard Module (cf. climada manual) ✓ GIS application for manipulation of hazard sets
PHASE 5: **Valuating Assets**	*This Phase outlines the essential steps towards a sound valuation of the asset categories selected in Phase 1. It will provide you with guidance on how to best value different categories of assets and how to insert them into climada. In addition, it will provide you with tips on how to value assets without monetary values or assets with low monetary values. Particular emphasis will be placed on a pro-poor approach dedicated to developing and emerging countries/economies.*	✓ climada Asset Phase (cf. climada manual) ✓ GIS application software
PHASE 6: **Creating Damage** **Functions and Risk Analysis**	*This Phase outlines the essential steps for creating damage functions for the different classes of assets and for the different types of hazards. It will give you information and guidance in order to organize an expert workshop to gather information on past disasters in your region/country. In addition it provides guidance on how to develop damage functions from historical observations and insert them into climada. At the end of this phase, you will have performed your risk analysis.*	✓ climada manual and climada damage function generator (cf. climada manual) ✓ ERN-Vulnerability damage function generator (cf. manual and download at http://www.ecapra.org/ern-vulnerability)
PHASE 7: **Simulating CCA measures**	*This Phase outlines the essential steps for selecting and simulating your CCA measures. It will assist you in creating a long list of CCA measures and provide information on how to create a short list of CCA measures using a multi-criteria selection. It will assist you in parameterising your short list of CCA measures into climada and calibrating them in order to provide sound results.*	✓ Table of parameters for different CCA measures for selected hazards (see Annex 3 for flood risk) ✓ climada CCA measure format table (cf. climada manual) ✓ Stakeholder workshop, discuss with local experts to identify a long list of measures
PHASE 8: Illustrating Results	*This Phase will show you how to summarise and present the findings of your analysis. For this task, it important to keep in mind whom these results are targeted at. According to your objectives, what was the target audience, who are the stakeholders and the beneficiaries of your CCA assessment? Which outcomes are important for subsequent tasks (for instance adaptation planning or strategy development)? What is the best format to convey your results?*	✓ Climada illustration tools

climada: An integrated tool for ECA

climada (from climate adaptation) implements the quantitative modelling and simulation part of the ECA methodology. While the present **ECA Guidebook** provides guidance on the application of the full ECA methodology, the climada manual documents the modelling platform that underpins ECA. Unlike many existing methodologies, ECA therefore provides a unique integrated approach (Methodology, Tools, Manuals and Guidebooks in one package) to natural catastrophes, climate variability and climate change adaptation.

Hence, climada is conveniently embedded into the methodology and integrates all steps of the ECA methodology in different phases. climada is a tool running either on MATLAB® or Octave and can be downloaded free of charge[11]. MATLAB®[12] is a basic and common computer language, Octave[13] is its open-source and free of charge surrogate. For more details about the damage calculation process, please refer to the climada manual[14], and to the climada wiki[15].

Because of the physical base of climate risk (different physical magnitudes of a climate event have different effects) and the resulting accumulated damage, traditional approaches to cost benefit analysis proved cost intensive and cumbersome. Consequently, a probabilistic model - climada - has been developed to deliver efficiently (and automatically) verifiable results, which can be compared to historical events. Because Phase 1 and Phase 2 are dedicated to gathering information and raising ownership of the project, and Phase 3 to the development of scenarios, climada (as a physically based model) provides assistance only to Phases 4-8:

Phase 4: Hazards: the variables defining the hazards (e.g. wind, inundation, landslides) are defined probabilistically for present and future conditions. Their spatial distribution is also determined at this stage.

Phase 5: Assets: assets are defined according to different classes or categories and are geographically distributed in order to estimate the expected damages from climate variability and climate change impacts under different socio-economic scenarios;

Phase 6: Damage functions: the damage function relates the intensity of a given hazard to the damaged caused to a certain category of asset.

Phase 7: CCA measures: At this stage, a set of different CCA measures is evaluated in terms of costs and benefits. Adaptation to a certain hazard or a set of hazards can be achieved in either reducing the hazard or the damages. To do so, different solutions exist such as: physical protection, structural modification, planning and early warning or socioeconomic development.

Phase 8: Illustrating your results: Thanks to its MATLAB® /Octave based interface, climada offers a large range of possibilities. In addition, raw data can be easily exported to other software packages such as GIS.

How do you use climada?

Use and application of climada have been described in detail in the climada manual which is available online, free of charge (cf. link above). The manual describes the core routines and Phases available in climada and complements the **ECA**

[11] *Available at https://github.com/davidnbresch/climada*
[12] *http://de.mathworks.com/products/MATLAB(r)/*
[13] *www.gnu.org/software/octave*
[14] *https://github.com/davidnbresch/climada/blob/master/docs/climada_manual.pdf*
[15] *https://github.com/davidnbresch/climada/wiki*

Guidebook. The use of climada requires a basic knowledge of the MATLAB® programming language in order to avoid any black box[16] use. climada consists of the core Phase, providing the user with the key functionality to perform an economics of climate adaptation assessment. Additional Phases implement global coverage (automatic asset generation), a series of hazards (tropical cyclone, surge, rain, European winter storms and even earthquake and meteorites) and further functionality, such as Google Earth access and animations. Skills and expertise needed for using the **ECA Guidebook** are listed above in Table 1.

climada is a powerful tool, providing assistance and guidance throughout Phases 4, 5, 6, 7 and 8 as described in this Guidebook. For illustration purposes, we have included a screenshot on what it looks like in Figure 7.

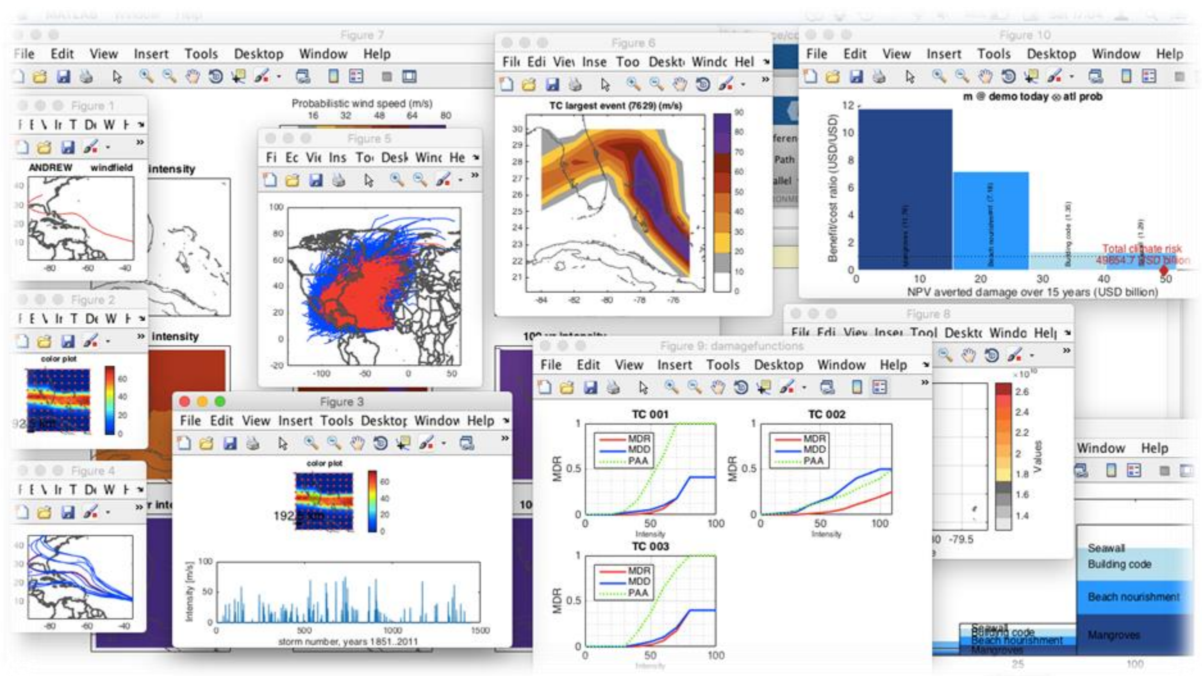


Figure 7 Output figures from climada as displayed on MATLAB® for a case study in Florida (from the climada manual 2016, available online[17])

16 Black box use refers to potentially incorrect modelling outcomes due to an incorrect use of model parameters. As with all models, climada is only a tool serving a purpose and its outcomes should be thoroughly tested and validated before publication.
17 https://github.com/davidnbresch/climada/blob/master/docs/climada_manual.docx

PHASE 1: Defining Your Research Area

DESCRIPTION OF THE PHASE

This Phase outlines the essential steps for preparing your CCA Assessment. The main output of this Phase will be a specifically defined research area (country wide or urban area depending on your focus), with its associated risks and assets. It shows how to assess the initial situation of your analysis, define – according to the objectives – what risks should be considered and what assets are relevant. In addition, it offers guidance in integrating stakeholders and decision makers at the earliest stage of the process in a stakeholder workshop. The general output of PHASE 1 will be a decision regarding where the analysis should be carried out, including the level of detail needed to assess risks in the selected area. The ideal framework to carry on Phase 1 might be a workshop regrouping all stakeholders. The main steps are briefly outlined below and discussed in further detail in the next section (climada will not be needed in this phase).

KEY STEPS

Step 1: Present the context of your CCA assessment

- ✓ *At what stage of adaptation planning is the assessment taking place?*
- ✓ *Are there already vulnerability or impact assessments in your region?*
- ✓ *What are the development and adaptation priorities (if already defined)?*
- ✓ *Which institutions and resources can and should be involved in your CCA assessment?*

Step 2: Define the objectives and outcomes of the CCA assessment and agree on deadlines

- ✓ *What do you and key stakeholders wish to learn from the assessment?*
- ✓ *Which processes will the CCA assessment support or feed into?*
- ✓ *Who is the target audience for the CCA assessment results?*

Step 3: Identify the scope of your analysis

- ✓ *Which sectors and groups should the assessment cover?*
- ✓ *Are there known key impacts, hazards or vulnerability you want to assess?*
- ✓ *What is the scope – area(s), period – of your CCA assessment?*
- ✓ *To which time frame will the CCA assessment refer (past, current, and future)?*

Step 4: Identify the main hazards to be considered

- ✓ *Which hazards have been impacting your region lately?*
- ✓ *Which hazards will impact your region in the future?*
- ✓ *Are there any low-frequency hazards in your region?*

Step 5: Develop an implementation plan for your CCA assessment

- ✓ *CCA assessment team: Who are the people and institutions involved?*
- ✓ *Tasks and responsibilities: Who does what?*
- ✓ *What is the time plan of the CCA assessment?*

INPUT NEEDED

For this Phase, you will need:

- ✓ *A good overview of institutions and individuals relevant for your assessment*
- ✓ *Key strategic documents of the organisations involved, such as sector strategies, community or national development plans, policy briefs (if available)*
- ✓ *Information – if available – on adaptation strategies, plans, policies and ongoing or planned CCA measures*
- ✓ *Information on climatic conditions, past extreme events, climate variability and climate change projections as well as potential climate variability and climate change impacts*
- ✓ *Information on socio-economic conditions, such as livelihoods, education, health issues, natural resource dependency, etc.*
- ✓ *Information – ideally in the form of maps – on key environmental challenges, such as water scarcity, soil degradation, loss of biodiversity and existing infrastructure.*

EXPECTED OUTPUTS

After this Phase, you will have:

- ✓ *A precisely formulated set of objectives – overall and specific – agreed with key partners and stakeholders*
- ✓ *A ranked list of hazards, most relevant for your objectives and scope*
- ✓ *A clearly defined scope for the spatial, thematic/sectoral and temporal dimensions of the CCA assessment*
- ✓ *A list of outputs to be produced*
- ✓ *An implementation plan that defines tasks, responsibilities and timetable for the CCA assessment.*

TOOLS AND ADDITIONAL INFORMATION

- ✓ *Hazard pre-selection grid (c.f. Table 4)*
- ✓ *Template CCA implementation plan (c.f. Figure 8)*

Getting Started

CCA assessments usually are unique in nature and serve specific purposes. So you should make sure that: You understand the context in which the assessment is taking place (Step 1), define clear objectives and outcomes for the assessment (Step 2), determine the thematic, spatial and temporal scope of your CCA assessment (Step 3), identify the main hazards you want to study (step 4), and prepare an implementation plan that defines tasks and responsibilities for different participants and stakeholders, as well as the schedule for the CCA assessment, taking into account available resources (Step 5).

In practice, these five steps are closely interlinked and preparing a CCA assessment is an iterative process balancing objectives, context, scope and resources. Steps 1 to 5 result in important decisions which will influence the entire CCA assessment, so it is essential that you document the results of this

preparatory phase well and share it with any actors who will be involved in your assessment. This ensures transparency and provides substantiation for any decisions as well as pending questions. There is a template hazard selection grid (cf. Step 4) and a template implementation plan (Figure 8) for documenting the results of Phase 1 (see Step 6); Make sure you include key institutions and stakeholders while filling these documents and use it for further communication and planning of the assessment.

Step 1: Present the context of your CCA assessment

Because every assessment takes place in a unique setting, it is important to explore the context of this assessment. It will help you to specify the objectives and the outcomes of your study and set the right balance of resources. To do so, keep in mind the following guiding questions (BMZ, 2014):

Related Activities:

- ✓ What are ongoing or planned activities related to adaptation?
- ✓ Which (ongoing) activities should or could benefit from the CBA Assessment?
- ✓ Which activities could the CBA Assessment benefit from?

Knowledge Baseline

- ✓ What is already known about climate variability and climate change and its impacts?
- ✓ Have there already been risk, vulnerability or impact assessments?
- ✓ Which information gaps should be filled by the CCA Assessment?

Stakeholders

- ✓ Which institutions or stakeholders will or should be involved in the CCA Assessment?
- ✓ What are their specific interests and objectives regarding the CCA Assessment?
- ✓ What and how can they contribute to the CCA Assessment?
- ✓ Should you include the private sector?

Resources

- ✓ Which (financial, human, technical, etc.) resources can be dedicated to conducting the CCA Assessment?
- ✓ How will the CCA measure be financed?
- ✓ When are results from the CCA Assessment needed?
- ✓ Which relevant information and data are available for the CCA Assessment?

External Factors

- ✓ Are there important external factors that should be taken into account?
- ✓ How do these external factors potentially influence the system under review?
- ✓ Are there any major threats to the realisation of this assessment?

Step 2: Define the objectives and outcomes

Define the objectives and outcomes of the CCA assessment and agree on deadlines

Cooperation with stakeholders is paramount to a successful outcome: CCA assessments requires knowledge from different disciplines and specific expertise in different sectors/regions and often rely on information gathered on the ground for analysis and validation.

Local institutions and experts can often provide such knowledge and access to data sources and thus improve the quality of the assessment. Moreover, involving local institutions and communities can help increase acceptance – and thus uptake – of your CCA assessment results and recommendations. Finally, it facilitates learning among institutions working on adaptation and can lead to up-scaling of identified CCA measures. Involvement of local institutions can be through bilateral consultations or take the form of an **inception workshop** which aims at defining the cornerstones of the assessment outlined in this Phase in Steps 1-5.

The objectives, scope and spatial scale of your CCA assessment will determine which institutions to approach. Since these aspects are defined in steps (specifically, Step 2 and 3), identifying and involving different institutions will often be a gradual and reciprocal process. Potential institutions and stakeholders to be contacted are listed below in Table 3. In the box below, a sample of guiding questions will assist you in defining your objectives and the expected outcomes

Table 3 Potential institutions and stakeholders to be considered for the inception workshop (adapted from BMZ, 2014)

Level	Potential Institutions and Stakeholders
International Level	Bilateral or Multilateral donor organisation involved in climate adaptation in your country. NGOs working at an international level
National Level	Ministries responsible for environment, spatial planning, natural resources (particularly water), planning and finance as well as resource-related sectors (such as agriculture), statistical offices and meteorological offices, NGOs working at the national level

District Level	District or regional governments, national entities such as ministries, statistical offices, meteorological offices, local NGOs, research institutions, private sector companies, international organisations, donor organisations
Local and Community Level	Local communities, farmer associations, community leaders, local non-governmental organisations (NGOs) and authorities, local businesses and companies, donor organisations, civil protection
Representatives of key infrastructures	Schools professionals, health centres and hospital, ministry of health, banking sector, tourism sector, commercial centre and water supply professionals, airports and road network
Research institution	Local universities (specifically, departments working on natural resources, rural or urban development, biodiversity, geography, disaster risk reduction etc.), research institutions
Private sector	Local and national insurance companies, private sector most affected by a set of hazards relevant to your country's economy

In practice, all these questions can be answered with or without stakeholder involvement. However, the discussion of the scope and available resources will influence the objectives and the achievable outcomes of the assessment. Therefore, with a certain degree of pragmatism, step 2, 3, and 4 should be addressed in an iterative way.

Step 3: Identify the scope of your analysis

Having explored the context of your assessment and identified its overall objectives, it is time to define the scope of your CCA assessment in greater detail, including factors like spatial level. This is also important preparation for the development of hazards to be considered. Use the following questions as a guide when determining the scope of your assessment (BMZ, 2014):

What exactly is your CCA assessment about?

What is the subject or thematic focus of your assessment (e.g. a certain sector or application field, such as urban areas, wetland ecosystems, agricultural production, water supply, etc.)? Are you considering particular social groups? And will the assessment focus on just one subject, or combined subjects (for example, vulnerability in the urban areas for different sectors)?

Do you already have potential climate impacts and key drivers in mind?

Potential impacts will be identified in detail in Phase 4. However, you might already be aware of key drivers for impacts, hazards, and vulnerabilities related to the subject(s) which you want to address. This knowledge of key impacts might come from previous studies or literature.

BOX: GUIDING QUESTIONS

What process will the CCA assessment support or feed into?

Are there ongoing activities in the field of adaptation that should be taken into account when designing and implementing the CCA assessment?

What do you want to learn from the CCA assessment? What is the information gap?

What are the climate change hotspots in your region? Or do you want to identify suitable CCA measures and test whether they help reduce vulnerability?

What do you want to use this knowledge for?

Input into ongoing adaptation efforts, planning concrete CCA measures at local level, developing a national adaptation strategy, or an overview of potential sectoral climate change hotspots?

Who is the target audience for the results of the CCA assessment?

Local communities, ministries and national agencies tasked with adaptation planning, decision makers at different administrative levels?

What outputs do you expect?

A map of vulnerability hotspots, ranking of vulnerable sectors, narrative analysis of vulnerability and its determining factors?

What is the geographical scope of the assessment?

Will it focus on specific entities such as a clearly definable ecosystem (e.g. urban areas, river delta or protected natural area)? Or will it cover a specific community, district/province or country? And are you focusing on a single spatial unit (e.g. one district) or comparing areas (e.g. two or more districts)? This decision on spatial scale might also be influenced by the availability of data relevant to your assessment (e.g. are urban planning and income data available at district level or are they also broken down to the community or even household level?)

What is the time period of the assessment?

Your assessment will depend on your reference period, but also on the total analysis period, especially regarding the development of scenarios in Phase 3. We recommend starting with current climate for a baseline assessment (current situation before an adaptation activity). Ideally this means a reference period covered by 30 years of climate records (e.g. 1981-2010). Anything below 15 years will not be sufficiently representative. You can use non-climatic data (e.g. household income) which covers shorter periods, although it should be as recent as possible. The time period for climate scenarios (called time horizon) will be defined at a later stage (Phase 3). However, it can be also beneficial to make up your mind at this early stage in order to discuss it with a broader audience.

Step 4: Identify the main hazards to be considered

Hazard Types

A hazard, and the disaster resulting from it, can have different origins: natural (geological, hydro-meteorological and biological) or induced by human processes (environmental degradation). Hazards can be single, sequential or combined in their origin and effects. Each hazard is characterised by its location, intensity, frequency, probability, duration, and area of extent, speed of onset, spatial dispersion and temporal spacing. We will look at this in more detail in later sessions. Hazards can be classified in several ways. A possible subdivision is between:

Natural hazards are natural processes or phenomena within the earth's system (lithosphere, hydrosphere, biosphere or atmosphere) that may constitute a damaging event (such as earthquakes, volcanic eruptions, hurricanes);

Human-induced hazards are modifications of natural processes within the earth's system (lithosphere, hydrosphere, biosphere or atmosphere) caused by human activities which accelerate/aggravate damaging events (such as atmospheric pollution, industrial chemical accidents, major armed conflicts, nuclear accidents, oil spills);

Human-made hazards: dangers originating from technological or industrial accidents, dangerous procedures, infrastructure failures or certain human activities, which may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation (some examples: industrial pollution, nuclear activities and radioactivity, toxic wastes, dam failures; transport, industrial or technological accidents (explosions, fires, spills).

In climada/ECA, while focusing on climate variability and climate change induced hazards, only natural and human-induced hazards will be considered. However, other hazard types such as earthquake can be simulated within the model.

How do you prioritise between hazards?

In many situations, an area of interest is subject to numerous hazards. Depending on the objectives of your study, it is often advisable to identify hazards which are most relevant to these objectives (see Step 2). One or several hazards could be chosen in the case of a multi-hazard approach. It is important to prioritise between hazards

In order to define relevant hazards, a methodology based on criteria selection is described below. The following steps could be applied during a stakeholder **inception workshop**, where experts and community are gathered.

1) A set of preselected relevant hazards are presented and discussed in group. In order to ease the discussion, the group should be provided with a clear definition of each pre-selected hazard. Pre-selection of hazards could be done based on aggregated data base such as EM-Dat (described in Phase 2).
2) A set of criteria is defined and discussed. The criteria are defined as follow:
    a) Impact level on the community
    b) Intensity and frequency of hazard
    c) Costs and period of recuperation after a disaster
    d) Level of local knowledge for a hazard
    e) Demand for adaptation from the community

3) Finally, each hazard is attributed a score according to the criteria. Scores range between 1 and 3, three being the highest score. In order to keep the analysis constrained, we recommend that the final selection of hazards should not exceed a total of three hazards. Final scores and the hazard matrix could be presented as follows:

Table 4 Example of criteria and scores for selected hazards

	EXPECTED IMPACT	INTENSITY/FREQUENCY	COST / PERIOD OF RECUPERATION	LEVEL OF KNOWLEDGE	DEMAND FOR ADAPTATION	**TOTAL SCORE**
HAZARD #1	3	3	2	3	3	**14**
HAZARD #2	1	1	1	1	1	**5**
HAZARD #3	1	1	1	2	1	**6**
HAZARD #4	3	3	3	1	3	**13**
HAZARD #5	2	2	1	1	2	**8**
HAZARD #6	3	3	3	2	3	**14**

Again, these questions could be theoretically answered without an inception workshop. However, we highly recommend including stakeholders at an early stage in order to raise acceptance of the later outputs.

Step 5: Develop an implementation plan

Building on the knowledge gained through steps 1 to 4, this last step offers the opportunity to develop a clear and transparent implementation plan for the CCA assessment. You will define specific tasks and responsibilities as well as a schedule. A template is provided in Figure 8.

Participating institutions and stakeholders should be involved in the creation of your implementation plan. To keep your scheduling realistic, you should balance carefully between the resources you have and the resources you might need from other partners. It might be worth considering the following points before you start with time and resource planning (BMZ, 2014).

Assessments with an explorative character (even with a wide scope) are usually less time-consuming. A well-structured, two or three-day workshop should result in a good understanding of vulnerability, even in larger regions. Note, however, that you will need to carefully select participants who can bring high levels of expertise to your assessment topics. Such an assessment might last in total between one to three months.

More in-depth assessments generally take longer as they usually require a large amount of data, either sourced from relevant institutions or from surveys conducted as part of the CCA assessment. Data acquisition (as well as data preparation and processing – see Phase 2) can often represent a scheduling bottleneck. If your schedule is particularly tight, evaluate data availability and quality as early as possible, leaving yourself plenty of time to explore different resources, or to change the methods or focus of your assessment. Figure 8 provides an overview of indicative time needed for your assessment. Additional indication can be found in Figure 2.

Figure 8 Timeline indication for the CCA assessment

PHASE 2: Data Acquisition and Management

DESCRIPTION OF THE PHASE

This Phase outlines the essential steps for identifying what data are needed for your CCA assessment. It shows how to assess what data are available and how to identify the right institutions in a timely manner. It helps define, based on the outcome of Phase 1, what data are of first order and what information remains optional. In addition, it offers guidance in data collection, database construction and storage (climada will not be needed in this phase).

KEY STEPS

Step 1: Identify what kind of data is needed and available

- ✓ *What kind of data do you need?*
- ✓ *Who can provide the data?*
- ✓ *Are the data you need available?*
- ✓ *What alternatives are available if your preferred data sources prove unreliable?*

Step 2: Quality control

- ✓ *Are the data in the format you expected? Are all the files legible and ready for further processing?*
- ✓ *Is the temporal and spatial coverage as planned?*
- ✓ *Is the value range of the data as expected?*
- ✓ *Are there any missing data values or outliers in your data?*
- ✓ *Are the data in the right geographical projection?*

Step 3: Data management

- ✓ *How are data transformed into climada format?*
- ✓ *How do you structure and compile your data in a common database?*
- ✓ *How can you document your data with metadata and/or data fact sheets?*

INPUT NEEDED

For this Phase, you will need:

- ✓ *A good overview of institutions and available resources in your country or region*
- ✓ *A list of hazards and asset categories selected in Phase 1*
- ✓ *Knowledge of available resources (financial, but also skills, including data analysis/processing, leading surveys and workshops)*

EXPECTED OUTPUTS

After this Phase, you will have:

- ✓ *A database containing all data needed for the following Phases*

TOOLS AND ADDITIONAL INFORMATION

- ✓ *A checklist with data needed for each Phase (Annex 1)*
- ✓ *Template data gathering for asset value (Annex 2)*

Getting Started

Because of the quantitative aspect of the ECA approach, data availability and data collection play a central role in the setting up of the model. The quality, spatial and temporal resolution of the data involved strongly influence the outcome of your assessment. In the same vein, depending on the goal of your analysis, it is important to determine what type and kind of data is needed to achieve these objectives.

In this Phase, the different types of data needed for a standard assessment are explored. Several recommendations will be made in order to prioritise between different criteria related to data such as temporal and spatial resolution. In addition, specialised websites shall be highlighted to facilitate access to open source information (step1) and special attention will be given to quality control (Step 2) and data management in order to make your data available for other Phases (Step 3).

Step 1: Identify what kind of data is needed

In order to address the different needs of the ECA methodology and the climada model, different types of data are required. Each dataset is required by the different components of climada or is used to develop these components. In the following sections, we present different types of data and relate them to the components of climada.

When considering different hazard types, it becomes clear why data types need to be adjusted for risk assessment. Indeed, for different hazard types such as earthquakes or hurricanes, different (i) spatial, (ii) spectral and (iii) temporal resolution exist (van Westen et al., 2011):

(i) **Spatial resolution**. A hazard can be very local and spatially confined (e.g. landslides), it can be very extensive (e.g. flooding or drought), or there can be a large distance between the actual source of the hazard and the area at stake. Examples of that can be the breaking of a dam that may lead to flooding far downstream. One has to consider the dimensions of the hazard: a dam or a hill slope is quite small in extent, while an area possibly exposed to a hurricane or a storm surge may be vast. The data chosen in the analysis need to reflect those dimensions and the level of detail needed.

(ii) **Spectral resolution**. Spectral resolution is very effective in differentiating between different surfaces. For example, a near infrared band, common to most passive satellite sensors, is well suited to map vegetation health or water. It is thus suitable, at times in combination with other spectral bands, to track vegetation health (e.g. to monitor drought hazard), or to map flood or other surface water. In situations where there are clouds, smoke, or in night-time conditions radar products can be used.

(iii) **Temporal resolution**. Hazard events can be sudden and of short duration (e.g. landslides), sudden but of long duration (e.g. a dam break leading to prolonged flooding), but can also show precursory signs (e.g. hurricanes). Some effects may also be delayed, such as disease outbreak after a flood or earthquake. This is also a good example of one hazard type event leading to secondary effects. Other examples of this phenomenon are slope or dam instability caused by heavy rain.

Hence, depending on the hazard type, it is important to match the right temporal, spectral or spatial resolution. However, there is a largely inverse relationship between coverage and level of detail. Consequently, it is often advised to combine several data sets to cover resolution requirements. In the next box, a checklist is provided in order to help in making these decisions.

BOX: HOW TO DECIDE WHICH DATA ARE SUITABLE?

Depending on the specific hazard situation, types of assets at risk, or secondary hazards, it is important to determine the correct data to be gathered. The following checklist is designed to help practitioners in taking decisions in a timely manner:

1) **Identify data types needed (e.g. thematic layers, images, maps)**

   Understanding the risk component and the assets at risks is a prerequisite to understanding what data might be needed.

2) **Timeframe and coverage**

   The period for which the data is required is of high importance, for instance in order to create hazard frequency, or build scenario for a given area. In the same vein, one should consider the coverage need for the analysis. The coverage is intimately interlinked with resolution and the research area.

3) **Cost**

   Cost of data is an important factor for decision making. Some data, especially secondary data (or data with added value) could be quite expensive. However, a list of data available free of charge can be found in the ECA Guidebook in Phase 7.

4) **Availability**

   It is import to ensure that data needed are also available for the timeframe of the study. In case data are not available, the practitioner should reconsider the area of research or even the hazard or the asset included in the study.

5) **Resolution**

   Resolution for data required in the analysis is a key parameter. As a general rule, the highest possible resolution for data is recommended. However, depending on the goal of the study, a lower resolution should be sufficient. It is also important to consider that higher resolution data will increase the overall duration of the analysis.

Choosing the right resolution

What is the interaction between resolution and other factors affecting the assessment?

1) Costs
2) Coverage
3) Time need to complete the study
4) Objective of the study
5) Mixed resolution is not meaningful (the end results will be strongly influenced by the coarser resolution)

As in any modelling exercise, it is important to define a resolution for the model output. This definition will dictate the level of detail required for input data. Defining such a resolution is not trivial. It involves considering the scope of the study, the timeframe available, the quality of input data and the hazard modelled. Hence, it requires reflecting on the project objectives by asking the following questions:

1) What is the size of the research area?
2) What level of detail is required for the scope of the study?
3) What are the resources available for the modelling exercise?
4) What is the timeframe for the modelling exercise?
5) Is the resolution of input feasible considering the input data available?
6) What resolution is needed for the hazard considered?

The following figure displays the relationship between the size of the research area to be modelled and the resolution of climada. If a high resolution is desired, then the size of the research area should be decreased accordingly. On the other hand, if a large research area is to be considered, a coarser resolution should be chosen. It should be noted that if certain areas require a higher resolution, an irregular resolution grid can be chosen. An irregular grid combines several resolutions in one location. For instance, where less information is needed, you would choose a grid with a lower resolution. Where more information is needed, you might use a grid with a higher resolution.

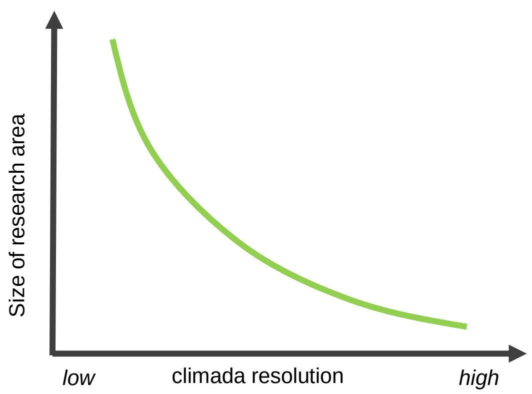


Figure 9 Relationship between resolution and size of areas considered in the study

Disaster data

Data on disaster occurrence, its effect upon people and its cost to countries are very important for disaster risk management. These data will help in comparing the climada model's output with real damages. In this sense, they are useful for the "calibration" model. There are now a number of organizations that collect information on disasters, on different scales and with different objectives.

A non-exhaustive list of these organisations is provided below:

Institution	Description	Source
EM-DAT	Since 1988 the WHO Collaborating Centre for Research on the Epidemiology of Disasters (CRED) has been maintaining an Emergency Events Database - EM-DAT. Disasters have to fulfil certain criteria in order to be included in the EMDAT database: they have to kill 10 people or more, 100 or more should be affected, it should result in a declaration of emergency or it should lead to a call for external assistance.	http://www.emdat.be/
Nathan	Data on disaster impacts are also collected by reinsurance companies e.g. www.MunichRe.com; www.swissre.com. For instance the Munich Re database for natural catastrophes NatCat SERVICE includes more than 23,000 entries on material and human damage events worldwide. However, these data are not publicly available but could be obtained on request. There is only a very general site where disaster information can be obtained.	https://www.munichre.com/en/reinsurance/business/non-life/natcatservice/index.html
ADRC	Recently, the Asian Disaster Reduction Center (ADRC) started a new disaster database, called Glidenumber. The database, however, is still very incomplete.	www.glidenumber.net
UNEP	Another useful source of disaster information for individual countries is the UNEP website:	http://preview.grid.unep.ch/
DesInventar	At a local level, disaster data has been collected by an initiative of NGO, called LaRed, initially in Latin America, but later on expanding also to other regions. They developed a tool called DesInventar, which allows local authorities, communities and NGOs to collect disaster information at a local level. Recently, the DesInventar database became available online	http://online.desinventar.org

Information systems have improved vastly in the last 25 years and statistical data is now more easily available, intensified by an increasing sensitivity to disasters occurrence and consequences. However, despite efforts to verify and review data, the quality of disaster databases can only be as good as the reporting system. The lack of systematisation and standardisation of data collection now reveals its major weakness for long-term planning. Fortunately, due to increased pressures for accountability from various sources, many donors and development agencies have increased their attention on data collection. These are summarised by UNISDR as follows for the case of EM-DAT:

1. "*Data on deaths are available most of the time because there is an immediate proxy for the severity of the disaster.*

2. *Data on the numbers of people affected by a disaster can be very useful for risk assessment, but are often poorly reported. Moreover, the definition of "affected" always remains open to interpretation, political or otherwise.*
3. *Data can also be skewed because of the rationale behind data gathering.*
4. *Dates of occurrence can be misleading for long lasting disasters (sea level rise or droughts)"* (UNISDR, 2013)

Spatiotemporal Data

Hazards, assets or persons at risk are of spatial and temporal nature. In order to make appropriate decisions it is important to gather a series of spatiotemporal data related to the area of interest. Such data are available in different national and regional institutions but also online. In this section we will provide a non-exhaustive list of sources for spatiotemporal data (adapted from van Westen et al., 2011).

Dataset	Description	Source
Global DEMs	There are two main sources for global DEMs: the older GTOPO30, or the more recent SRTM-based DEM. The GTOPO30 is a coarse, global DEM, with grid cells of 1km across. A more detailed source for DEMs is provided by the Shuttle Radar Topography Mission (SRTM). A radar pair mounted on a space shuttle was used to map nearly the entire globe at 30m resolution. Data outside the US are aggregated to 90m. These files are available free of charge.	https://lta.cr.usgs.gov/GTOPO30 http://www.jpl.nasa.gov/srtm/
ASTER	ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) has become a very widely used satellite image source. Launched in 1999, the sensor carries a spectacular 15 channels, with 4 bands at 15 m resolution, 6 at 60m, and 5 at 90m. The spatial and spectral details are thus excellent, and, in addition, the data can be used to create DEMs.	http://asterweb.jpl.nasa.gov/data.asp
MODIS	MODIS data are often considered together with ASTER, as the sensor is also NASA operated and compliments ASTER. There are actually MODIS sensors on two different satellites, acquiring data at moderate resolution in a remarkable 36 channels. Like ASTER, the resolution is variable, with some bands at 250m, some at 500, and some at 1,000m. The data are free, but as with ASTER it is important to be careful in the product selection.	http://modis-land.gsfc.nasa.gov
Landsat MSS/TM data	Data can be searched for and downloaded using the GLOVIS tool already mentioned. There is also a source for free orthorectified Landsat data. A good place to search is also the Global Land Cover Facility. Be aware that Landsat datasets, even when compressed, can easily reach several hundred MB in size, which can make their download difficult. As with the other datasets mentioned above though, the files have geographic reference information and can easily be imported into a GIS or similar program.	http://landsat.usgs.gov/ http://glcf.umd.edu/index.shtml http://earthexplorer.usgs.gov
SPOT Vegetation	The SPOT satellites were initiated by the French Space Agency, but are now operated by Spot Imaging, a commercial company. The regular images are expensive, but the latest Spot satellite includes a vegetation mapper which collects data that are available for free if they are older than	http://free.vgt.vito.be/

	3 months. The resolution of the vegetation data is comparable to AVHRR at about 1.1 km.	
Google Earth	The best example of the satellite imagery that has been converted to pictures is Google Earth. With Google Earth Pro (license comes at a cost) it is possible to save high-resolution pictures. They can then be integrated with other spatial data in a GIS. This can be very valuable when performing detailed analysis or valuation of assets, or for change detection for scenario building.	https://www.google.com/earth/

TIP: OBTAINING DATA

When using data from different institutions, you should familiarise yourself with their data sharing policies, which may be relatively open or more restrictive. Data acquisition may also require formal agreements with data providing bodies. Make sure that any property rights for the distribution and publication of data, or products derived therefrom, are respected.

IRI	The IRI Data Library is a powerful and freely accessible online data repository and analysis tool that allows a user to view, analyse, and download hundreds of terabytes of climate-related data through a standard web browser.	https://iridl.ldeo.columbia.edu/
NOAA's Hazard Frequency	For many specific hazards (not disasters), detailed databases also exist, which can be used to find out the approximate frequency of events for a given area and time frame. For example, for geophysical hazards check out NOAA's National Geophysical Data Center, or specifically for seismic events, the USGS's Earthquake Hazard Program.	http://www.ngdc.noaa.gov/hazard http://neic.usgs.gov/neis/sopar/

Socio-Economic and Climate Data

climada uses mainly data which are readily available at many governmental institutions. However, in some cases, additional sources for comparison or encompassing larger areas might be useful.

Dataset	Description	Source
Population data	Population data are useful for both assets and socio-economic scenario. If population data are required, and non-national or regional sources are available, the global population database at Columbia University might be helpful. However, census datasets constitutes more reliable sources if available and are usually provided by national and regional governments.	http://sedac.ciesin.columbia.edu
Digital Chart of the World (DCW)	The DCW is a global base map of coastlines, international boundaries, cities, airports, elevations, roads, railways, water features, cultural landmarks, etc. It was originally developed in 1991/1992, and national boundaries reflect political reality as of that time, thus in parts it is outdated. However, it still forms a widely used dataset that is free and easily obtained. One can search by country, and decide which data layers are needed.	https://www.libraries.psu.edu/psul/maps/SearchingCAT.html
FAO/Geonetwork	The Food and Agricultural Organisation (FAO) of the UN has prepared a number	http://www.fao.org/geonetwork/srv/

	of useful geotools, including the Geonetwork. Here you can search globally or by region, use existing maps or customised ones. The available data comprise base layers (e.g. boundaries, roads, rivers), thematic layers (e.g. protected areas), or a backdrop image (e.g. World Forest 2000).	en/main.home
Climate Change Data	This portal is intended to serve a community of GIS users interested in climate change. The free datasets of climate change projections can be downloaded as a shapefile, a text file, or as an image. Many 2D variables from modelled projected climate are available for the atmosphere and land surface. These climate change projections were generated by the NCAR Community Climate System Model for the 4th Assessment Report (AR4) and for the 5th Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC).	https://gisclimatechange.ucar.edu/

Step 2: Quality control

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

- ✓ Are the data in an appropriate format?
- ✓ Is the temporal or spatial coverage adequate for your purpose?
- ✓ Do you have missing values or outliers in your data?
- ✓ Are the data in the correct geographical projection?

If your datasets fail this quality check – and you are unable to apply any of the remedies described above – you will need to consider another approach. This may be an alternative data source, a proxy, or an alternative indicator (e.g. distance to school instead of census data on education levels) or alternative means of data acquisition such as expert input. As a last resort you may need to modify your scope or the set of hazards selected. The following Phases are closely linked to Phase 2 and depend heavily on the quality and availability of the data.

Step 3: Data management

Once datasets are collected (Step 1) and checked for quality (Step 2) they should be stored in a common database to avoid the risk of redundancy and data loss.

This might range from a simple data collection in a structured set of folders to more complex databases (e.g. Excel spread sheets, geo-databases, Access databases, distributed web-based databases). You may need to transform different types of data into a common data format (see climada manual). If you are working with multiple partners and stakeholders, you should ensure that they can all access the different datasets required for further analysis. Depending on the scope of your

assessment you may also need to assign responsibilities for database management and maintenance.

We recommend also the use of metadata as it is an important element in data management. Metadata are, simply, data about data, functioning much like a catalogue which provides data on the books in a library. It describes the content and characteristics of the different datasets and instructions for interpreting values. This includes where and when the data were obtained and analysed, the institution responsible for it and instructions for searching and other functions. Although this is a time-consuming exercise, experience has shown the importance of documenting data, particularly when qualitative or quantitative questions regarding your data arise. Documenting and organising your data properly might save time at a later stage of the project or for further iterations.

PHASE 3: Developing Scenarios

DESCRIPTION OF THE PHASE

This Phase outlines the essential steps for defining your climate and socio-economic scenarios. It shows how to assess the current situation and decide what scenarios, life span of investment, key issues are relevant for your objectives. It assists you in defining a time horizon relevant for the CCA measures, hazards and financial/economic scenarios you have considered in Phase 1. In addition, it provides guidance in obtaining and developing scenario relevant information for hazards, assets and economic scenarios (climada will not be needed in this phase).

KEY STEPS

Step 1: Analyse the current socio-economic situation and develop socio-economic scenarios

- ✓ *What is the actual economic development and population growth?*
- ✓ *What sectors are growing faster than others?*
- ✓ *Is there any strategic planning in your region of interest (also in terms of planned settlements, infrastructure)?*

Step 2: Define a time horizon

- ✓ *Considering discussion in Phase 1, what time horizon is best appropriate to the needs of your study?*
- ✓ *Do you want to choose one or several time horizons?*
- ✓ *What are the main uncertainties in your model and scenarios?*

Step 3: Develop one or more climate scenarios

- ✓ *Is there a need to consider several scenarios?*
- ✓ *What would be the benefit of having several scenarios?*
- ✓ *What type of scenario aggregation fits your needs*

INPUT NEEDED

For this Phase, you will need:

- ✓ *Climate and socio-economic data from Phase 2*
- ✓ *A good overview of the current situation in terms of climate variability and climate change, socio-economy and planning in the selected region*
- ✓ *A general idea of what kind of CCA measures you want to implement (implementation time might be an issue)*
- ✓ *A general idea of the uncertainty related to climate and socio-economy in your region*

EXPECTED OUTPUTS

After this Phase, you will have:

- ✓ *A time horizon defined for your CCA measures and for your scenarios*
- ✓ *Well defined climate scenarios (moderate or extreme)*
- ✓ *Well-defined socio-economic scenarios*

TOOLS AND ADDITIONAL INFORMATION

- ✓ *Criteria for time horizon selection*

Getting Started

Scenarios are consistent stories describing possible futures. For your assessment, scenarios can be relevant for evaluating impacts of climate variability and climate change in your region and the consequences for potential CCA measures regarding adaptation. The main idea is to develop realistic alternative development paths for your region and see how population and assets at risks are affected by climate risks.

This Phase summarises the design and development of baseline socio-economic and climate scenarios for use in your assessment. Although scenario development can be very time-consuming, it should not divert you from the main objective of your assessment. The point of the exercise is to help understand how future development paths can affect vulnerability to climate change. Several steps are necessary to develop scenarios. In a first step, an analysis of the current situation will provide you with a good overview of existing drivers. In a second step, you will decide which time horizon(s) are most appropriate to your study. Although it is a small step, it is very important for the rest for your assessment. In Step 3, you will develop your climate scenarios and aggregate them into climada.

Step 1: Analyse the current situation and develop scenarios

In examining vulnerability and adaptation to climate variability and climate change, it is important that the climate be projected to change over many decades. During this time, it is reasonable to expect that socio-economic and natural conditions will change, in some cases quite dramatically. As a result of these changes, vulnerability to climate variability and climate change and effectiveness of adaptations could also change.

In Phase 1 and Phase 2, data and discussion have been made about key drivers relevant for the future magnitude and character of climate impacts in your region. These key drivers have been prioritised with stakeholders for example during different workshops.

Example of key drivers could be:

i) economic development and diversification
ii) the expected magnitude of climate variability and climate change
iii) population growth
iv) cultural and religious driver
v) technological driver

You should make sure that your approach is consistent with existing development plans in your study area. Economic growth is often linked to core determinants as education and population growth. You can develop as many scenarios as you see fit, however, considering that climate scenarios will add up, we recommend restricting the number of socioeconomic scenario to a maximum of four (4). It is important to note that your scenarios will influence the overall asset value (and your future population).

Guiding Questions

Below, we suggest a series of guiding questions in order to better formulate your socio-economic scenarios:

- ✓ What is the actual economic growth?
- ✓ What are the projections from different institutions for my country/regions?
- ✓ Is there any existing report or development plan available?
- ✓ What are the key drivers in my regions?
- ✓ How many scenarios are sufficient to cover different (uncertain) future?
- ✓ What are the main uncertainties linked with these scenarios/drivers?
- ✓ What is the actual and expected discount rate?

It is also important to note that the discount rate is rather not a very sensitive parameter in climada. It means that introducing different discount rates will not significantly influence the outcome of your assessment and CCA measures will still have the same ranking and effect.

Step 2: Define a time horizon

A time horizon generally represents the time when you want the projection to end. Typically, one also speaks of short-term, long-term or middle-term scenarios. Choosing the right time horizon is very important, as it will help you in projecting the cost and benefits of the CCA measures you will select into the future. A time horizon too far into the future might be perceived as unrealistic, whereas a time horizon too close might diminish the positive effect of some CCA measures (especially green CCA measures). Hence, an appropriate time horizon over which climate change impacts are assessed should be established. This should match the intended lifespan of the assets, systems or institutions being financed under the project. In some cases, it may be appropriate to use observed data plus more than one time horizon to understand shorter-term and longer-term climate change implications, bearing in mind that the longer the time-span, the greater the uncertainty. This should consider planning, construction, financing, operational and design life cycles as well as decommissioning and/or removal or replacement. In order to assess the climate change signal above observed climatic variability, the characteristics of future climate should be assessed over a period of at least 20 to

30 years, e.g. near future (2021-2050) and distant future (2070-2099). A baseline scenario of a suitable historical reference period should also be used.

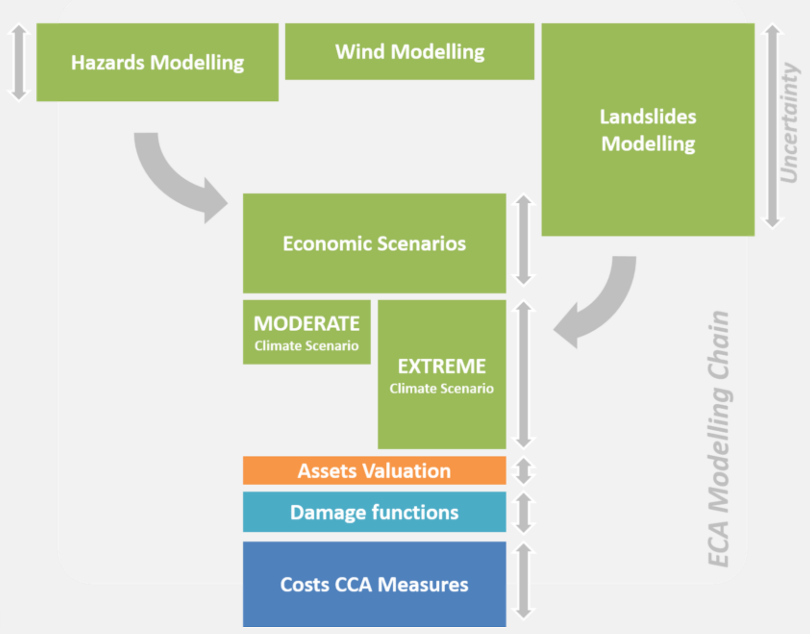
Whereas climate modellers often use scenarios that look forward 100 years or more, socioeconomic scenarios with similar time horizons may be needed to drive models of climate variability and climate change, climate impacts, and land-use change. However, policymakers also may wish to use socioeconomic scenarios as decision tools in framing current policies for climate variability and climate change adaptation. In this context, time horizons in the order of 20 years may be more appropriate, reflecting the immediate needs of decision makers. Short-term socioeconomic scenarios can still be very uncertain. "Surprises" such as economic slumps or booms, wars, or famines frequently occur in social and economic systems. Over the course of 50–100 years, even the most basic scenario drivers, such as population and aggregate economic activity, are highly uncertain, and their future development can be projected with any credibility only by using alternative scenarios. Moreover, technologies will have been replaced at least once, and those in use 100 years hence could have unimagined effects on climate sensitivity and vulnerability. Politically led developments in local, regional, and international systems of governance also will unfold along unpredictable paths.

TIP: DISCOUNT RATE

If you want to compare benefits and costs occurring at different time scales, "discounting" is needed to express future costs or benefits at today's equivalent value. Discounting is mechanically easy, but no agreement exists on what the correct discount rate is. Controversy over discounting lies at the heart of the debate on CBA, in that the choice of discount rate can often determine whether net benefits are found to be positive or negative. So how and why are discount rates chosen? Here are some quick and dirty answers. The real rate of interest is the appropriate discount rate for benefit cost analysis. Market interest rates should be used for discounting because they reflect the rate at which those in the economy are willing to trade present for future consumption. Market rates also reflect social preferences.

BOX: UNCERTAINTIES

While using the ECA methodology, you'll find uncertainties are inevitable. They also should be qualified whenever possible. In the figure below, uncertainties associated with each component of the ECA modelling chain is displayed.



An important source of uncertainty in the ECA methodology is introduced by economic and climate scenarios. Indeed, producing scenarios always introduce uncertainty in a modelling exercise. The economic and population growth scenarios, although based on actual observations, are simple and do not reflect possible fluctuations. Nevertheless, they provide a good estimation of a mean trend and should be treated as such. Climate scenarios are more challenging to evaluate. Although the scenarios used are based on validated scientific data and models, not all climate scenarios agree in their conclusions. In addition, models are seldom calibrated for a certain region and especially precipitation simulations are sensitive to scale. Finally, there is usually less confidence in extreme scenarios than in moderate scenarios, the latter often being the results of a consensus among different models.

Below, we provide a couple of guiding questions to define the time horizon for your scenarios:

- ✓ What is the time horizon of the development plan (if any)?
- ✓ Does the time horizon fit the vulnerability of climate CCA measures?
- ✓ How many time horizons do you want to consider?
- ✓ What are the main hazards you want to consider and what time horizons are they normally associated with?
- ✓ How uncertain are the climate projections in your region?

Step 3: Develop your climate scenarios

A climate scenario is a plausible representation of future climate that has been constructed for explicit use in investigating the potential impacts of anthropogenic climate change. Climate scenarios often make use of climate projections (descriptions of the modelled response of the climate system to scenarios of greenhouse gas and aerosol concentrations), by manipulating model outputs and combining them with observed climate data. Examples of climate change scenarios are increased frequency of strong hurricanes, increase of storm surge height, sea level rise, prolonged droughts, and increase in extreme precipitation. Generally, developing climate scenarios could be extremely time-consuming. Given the purpose of your study, you should consider studying literature for your region or consult directly the meteorological office or research institutions, which might have available (and validated) information about your region. Below, we propose some guiding questions in order to help you to develop your climate scenario:

- ✓ Are there any existing climate scenarios already available for your region?
- ✓ Is there any additional information regarding your NAPs, NDCs and NatComs?
- ✓ Considering the hazard selected, what scenarios are meaningful?
- ✓ What is the scientific literature suggesting about the hazards selected?
- ✓ How will projections in temperature and precipitation influence the hazards you have selected?
- ✓ How can the drivers (cf. step 1) influence your scenarios?
- ✓ Will a moderate scenario be sufficient, or do you want to consider an extreme climate as well (recommended)?

Aggregate climate and socio-economic scenarios

In order to introduce your scenarios into climada, it is advisable to create an aggregated version of them, not exceeding 4 scenarios in total. There are several ways to aggregate your scenarios as shown in Figure 10. We recommend a "matrix" approach, combining drivers for climate and socio-economic drivers. It will facilitate your communication with stakeholders and offer viable alternatives for planning.

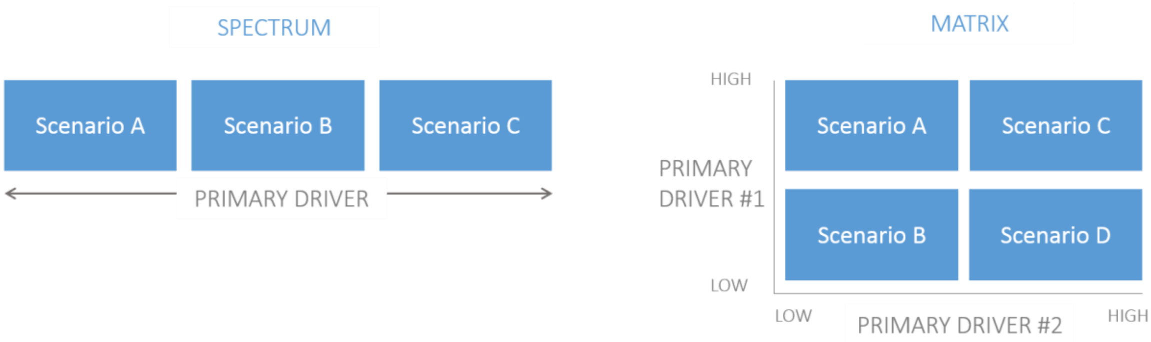


Figure 10 Different types of scenario aggregations

PHASE 4: Modelling Hazards

DESCRIPTION OF THE PHASE

This Phase outlines the essential steps for modelling hazards selected in Phase 1. It will assist you in using the data gathered in Phase 2 and include scenarios developed in Phase 3. In addition, it will provide you with guidance on how to create hazard maps using climada for selected hazards.

KEY STEPS

Step 1: Generate hazard set frequency and intensity (can be done within climada, see the different hazard modules, i.e. tropical cyclone, storm surge, torrential rain, earthquake, winter storm in Europe).

- ✓ *How are return periods generated from historical data?*
- ✓ *What are return periods?*
- ✓ *How are hazard sets produced?*

Step 2: Generate probabilistic hazard event sets for today and for your scenarios

- ✓ *How do I create hazard events?*
- ✓ *What information should be included in my hazard events?*

Step 3: Export your hazard probability to climada (if you have not used the preinstalled climada hazards)

- ✓ *What format can I export into climada?*
- ✓ *How is this format generated?*

Step 4: Double check your probability maps against historical extreme events

- ✓ *How do I make sure my results fits observation?*
- ✓ *What are the limitations of my approach?*

INPUT NEEDED

For this Phase, you will need:

- ✓ *Selected Hazards from Phase 1*
- ✓ *Historical data about hazards (Phase 2)*
- ✓ *Scenarios from Phase 3*
- ✓ *A general understanding of a probabilistic approach*
- ✓ *A good understanding of GIS applications*
- ✓ *Historical maps of extreme events in your region*

EXPECTED OUTPUTS

After this Phase, you will have:

- ✓ *Probabilistic hazard sets in climada format*
- ✓ *Probability maps for your region*

TOOLS AND ADDITIONAL INFORMATION

- ✓ *climada hazard module (cf. climada manual)*
- ✓ *GIS application for manipulation of hazard sets (optional)*

Getting started

climada offers for some hazards an embedded approach to hazard modelling. In this Phase, in order not to duplicate the climada manual, we will focus on how to introduce hazards which are not included in climada. In principle, these steps follow the concept offered with climada and will allow you full flexibility in modelling your hazard “ex-situ”. You will learn how to generate probabilistic events from historical values from historic data sets (step 1). Then we will show examples of hazard probability maps and see how to generate them for current and future scenarios (step 2). In step 3, we will review how to export these maps to climada, and how to validate them against historical events (step 4).

Step 1: Generate hazard set frequency and intensity

Step 1 sets the basis of the overall hazard approach. Basically, it consists in transforming historical observations you have gathered in Phase 2, such as rainfall records, or water level records into statistical events. Rainfall and water level data should be of high quality with few data gaps. In case no water level data are available, they could be simulated using inundation models or extrapolated using standard procedures and correlation between rainfall intensity and flood intensity.

It is important to adapt your approach to the data available in your region. And you should make sure to choose the best data available for your assessment. In the BOX below, we showcase an example of how to create hazard maps from secondary data provided by the government in San Salvador.

Creating return periods

The damage frequency curve (DFC) is an annual per-occurrence damage exceedance frequency curve, showing the return period of a certain damage level to be reached or exceeded for a given return period. A DFC is constructed by sorting a per-occurrence damage event set by descending damage amount and assigning the corresponding return periods, as given by the temporal extent of the damage event set. If the damage event set spans say 100 years and contains for

example only three damaging events of amounts a, b and c, with a>b>c, the largest damage reached or exceeded only once in these 100 years is a, while a damage level of b is reached or exceeded twice in these 100 years, hence the return period for a damage level of b is 50 years, and c is reached or exceeded three times, hence its return period is 33.3 years. Please note that large events occur less frequently than smaller events, therefore a 100yr (an event having a probability of occurring every 100 years) is larger than a 50yr event. It is common practice to use the following return period: 2yr, 5yr, 10yr, 25yr, 50yr and 100yr.

The frequency (return period) is the inverse of the expected number of occurrences in a year). For example, a 100-year flood has a probability of 1/100= 0.01 or 1% chance of being exceeded in any one year and a 50-year flood has a 0.02 or 2% chance of being exceeded in any one year. This does not mean that a 100-year flood will happen regularly every 100 years, or only once in 100 years. Because return periods are statistical values, in any given 100-year period, a 100-year event may occur once, twice, more, or not at all, with each outcome sharing the same probability.

Step 2: Generate hazard probability maps

Once you have generated your return periods, it is important to locate where the hazard selected will take place. We recommend drawing intensity maps for every return period. If you are working with rasterised data sets, you will make sure that you gather information about every cell located in your hazard zone. In this case, resolution is an important factor and you will make sure it is in an equation with the resolution of your assets and with the data available for your study. In Figure 11 we show water depths in San Salvador, at a 10m resolution. Higher depths are displayed in dark blue and light blue indicates lower depths. Unsurprisingly, the river channel is where water depth is the highest, with depths exceeding 7m at certain points. Water depths for other return periods (2yr, 5yr, 10yr, 25yr and 50yr) are not displayed on this figure and were provided in different files.

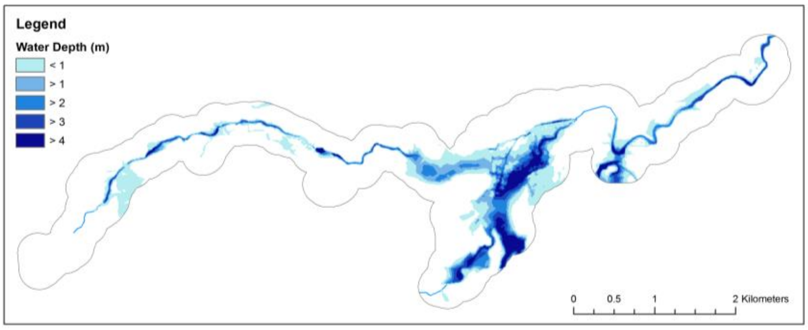


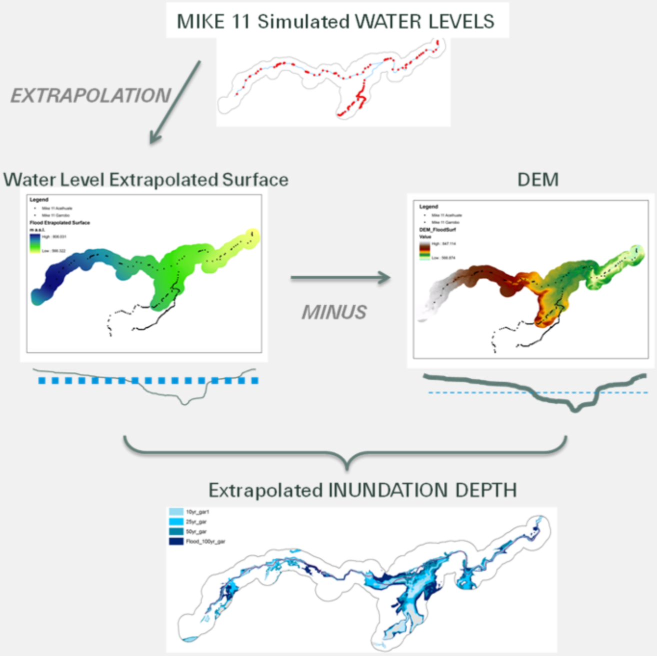
Figure 11 Water depth for 100yr flood events in San Salvador (KfW, 2015a)

BOX: Creating Hazard maps in San Salvador

The Environment Ministry of El Salvador (MARN) has provided water levels *for research areas described below. These water levels were obtained using both a rainfall-runoff model (HBV) and the hydraulic model (Mike11). With Mike11, a 1D-inundation model widely used, boundary conditions are necessary for the simulation of water levels. These boundary conditions (river inflow and river outflow) can be determined using a rainfall-runoff model. This model simulates a set of different boundary conditions for selected rainfall events. In this study the following return periods have been selected: 2yr, 5yr, 10yr, 25yr, 50yr and 100yr.*

In addition to model simulation, a 2m resolution DEM (MOP, 2014) was provided, courtesy of the Ministry of Obras publicas (MOP). This high-resolution Digital Elevation Model (DEM) was tested for sink holes in order to produce a hydrologically-correct DEM.

Because data were originally not collected for the purpose of simulating large extreme events, they do not cover the whole food plain, as necessary in this study to simulate inundation maps for different return periods. Nevertheless, to create inundation maps, water depth, there is crucial information at each point in the research area. Hence, the extrapolated water level surface, generated by this process, is thereafter subtracted from the DEMs. During this process, positive and negative water depths are generated relative to their respective ground elevation. In our case, only positive values - representing the water depth relative to elevation – were considered. The method illustrated below was reiterated for all return periods.



Step 3: Export your hazard probability to climada

For events generated with climada, intensities and coordinates are automatically generated. Externally generated events, (i.e. not automatically generated by climada, for instance inundation) need to be imported into climada. Once you have created your water depth (hazard intensity) maps, it is time to export them into climada. Because climada is based on MATLAB®/Octave, it accepts different formats in its raw form. However, we recommend transforming them from your rasterised map into a geo-ascii file. In this file, or files, you will provide information about your data which can be read by MATLAB®. Most GIS software packages create ascii files automatically. Please refer to the climada manual for further information.

Step 4: Double check against historical events

Once hazards have been modelled and return periods (frequency) of hazards determined, it is essential to verify that the model output fits reality. Henceforth, model output should be compared against observed data and validated as far as possible. In order to validate your results, and in the absence of available satellite data, you could use existing inundation maps which might have been provided by your partners. In the case of San Salvador, a synthetic inundation map based on a 1:25000 topographic map, with basic water level (very high, high and moderate) was provided. Although relatively approximate, this method was validated by local expert knowledge and constitutes a good base for comparison purposes. As shown in Figure 12, we assumed that “very high” inundation levels correspond to 100yr and 50yr floods and superposed them for comparison.

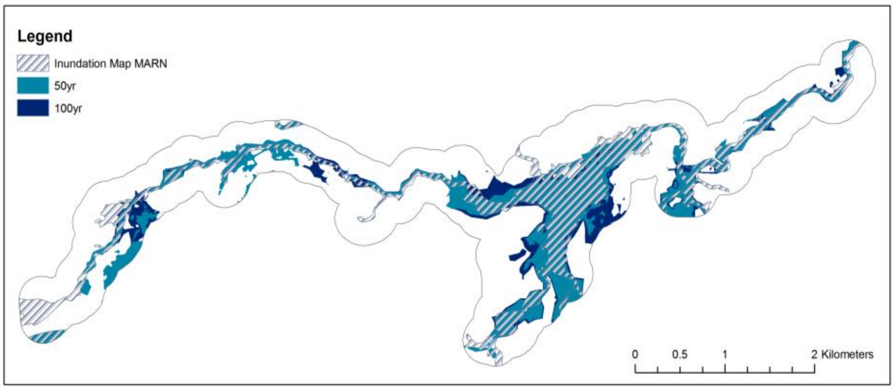


Figure 12 Comparison of 100yr and 50yr flood extend with “very high” inundation map provided for comparison purposes (KfW, 2015a)

This figure shows a significant agreement between both synthetic and created inundation maps based on water depth. Disagreements between both inundation areas are explained by the differences in the methodology applied and to the difficulty in applying the synthetic “very high” flood extend to a return period. Nevertheless, such a level of agreement is encouraging and points towards a high reliability in the hazard map simulation.

Considerations on uncertainties

Uncertainty is inherent to spatial data and spatial analysis and therefore it is of essential importance to effectively communicate it, particularly when dealing with decision-making in a changing climate. As in all modelling exercise, the quality of input data is crucial to the final output. Quality issues with the DEM, historic data, or fitted distribution have been reduced to a minimum through careful quality control. In addition, hydraulic (external) modelling introduces a series of uncertainties in water level due to a series of parameters which are calibrated rather than observed. Uncertainties at all stage of your assessment should be carefully listed and presented accordingly.

PHASE 5: Valuating Assets

DESCRIPTION OF THE PHASE

This Phase outlines the essential steps towards a sound valuation of the asset categories for hazards selected in Phase 1. It will provide you with guidance on how to best value different categories of assets and how to insert them into climada. In addition, it will provide you with tips on how to value assets without monetary values or assets with low monetary values. Particular emphasis will be placed on a pro-poor approach dedicated to developing and emerging countries/economies.

KEY STEPS

Step 1: Select assets categories fitting your scope

- ✓ *How many assets categories are necessary?*
- ✓ *How can I tailor categories to my scope and objectives?*

Step 2: Localise your assets

- ✓ *What are the methods for localising my assets?*
- ✓ *Which methods are adapted to my needs?*

Step 3: Give a monetary value to your assets

- ✓ *What are the best practices to obtain monetary values for my assets?*
- ✓ *How does monetary value change with hazards?*

Step 4: Export your asset values into climada format

- ✓ *How can I import asset data into climada?*
- ✓ *Where are the major pitfalls?*

Step 5: Validate your total asset value

- ✓ *Why is it important to validate your results?*

INPUT NEEDED

For this Phase, you will need:

- ✓ *Selected asset categories from Phase 1*
- ✓ *Geographical data about asset locations from Phase 2*
- ✓ *Scenarios from Phase 3*
- ✓ *A field team/consultant for your field survey*
- ✓ *A good overview of monetary values for structural assets*
- ✓ *A good understanding of valuation techniques for environmental assets (if applicable)*
- ✓ *A good command of GIS or Google Earth applications*

EXPECTED OUTPUTS

After this Phase, you will have:

- ✓ *A map of your assets with values (population) related to them*
- ✓ *Your asset input ready for climada*
- ✓ *A good understanding of your global asset value and population for different scenarios*

TOOLS AND ADDITIONAL INFORMATION

- ✓ *climada Asset Phase (cf. climada manual)*
- ✓ *GIS application software*

Getting started

climada offers the possibility to introduce asset value and location and align them with probabilistic hazards. In this phase you will learn how to select different type of assets according to the scope of your project (step 1). You will learn how to localise your assets using different methods (step 2). Then we will show examples on how to give a monetary value to your assets (step 3). In step 4, we will review how to export this information to climada, and how to validate them against historical events (step 5).

Step 1: Select assets categories fitting your scope

Selecting categories of assets is an important step in your CCA assessment. Depending on the scope of your study and on your specific objectives, you might choose different asset categories. Because assets will be valued, bias on efficiency of CCA measures is introduced for assets with larger values. In practice it means that assets with higher values (for instance hospitals, school or government buildings) will receive damage with a higher total cost than assets with lower value (such as informal settlements). In order to reduce this bias, it is essential to differentiate between different categories. You will later be able to present your results by assets, and therefore focus on your scope. Below, we provide a box focusing on pro-poor approach in CCA assessments.

TIP: NUMBER OF ASSETS

It is best practice not to define more than 8 assets. By doing so, you reach a sufficient level of detail and you will keep your study time efficient. Typical categories of assets can be: **housing** (in and outside of informal settlements), **hospitals** and health centres, **schools**, **road networks** and large **buildings**, **industry**, **agriculture** and in addition **persons.**

Please note that it is important to attribute a unique number to each asset categories!

How do you define categories?

Asset selection is an essential step in the model development and we recommend following the stages listed below:

1) First, define a maximum number of asset categories (see TIP below),
2) A long list of possible categories of asset is defined
3) Categories of asset are well defined
4) Selection criteria are defined
5) Scores are attributed to each category of asset. Scores range from 1 to 3, 3 being the highest score.

The following criteria can be selected

a) Focus of the study (for example: poverty);
b) The percentage of the total population represented by a category of asset. The higher the percentage of population represented, the higher the score;
c) Vulnerability of assets within a category. The higher the vulnerability, the higher the score;
d) Accessibility to information. Defining asset where no information about their value is available should be avoided;
e) In case of damage, what percentage of the population will be affected;
f) Do assets in a category have a societal value? For instance cultural assets or social assets such as a hospital have a strong societal value for a community;
g) The approximate contribution of the asset category to the total value of assets in the area.

TIP: PRO-POOR FOCUS AND CHOICE OF ASSET SUBCATEGORIES

In the case of Barisal, available housing statistics differentiated housing into four subcategories of quality and value. This provided the opportunity to spatially concentrate measures on those regions where hazard impacts in relation to household income were most detrimental. Especially in the case of housing it can be insightful to differentiate assets which correspond to different levels of household income.

Step 2: Localise your assets

Once you have defined your asset categories, you should geo-localize your assets. You will have to identify each asset in your categories and assign it latitude and

longitude values in order to export it into climada later. To obtain spatial information about your asset, there are several options available:

Method 1: Google Earth

Using this method, you can pinpoint assets online and export them directly into climada. However, using this method is cumbersome and you will need prior knowledge of the region in order to different between asset categories. On the other hand, this method is very beneficial if you are interested in a rapid appraisal study, rather than an in-depth analysis.

Method 2: GIS software packages

If GIS raster files and/or shape files are available in your region (cf. Phase 2) you can use them to build your own asset portfolio. This approach has the advantage that assets are readily geo-located and you have the opportunity to reach a greater level of detail, depending on the quality of your data set. If unavailable, please refer to method 1.

Method 3: Field Survey

A field survey is the best solution to validate assets you might have identified using one of the above-mentioned methods. The main advantage is a direct validation of your asset value with direct observation. In addition, it offers a greater recognition of your results when presented to stakeholder and decision makers. However, such field surveys can be resource intensive and should be planned carefully. Sub-contracting teams of technical field agents is possible and can also be done in parallel to other tasks such as gathering geo-location data. Photography and field sheets can be created for a sample of sites representative of a given neighbourhood. Information gathered at each site was thereafter analysed according to several structural criteria relevant to the property value such as:

- ✓ Frame structure (column, beam) of structural walls
- ✓ Roof system
- ✓ Overall finishes, external works
- ✓ Doors and windows quality

These criteria were subsequently analysed and information relating to construction costs (such the age of the building) or construction quality and number of floors, are introduced in the valuation exercise. A template of a field survey sheets is provided in Annex 2.

Step 3: Construction value for Housing, Schools and Hospitals

Building quality and stability of the elements as well as the degree of maintenance of a construction is a key indicator of a building's value. Older buildings, even well maintained, see their value decrease with time. Periods of depreciation can be considered: for example up to 20 years, 20 to 40 years and over 40 years. Based on local expert knowledge and on the outcomes of your field study (if applicable), ranges for value per square metre can be determined: for example in San Salvador it was found that USD 500.00/m² for recent buildings (up to 20 years), USD 350.00/m² for buildings constructed 20-40 years ago and USD 200.00/m² for buildings constructed over 40 years ago were accurate values. Based on these price ranges, and on an estimation of building area, construction values were evaluated for every asset. Table 5 summarises the different depreciated costs assigned to buildings in San Salvador.

Table 5 Overview of depreciated construction costs for different asset types in San Salvador

Asset Type	Depreciated construction costs per m² (in USD)		
	Up to 20 years	20-40years	Over 40 years
Housing	500	350	200
Schools	500	350	200
Hospitals	500	350	-

Figure 13 provide an overview of asset valuation in San Salvador. Values in USD are given for housing in poor areas and other areas, whereas other categories are located in the region of interest.

Depending on the hazard considered, the reconstruction cost of your asset might be different. In this case, for landslides, the road network is likely to be totally damaged. It implies higher costs for re-construction including earthwork, clearing and piling. In the case of inundation, water causes damage which is more superficial and only surfacing and drainage ware considered in the cost estimation.

In the context of developing countries, one can often observe trends of increased quality and value of buildings and lower household sizes as a result of economic growth. This could drive a non-linear increase of assets which are at risk. In order to project this increase in a transparent way, one can separately project the number of households, household size and average floor space per household, to subsequently confront this with an average value of floor space.

TIP: VALUATING INFORMAL SETTLEMENT

For the particular case of housing in informal settlement in San Salvador, an average value of USD 5,000 was estimated per asset, for an average surface of 35m². In order to reflect the heterogeneity of asset values in urban poor areas, the average value was distributed across a normal distribution using the following parameters: μ=5000; r=5000*20% where μ is the average value of each assets and r the standard deviation for the normal distribution. Values are thereafter randomly distributed among housing assets in poor areas.

Note: poor areas were previously identified and delimited spatially.

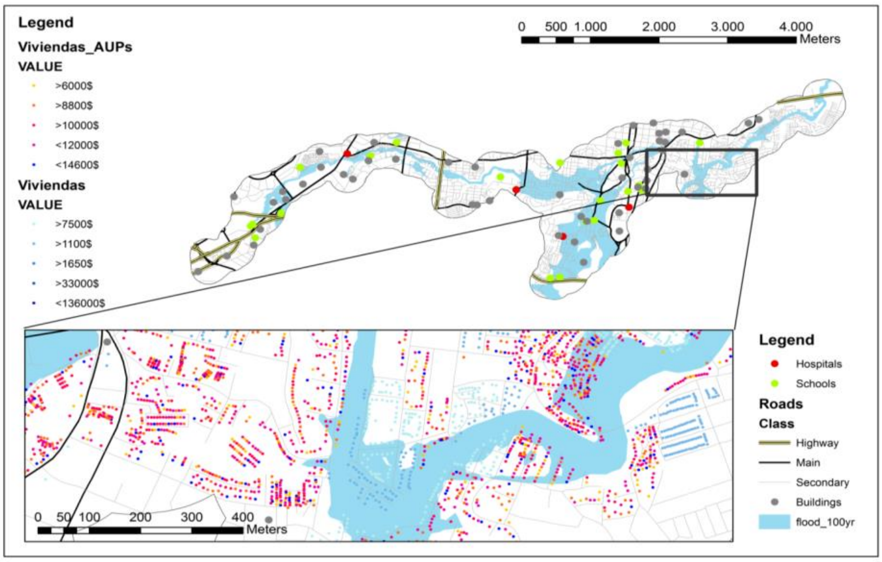


Figure 13 Location of assets in San Salvador (KfW (2015a)

Road Network Valuation

We provide herein another example of asset valuation using different proxies. In this case, we will discuss an approach to road network valuation. The unit cost of road construction in USD per kilometre consists of the sum of the sub-costs of the road construction activities. Road construction unit costs are estimated by dividing the machine rates by the production rates for the various activities involved in road construction. You can consider the following road construction activities: clearing, piling and earthwork (in the case of landslides only), surfacing, and drainage. In absence of local knowledge, cost and calculations can be based on the FAO costs report on road construction cost estimation[18].

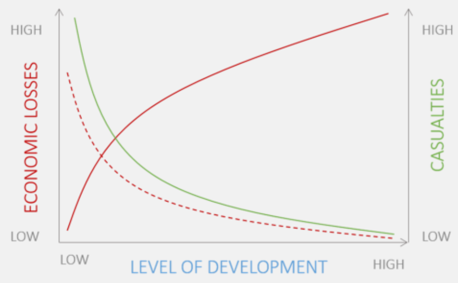
[18] http://www.fao.org/docrep/t0579e/t0579e06.htm

BOX: PROMOTING A PRO-POOR APPROACH

One of the main issues with monetary assets, and quantitative approaches in general, such as the one promoted in the ECA Guidebook, is the inherent bias towards the richest populations. Although the poorest of the population are usually the most vulnerable, their assets and corresponding damages are of lower value and measures to reduce this damage thus offer a lower return on investment,. In addition, there is an inverse relationship between the level of development and loss of human lives in the case of a disaster. About 95% of the disaster related casualties occur in less developed countries, where more than 4.200 million people live. The greater loss of lives due to disasters in developing countries is due to several reasons:

- *The buildings are often of lesser quality, due to lack of building codes or lack of enforcement of them;*
- *More buildings are constructed in hazardous areas due to lack of land use planning;*
- *Lower awareness and disaster preparedness;*
- *Less accurate or missing early warning systems;*
- *Less accurate or missing evacuation planning;*
- *Less adequate search-and-rescues and medical facilities after a disaster.*

In the period 1991 – 2005 for instance, the USA had an estimated loss of USD 365 billion , Japan USD 209 billion, and China USD 173 billion.. However, economic losses attributable to natural hazards in less developed countries may represent as much as 100% of their Gross Domestic Product. GDP is the total market value of all final goods and services produced in a country in a given year, equal to total consumer, investment and government spending, plus the value of exports, minus the value of imports. UNISDR proposes a list of 50 events that caused the highest losses in terms of GDP, which highlights the fact that developing countries are relatively less resilient to disasters. As a general illustration, the figure below gives an indication of the relationship between the level of development and disaster losses.



Economic losses in absolute terms (billions of USD) are shown as a red line. They show an increase with the level of development, as the absolute value of elements at risk that might be damaged during a disaster increases with increasing level of development. Consequently, the choice of categories for assets is key to answer the objectives of the study. If the analysis is carried out in a developing context, or mixed-development context, categories should differentiate between high-income, lower-income, high-value and lower-value assets.

Clearing and piling costs can be calculated by estimating the area to be cleared and piled per kilometre of road. The earthwork cost is calculated by estimating the number of cubic metres of common material and rock which must be moved to construct the road. Surfacing costs are a function of the type of surfacing material, the quantity of surfacing material per square metre, and the length of haul. Drainage costs vary widely with the type of drainage being installed. The costs of drainage dips (water bars), culverts, and bridges are often expressed as a cost per distance which can then be easily applied in roads. In the following example from San Salvador, we have divided the road network into sub categories in order to reflect the existing conditions:

- ✓ **Highways**. Larger roads with 4 lanes, and advanced drainage system;
- ✓ **Major roads**: Large secondary roads, paved with up to 2 lanes;
- ✓ **Minor roads**: tertiary road network: roads are only partially paved with one lane.

Details about the differentiated costs calculation for inundation and landslides are displayed in Table 6. Please note that for more convenience, we suggest providing cost by distance units (/km).

Table 6 Detailed calculation of construction costs for roads in the case of inundation and landslide

	Surfacing (USD/**km**)	**Drainage** (USD/**km**)	**TOTAL/km (Inundation)**	**Earthwork and clearing (USD/km)**	**TOTAL/km (Landslide)**
Highways	14,314	2,448	**USD 16,762**	3,200	**USD 19,962**
Major Roads	7,157	1,224	**USD 8,381**	3,200	**USD 11,581**
Minor Roads	7,157	-	**USD 7,157**	3,200	**USD 10,357**

Population Estimation

Population estimation is essential if you have included this category in your assets. Information is not readily available. However, it can be derived, for example, from census or based on estimation of persons living per assets (housing). In San Salvador, according to the 2007 census, the number of persons per household varies between 3.7 to 3.8 people. In addition, based on other national and local estimations for allocations of drinking water in the urban area of San Salvador, a value of 5 persons per household is recommended. However, in order to represent the observed variability of number of persons per household, a “Poisson” distribution was used to generate random numbers of persons per household, keeping an average of 5 persons per household, whereas larger and smaller households are allowed within our sample. We used the following parameters in our distribution function. The Poisson distribution for this example is shown in Figure 14.

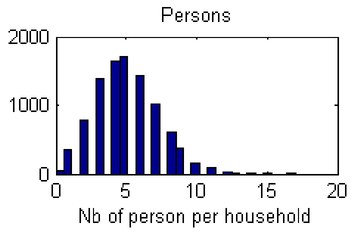
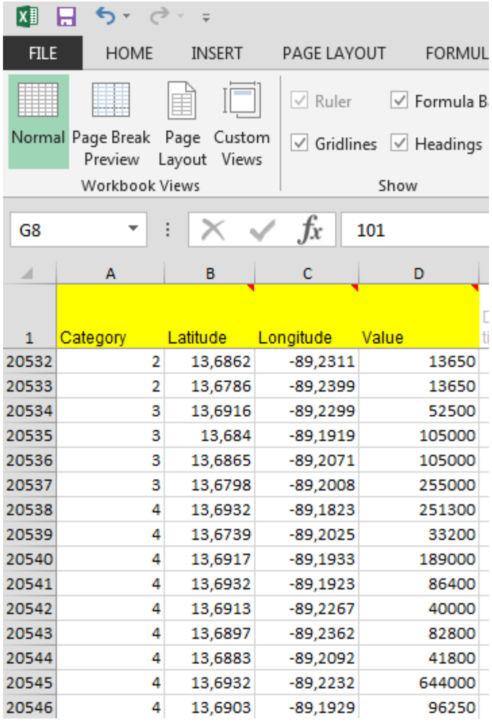


Figure 14 Population distributions for housing in informal settlement.

Step 4: Export your asset values into climada format

Once you have assigned values to your categories of assets, spatial location of assets and their respective values should be exported to climada. In this section we will show what is the format accepted by climada and what are the main pitfalls associated with it. In the climada manual additional detailed information is provided and we will therefore here only concentrate on the major pitfalls. Figure 15 provides a screenshot of the most important information related to formatting assets for climada. It is essential to provide a category identifier (or number) for each different category. Without this number climada will not be able to recognize your category. In the next column, latitude and longitude should be provided in decimal degrees in

order to be understood by climada. Finally, values are provided consistently in the same currency throughout your assessment for every asset.



	A	B	C	D
1	Category	Latitude	Longitude	Value
20532	2	13,6862	-89,2311	13650
20533	2	13,6786	-89,2399	13650
20534	3	13,6916	-89,2299	52500
20535	3	13,684	-89,1919	105000
20536	3	13,6865	-89,2071	105000
20537	3	13,6798	-89,2008	255000
20538	4	13,6932	-89,1823	251300
20539	4	13,6739	-89,2025	33200
20540	4	13,6917	-89,1933	189000
20541	4	13,6932	-89,1923	86400
20542	4	13,6913	-89,2267	40000
20543	4	13,6897	-89,2362	82800
20544	4	13,6883	-89,2092	41800
20545	4	13,6932	-89,2232	644000
20546	4	13,6903	-89,1929	96250

Figure 15 Screenshot from climada input file for assets

It is good practice to plot all your asset values and check their distribution (per asset category) to avoid typos and wrongly included commas. Please check the settings for your numeric system in Excel, especially concerning your decimal separator.

Step 5: Validate your total asset value against existing observations

In a last step, it is best practice to validate your aggregated values per asset against expert knowledge, so you are sure these momentary values (or population) are in line with reality. climada automatically generates such aggregated sums, but you can also do that externally. Such aggregate tables might be inspired from the following example from San Salvador:

Table 7 Overview of aggregated value per asset category for San Salvador

Code (LS)	Name	Total value (USD/people)	Unit	Sample Size	Mean	Min	Max
31	Housing in informal settlements	27,213,698	USD	2,634	10,331	5,416	14,081
32	Housing	359,476,870	USD	18,343	19,597	9,330	50,700
33	Schools	1,552,500	USD	7	221,785	52,500	250,000
34	Hospitals	6,161,300	USD	47	131,091	40,000	396,900
35	Road Network	88,549,376	USD	1,941	45,620	716	1,419,572
36	Large Buildings	23,036,300	USD	13	1,772,023	119,700	6,823,250
37	People in informal settlements	13,023	people	2,634	5	1	17
38	People	91,668	people	18,343	5	1	15
Total Asset Value		**505,990,044**	**USD**			**22,985 Assets**	
Total Person		**104,691**	**People**			**20,977 Households**	

PHASE 6: Creating Damage Functions

DESCRIPTION OF THE PHASE

This Phase outlines the essential steps for creating damage functions for the different classes of assets and for the different types of hazards. It will give you information and guidance in order to organise an expert workshop to gather information on past disasters in your region/country. In addition, it provides guidance on how to develop damage functions from historical observations and insert them into climada.

KEY STEPS

Step 1: Creating damage functions

Step 2: Exporting damage function in climada

Step 3: Calibrating and validating your damage functions

INPUT NEEDED

For this Phase, you will need:

- ✓ *Data about historical damages (per hazard)*
- ✓ *Construction details about your assets*
- ✓ *Basic knowledge of polynomial functions*
- ✓ *A general understanding on how your assets are affected by the selected hazards*

EXPECTED OUTPUTS

After this Phase, you will have:

- ✓ *Damage functions per asset categories and per hazard*
- ✓ *Calibrated results between assets and hazards*

TOOLS AND ADDITIONAL INFORMATION

- ✓ *climada manual and climada damage function generator (cf. climada manual)*
- ✓ *ERN vulnerability damage function generator (cf. manual and download at http://www.ecapra.org/ern-vulnerability)*

Getting Started

Damage functions are cumulative distribution functions used to represent the relation between hazard intensity and damages to a particular asset. They are

therefore central to bridge between hazard and damages. Damage functions are very sensitive and should be created with care. In Step 1, you will use historic damage information in order to build breaking point (where the curve change its directions) in certain damage function. You will then integrate the damage function you have created in climada (Step 2) and validate them in order to obtain realistic outputs (Step 3).

Step 1: Constructing damage functions

Damage data collected in Phase 2 can be useful to create damage functions. In addition to historic damages, we recommend organising at least one expert workshop in order to determine maximal damages on particular sets of assets and benefit from technical expertise for particular events or set of hazards.

Typical for damage functions

Typically, a damage function is a function evolving between 0 (no damage) and 1 or 100% (total damage of asset). But even in cases of extreme events, there will rarely be complete damage of all material assets. It means that only in rare cases, the asset will be destroyed totally. In Figure 16, we show a synthetic example of a damage function. Point A represents the level of hazard's intensity needed to trigger damage greater than 0, and point B represents the level of hazards intensity needed to reach the maximum level of damage on a particular asset. Note that the maximum level of damage is not necessarily 100%. Curves with different colours represent damage functions for different categories of assets. Each asset category has a specific hazard function depending on construction type, material and/or location.

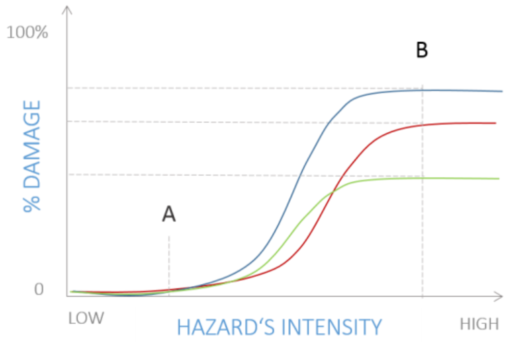


Figure 16 Example of synthetic damage functions as used in climada

Hence, damage functions are characterised by the following parameters:

- ✓ first occurrence of damage (Point A)
- ✓ maximum damage value (asset value) (Point B)
- ✓ shape of the function

The development of damage function usually needs the following steps:

- ✓ Representative categories of assets are selected in the area
- ✓ Sample of assets in a given area
- ✓ Values are averaged across each sample for each category of house and the damage function is constructed.

Expert knowledge workshop

In order to determine Point A and Point B, it is advisable to include stakeholders and technical experts in a technical workshop. At the workshop, which should not exceed a day; make sure to answer the following questions:

- ✓ What is your experience of damage for a particular hazard and category of asset?
- ✓ What was the intensity of the hazards?
- ✓ Where did it happen and when?
- ✓ Did you experience how CCA measures have reduced the damage on particular assets?

During this workshop, damage function should be explained in order to streamline understanding about the main underlying concepts.

Example for Housing in Informal Settlements for flood hazard in San Salvador

Data collected for the construction of the function of damage or vulnerability function to the category of housing in informal settlements:

- ✓ Damage is total (100%) when the water level reaches 2.8m (average height of informal settlement buildings),
- ✓ The damage is 90% when the water reaches the 1.5m depth,
- ✓ The percentage of damage is very abrupt after a metre and has a percentage of 50% (this could be higher) - This was reported or collected at the seminar and is mainly due to the construction type and light materials used for construction.

Figure 17 below illustrates the example described above:

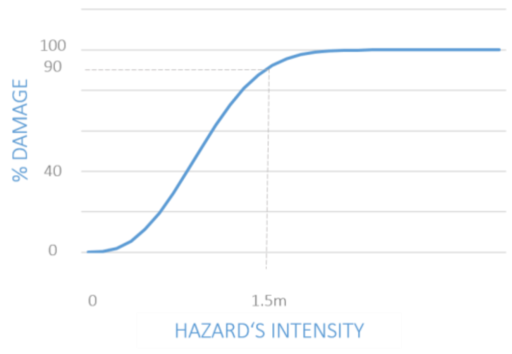


Figure 17 Illustration of a synthetic damage function developed for flood and housing in informal settlement in the urban area of San Salvador

TIP: DAMAGE FUNCTIONS FOR FLOOD

In normal conditions, floods cause damages only in *the cellar and on the ground floor. This is why it doesn't make sense to calculate damage arising in the whole building. Therefore a function is needed which reduces the asset value to the amount of actually expected loss. Damage functions give information on the amount of damage in percent for different water depths while considering the respective asset.*

A tool for generating damage functions

climada offers a function embedded in MATLAB® for automatic generation of damage function. Please refer to the climada manual for additional information. In addition, the following software has proven very convenient for constructing synthetic damage functions: ERN-Vulnerabilidad[19] (in this case damage functions are called vulnerability functions). This software package is available free of charge and generates synthetic damage functions curve for different type of hazards using a series of relevant parameters. ERN-Vulnerabilidad also includes a vulnerability curves database, and allows their elaboration depending on the main characteristic of the structural types under analysis. All curves can be exported to climada.

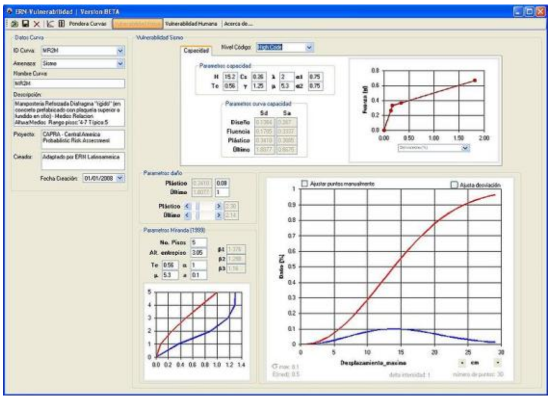


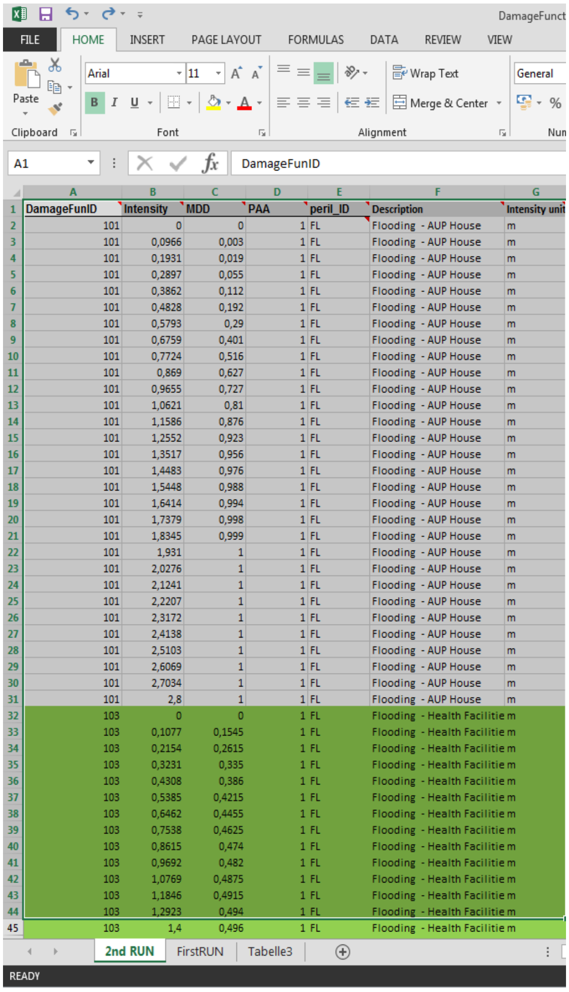
Figure 18 Screenshot of ERN-Vulnerabilidad

[19] http://www.ecapra.org/ern-vulnerability

Step 2: Exporting damage function in climada

Once you have developed your damage functions for your assets and for the hazards selected in Phase 1, it is essential to format these functions for climada. As for assets, climada has a convenient Excel interface allowing you to transfer your data relatively easily.

In the case of damage function, please refer to the climada manual for detailed instructions about the format. It is essential to allocate a unique identification number to your damage function. This way, climada will easily identify each function. It is best practice to link this identification number logically to those you chose for your assets and for hazards. For example if your asset ID for housing was “01”, choose “101” for the damage function related to housing and flood, “201” for the damage function related to housing and landslides etc. It will make finding and modifying damage functions easier for you at a later stage. Figure 19 shows a screenshot of the climada damage function file for San Salvador for different hazards and assets.



DamageFunID	Intensity	MDD	PAA	peril_ID	Description	Intensity unit
101	0	0	1	FL	Flooding - AUP House	m
101	0,0966	0,003	1	FL	Flooding - AUP House	m
101	0,1931	0,019	1	FL	Flooding - AUP House	m
101	0,2897	0,055	1	FL	Flooding - AUP House	m
101	0,3862	0,112	1	FL	Flooding - AUP House	m
101	0,4828	0,192	1	FL	Flooding - AUP House	m
101	0,5793	0,29	1	FL	Flooding - AUP House	m
101	0,6759	0,401	1	FL	Flooding - AUP House	m
101	0,7724	0,516	1	FL	Flooding - AUP House	m
101	0,869	0,627	1	FL	Flooding - AUP House	m
101	0,9655	0,727	1	FL	Flooding - AUP House	m
101	1,0621	0,81	1	FL	Flooding - AUP House	m
101	1,1586	0,876	1	FL	Flooding - AUP House	m
101	1,2552	0,923	1	FL	Flooding - AUP House	m
101	1,3517	0,956	1	FL	Flooding - AUP House	m
101	1,4483	0,976	1	FL	Flooding - AUP House	m
101	1,5448	0,988	1	FL	Flooding - AUP House	m
101	1,6414	0,994	1	FL	Flooding - AUP House	m
101	1,7379	0,998	1	FL	Flooding - AUP House	m
101	1,8345	0,999	1	FL	Flooding - AUP House	m
101	1,931	1	1	FL	Flooding - AUP House	m
101	2,0276	1	1	FL	Flooding - AUP House	m
101	2,1241	1	1	FL	Flooding - AUP House	m
101	2,2207	1	1	FL	Flooding - AUP House	m
101	2,3172	1	1	FL	Flooding - AUP House	m
101	2,4138	1	1	FL	Flooding - AUP House	m
101	2,5103	1	1	FL	Flooding - AUP House	m
101	2,6069	1	1	FL	Flooding - AUP House	m
101	2,7034	1	1	FL	Flooding - AUP House	m
101	2,8	1	1	FL	Flooding - AUP House	m
103	0	0	1	FL	Flooding - Health Facilitie	m
103	0,1077	0,1545	1	FL	Flooding - Health Facilitie	m
103	0,2154	0,2615	1	FL	Flooding - Health Facilitie	m
103	0,3231	0,335	1	FL	Flooding - Health Facilitie	m
103	0,4308	0,386	1	FL	Flooding - Health Facilitie	m
103	0,5385	0,4215	1	FL	Flooding - Health Facilitie	m
103	0,6462	0,4455	1	FL	Flooding - Health Facilitie	m
103	0,7538	0,4625	1	FL	Flooding - Health Facilitie	m
103	0,8615	0,474	1	FL	Flooding - Health Facilitie	m
103	0,9692	0,482	1	FL	Flooding - Health Facilitie	m
103	1,0769	0,4875	1	FL	Flooding - Health Facilitie	m
103	1,1846	0,4915	1	FL	Flooding - Health Facilitie	m
103	1,2923	0,494	1	FL	Flooding - Health Facilitie	m
103	1,4	0,496	1	FL	Flooding - Health Facilitie	m

Figure 19 Screenshot of damage function for flood hazard for different assets

Step 3: Calibrate and validate your damage functions

Damage functions are the most sensitive parameter in climada (and in risk modelling in general). It means that small changes in shape can possibly have large impacts on overall damage calculation in your CCA Assessment. It is illustrated in the example in Figure 20. In this example, for flood hazards, the original curve (in blue) was generated with the same parameters as the validated curve (in red). However, one can see that 50% of damage occurs faster using the red curve as the blue curve, or put differently, there is more damage for events with a lesser intensity. Repeated on a large number of assets, using the blue curve would lead to an underestimation of the damage value. Best practice is therefore to simulate damages on asset categories using the original curve and testing the overall damage (for all assets) against observed/historic damages. If values are in a range of acceptance, the original curve can be used. If not, it should be modified accordingly, for example as the red curve, in order to obtain larger damages for smaller flood intensities (between 0 and 1.5m of water depth).

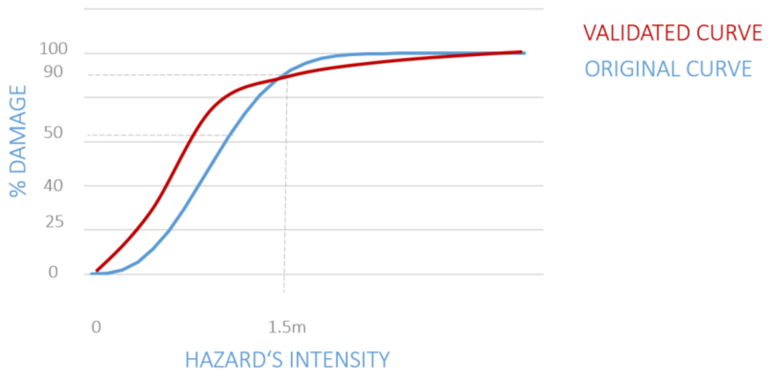


Figure 20 Illustration of damage function sensitivity

PHASE 7: Simulating CCA measures

DESCRIPTION OF THE PHASE

This Phase outlines the essential steps for selecting and simulating your climate change adaptation (CCA) CCA measures in climada. It will assist you in creating a long list of CCA measures and provide information on how to create a short list of CCA measures using a multi-criteria selection. It will assist you in parameterising your short list of CCA measures into climada and calibrating them in order to provide sound results. Finally, you will learn how to move from a short list of pre-selected cost/effective CCA measures to a feasibility study, and why this step is important for implementation.

KEY STEPS

Step 1: List CCA measures per hazard and per assets (long list) including costs

Step 2: Select most promising CCA measures to be investigated in climada (short list)

Step 3: Parameterise CCA measures into climada (cost, risk reduction, damage function impact)

Step 4: Simulate and validate results with historical observation for different scenarios

Step 5: From the short list to the feasibility analysis

INPUT NEEDED

For this Phase, you will need:

- ✓ *Quantitative data from Phase 2*
- ✓ *A general idea of what CCA measures are relevant for your region and for the selected hazard*
- ✓ *Information about cost and impact of several CCA measures relevant for your region*

EXPECTED OUTPUTS

After this Phase, you will have:

- ✓ *A long list of CCA measures*
- ✓ *A short list of CCA measures*
- ✓ *Validated and simulated CCA measures for different scenarios*

TOOLS AND ADDITIONAL INFORMATION

- ✓ *Table of parameters for different CCA measures for selected hazards (see Annex 3 for flood risk and Annex 4)*
- ✓ *climada CCA measure format table (cf. climada manual)*
- ✓ *Stakeholder workshop, discuss with local experts to identify a long list of measures*

Getting Started

In previous Phases, risk and vulnerability has been quantified for pre-defined research area. One of the major strength of the ECA methodology is the inclusion of a cost benefit analysis (CBA) of CCA measures. This set of CCA measures are tailored to the existing risk for the assets and population you have chosen to focus on. Hence, introducing CCA measures is an essential instrument for your project appraisal and will help to determine its economic viability and sustainability. You will first select a long list of CCA measures that might be of interest for the region or are already on the political agenda (Step 1). Following the pre-selection of this long list of CCA measure, you will create a short list of CCA measures to be investigated further with climada (Step 2). These CCA measures will need to be parameterised within climada (Step 3). Thereafter, CCA measures will be simulated and validated against observations (Step 4). Finally, during the feasibility study, you will investigate further in greater detail which CCA measures are feasible, including a detailed engineering and cost analysis (Step 5). The main objective is to reach consensus and mutual understanding on key methodological concepts and assumptions for the selection of CCA measures. It will also offer a more common ground for the (investment) decision-making process for suitable adaption CCA measures, which can contribute to increasing the climate resilience of your area. At the end of the ECA methodology process, you will therefore have a proposal of specific CCA measures including CBA and risk reduction potential.

Step 1: List CCA measures per hazard and per assets (long list) including costs

In this first step, you will identify a list of CCA measures, ideally during a stakeholder workshop including city planners, engineers, institutional experts and economists. During this workshop you will address the following questions:

- ✓ What CCA measures are already included in the existing master plan?
- ✓ What CCA measures are already included in local and national climate strategy and action plans?
- ✓ What CCA measures are used for hazards similar to the region's conditions?

What positive experiences have been made in other regions or area with similar conditions?

- ✓ You should make sure that your long list include several types of CCA measures such as:
- ✓ Technical CCA measures (grey CCA measures);

- ✓ Environmental (green CCA measures);
- ✓ Systemic CCA measures – behaviour change or policy planning related;
- ✓ Regulation/Enforcement CCA measures;
- ✓ Financial CCA measures (such as community participation, saving schemes)
- ✓ Risk transfer (e.g. micro-insurance, regional insurance pool)

It is good practice to provide for each CCA measure the following information:

- ✓ Qualitative expert judgement on:

TIP: HOW SHORT SHOULD BE THE SHORT LIST?

It is helpful to provide scale in order to dimension your long list, short list and selected CCA measures for a detailed feasibility study.

A long list can include up to 100 CCA measures. For the short list, as an indicative scale, for Barisal, a total of 13 CCA measures were included in the short list for parameterisation in climada. In San Salvador, a total of 38 CCA measures were included (19 CCA measures were short listed for flooding, 12 for landslides, and 7 for tropical cyclones /winds).

The feasibility study for Barisal included 11 CCA measures, and in San Salvador 14 measures were included.

  - o The relevance of the CCA measure (does the CCA measure have a sound intervention logic?)
  - o Costs and maintenance for the CCA measure;
  - o Potential effectiveness of the CCA measure for averting damage (how much does a CCA measure reduce an hazard impact);
  - o Institutional feasibility of the CCA measure.

This long list of CCA measures could include up to 100 CCA measures depending on your region. In the next step, we will see how you can reduce this long list for a more detailed parameterisation.

BOX: RELATIONSHIP BETWEEN AVOIDED DAMAGE AND SAVED PERSONS

The best risk reduction measures are also the most relevant ones to prevent damage to people. This has been clearly demonstrated in field studies for hazards such as landslide and wind. We can thus presume that there is no conflict of interests between protecting human livelihood and protecting assets of most vulnerable populations.

In case of flood hazard, the situation is more differentiated. In this case, best practice is to consider all measures and combine the most effective ones for both goals of reducing risks to people and risks to material assets.

Step 2: Select most promising CCA measures to be investigated in climada (short list)

After pre-selecting a long list of CCA measures, the most promising CCA measures should be parameterised within climada. Because parameterisation, including costs and impact reduction, can be very time-consuming, it is best practice to reduce the long list of CCA measure into a short list. This short list will be further investigated in terms of cost-benefit and impact reduction, using integrated climada facilities.

Reducing the number of long list CCA measures is not a trivial exercise, and it should be done during a dedicated workshop with experts including city planners, engineers, institutional experts and economists. A pre-screening of the long list of CCA measures could be performed by external consultants following criteria specific to the region and the political setup. In Barisal and San Salvador, this pre-screening was followed up by a stakeholder workshop, the outcomes of which were the inclusion of additional CCA measures (mostly green CCA measures).

Step 3: Parameterise CCA measures into climada

In this step, the short list, agreed between all stakeholders need to be parameterised into climada. Like other modelling tools, climada will “run” all CCA measures and compare their performance against different hazards and different scenarios and allow you to compare CCA measures with one another. However, note that it is not possible to model how measures will influence one another.

Parameterisation means that several “parameters”, unique to a given CCA measure, will be entered in climada, using a pre-defined format in Excel. Additional information on how to parameterise CCA measures into climada are provided in the climada manual.

These parameters include:

- ✓ The cost of a particular CCA measure
    - o The cost of implementing a CCA measure including its maintenance costs. The costs are in the same currency as the asset value.
- ✓ The impact of this CCA measure on hazard intensity

- A CCA measure is likely to influence the impact of hazard intensity. For instance, some CCA measures reduce hazard intensity by 2%, the resulting hazard becoming therefore 98%.

✓ Impact on hazard high frequency

- Many CCA measures are designed to reduce the hazard intensity. For instance, a seawall will offer protection from hazards with a high frequency (smaller events). If it is designed to stop events with a return period up to 10yr, the parameter entered in hazard high frequency cut-off should be 1/10=0.01

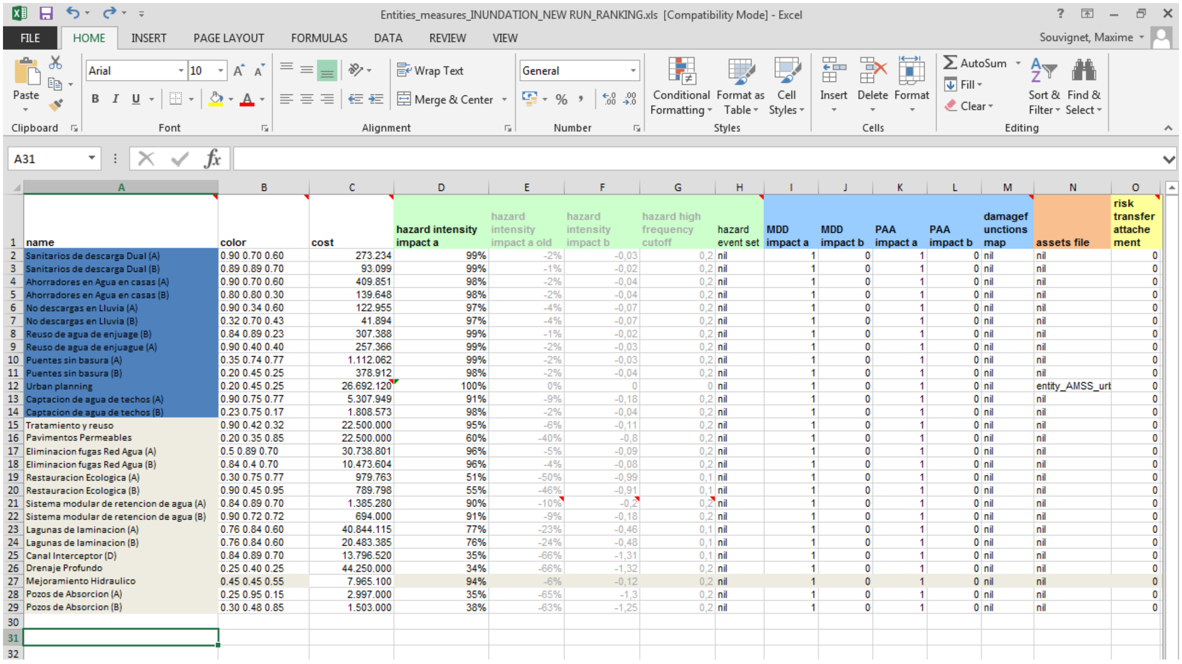
✓ Impact on the asset damage function (MDD and PAA curves)

- CCA measures such as building enhancement of building construction rules will change how certain assets react to a certain level of damage. It is therefore sometimes more efficient to influence change through the damage function. It is done with the MDD (Mean Damage Degree) and PAA (Percentage of Assets Affected) parameters. 100% MDD means no change to MDD. 70% MDD means that mean damage degree is scaled down to 70% of the original MDD value due to a certain measure.

✓ Impact on the asset files

- For CCA measures such as relocation or urban planning, assets location are likely to be altered by the CCA measures and are no longer valid, as described previously. Therefore, you can enter in “asset files” a new asset file for a particular CCA measure, which will result in a new asset distribution.

An illustration of parameterisation in climada is provided in Figure 21. This file can be modified and tailored to the needs of your study.



	name	color	cost	hazard intensity impact a	hazard intensity impact a old	hazard intensity impact b	hazard high frequency cutoff	hazard event set	MDD impact a	MDD impact b	PAA impact a	PAA impact b	damagefunctions map	assets file	risk transfer attachement
2	Sanitarios de descarga Dual (A)	0.90 0.70 0.60	273.234	99%	-2%	-0,03	0,2	nil	1	0	1	0	nil	nil	0
3	Sanitarios de descarga Dual (B)	0.89 0.89 0.70	93.099	99%	-1%	-0,02	0,2	nil	1	0	1	0	nil	nil	0
4	Ahorradores en Agua en casas (A)	0.90 0.70 0.60	409.851	98%	-2%	-0,04	0,2	nil	1	0	1	0	nil	nil	0
5	Ahorradores en Agua en casas (B)	0.80 0.80 0.30	139.648	98%	-2%	-0,04	0,2	nil	1	0	1	0	nil	nil	0
6	No descargas en Lluvia (A)	0.90 0.34 0.60	122.955	97%	-4%	-0,07	0,2	nil	1	0	1	0	nil	nil	0
7	No descargas en Lluvia (B)	0.32 0.70 0.43	41.894	97%	-4%	-0,07	0,2	nil	1	0	1	0	nil	nil	0
8	Reuso de agua de enjuage (B)	0.84 0.89 0.23	307.388	99%	-1%	-0,02	0,2	nil	1	0	1	0	nil	nil	0
9	Reuso de agua de enjuague (A)	0.90 0.40 0.40	257.366	99%	-2%	-0,03	0,2	nil	1	0	1	0	nil	nil	0
10	Puentes sin basura (A)	0.35 0.74 0.77	1.112.062	99%	-2%	-0,03	0,2	nil	1	0	1	0	nil	nil	0
11	Puentes sin basura (B)	0.20 0.45 0.25	378.912	98%	-2%	-0,04	0,2	nil	1	0	1	0	nil	nil	0
12	Urban planning	0.20 0.45 0.25	26.692.120	100%	0%	0	0	nil	1	0	1	0	nil	entity_AMSS_urt	0
13	Captacion de agua de techos (A)	0.90 0.75 0.77	5.307.949	91%	-9%	-0,18	0,2	nil	1	0	1	0	nil	nil	0
14	Captacion de agua de techos (B)	0.23 0.75 0.17	1.808.573	98%	-2%	-0,04	0,2	nil	1	0	1	0	nil	nil	0
15	Tratamiento y reuso	0.90 0.42 0.32	22.500.000	95%	-6%	-0,11	0,2	nil	1	0	1	0	nil	nil	0
16	Pavimentos Permeables	0.20 0.35 0.85	22.500.000	60%	-40%	-0,8	0,2	nil	1	0	1	0	nil	nil	0
17	Eliminacion fugas Red Agua (A)	0.5 0.89 0.70	30.738.801	96%	-5%	-0,09	0,2	nil	1	0	1	0	nil	nil	0
18	Eliminacion fugas Red Agua (B)	0.84 0.4 0.70	10.473.604	96%	-4%	-0,08	0,2	nil	1	0	1	0	nil	nil	0
19	Restauracion Ecologica (A)	0.30 0.75 0.77	979.763	51%	-50%	-0,99	0,1	nil	1	0	1	0	nil	nil	0
20	Restauracion Ecologica (B)	0.90 0.45 0.95	789.798	55%	-46%	-0,91	0,1	nil	1	0	1	0	nil	nil	0
21	Sistema modular de retencion de agua (A)	0.84 0.89 0.70	1.385.280	90%	-10%	-0,2	0,2	nil	1	0	1	0	nil	nil	0
22	Sistema modular de retencion de agua (B)	0.90 0.72 0.72	694.000	91%	-9%	-0,18	0,2	nil	1	0	1	0	nil	nil	0
23	Lagunas de laminacion (A)	0.76 0.84 0.60	40.844.115	77%	-23%	-0,46	0,1	nil	1	0	1	0	nil	nil	0
24	Lagunas de laminacion (B)	0.76 0.84 0.60	20.483.385	76%	-24%	-0,48	0,1	nil	1	0	1	0	nil	nil	0
25	Canal Interceptor (D)	0.84 0.89 0.70	13.796.520	35%	-66%	-1,31	0,1	nil	1	0	1	0	nil	nil	0
26	Drenaje Profundo	0.25 0.40 0.25	44.250.000	34%	-66%	-1,32	0,2	nil	1	0	1	0	nil	nil	0
27	Mejoramiento Hidraulico	0.45 0.45 0.55	7.965.100	94%	-6%	-0,12	0,2	nil	1	0	1	0	nil	nil	0
28	Pozos de Absorcion (A)	0.25 0.95 0.15	2.997.000	35%	-65%	-1,3	0,2	nil	1	0	1	0	nil	nil	0
29	Pozos de Absorcion (B)	0.30 0.48 0.85	1.503.000	38%	-63%	-1,25	0,2	nil	1	0	1	0	nil	nil	0

Figure 21 Illustration of parameterization of CCA measures in climada

In order to assist you in the parameterisation of CCA measures in climada, the ECA Working Group provides a list of CCA measures already available in climada format[20] and example are provided in the following

Table 8. These CCA measures are derived from the Barisal and San Salvador experience, as well as other studies using climada and the ECA methodology. No costs for construction or for maintenance are provided, as this information is very region specific and may also vary greatly over time. However, for indication purposes only, we provided in Annex 3 a series of cost for different green CCA measures for flood risk (See box below for additional information on green CCA measures) and a catalogue of standard measures in climada format (Annex 4). In this example, “hazard intensity impact a” are numbers between 34% and 100%. 100% meaning no hazard reduction. 34% means hazard is reduced to 34% of original intensity.

Table 8 Example of parameters for CCA measures from the Barisal and San Salvador pilot studies

name	Hazard	hazard intensity impact a	hazard high frequency cut-off	hazard event set	MDD impact a	MDD impact b	PAA impact a	PAA impact b	damage functions map	assets file	source (see next tab)
Urban planning	All Hazards	100,00%	0	nil	100%	0	1	0	nil	Exter nal	ECA San Salvador
Water saving facilities in households	Flood	100,00%	0	nil	100%	0	1	0	nil	no	ECA San Salvador
Capture water from the roof	Flood	91,00%	0	nil	100%	0	1	0	nil	no	ECA San Salvador
Permeable pavements	Flood	60,00%	0	nil	100%	0	1	0	nil	no	ECA San Salvador
Reduce water leakage in pipes (canal lining)	Flood	96,00%	0	nil	100%	0	1	0	nil	no	ECA San Salvador
Ecological restoration of the upstream catchment	Flood	50,50%	0	nil	100%	0	1	0	nil	no	ECA San Salvador
Modular water retention system	Flood	54,50%	0	nil	100%	0	1	0	nil	no	ECA San Salvador
Emergency/overflow canal	Flood	35,00%	0	nil	100%	0	1	0	nil	no	ECA San Salvador
Groundwater infiltration	Flood	34,00%	0	nil	100%	0	1	0	nil	no	ECA San Salvador
Improve drainage system	Flood	94,00%	0	nil	100%	0	1	0	nil	no	ECA San Salvador
Embankments, gates, pumps	Flood	42,00%	0	nil	100%	0	1	0	nil	no	ECA Barisal
Flood resilient crops	Flood	100,00%	0	nil	65%	0	1	0	nil	no	ECA Barisal
Embankment, gates	Flood	52,00%	0	nil	100%	0	1	0	nil	no	ECA Barisal
Drainage improvement	Flood	80,00%	0	nil	100%	0	1	0	nil	no	ECA Barisal

[20] *https://github.com/davidnbresch/climada/blob/master/data/entities/catalogue_of_standard_CCA measures.xlsx*

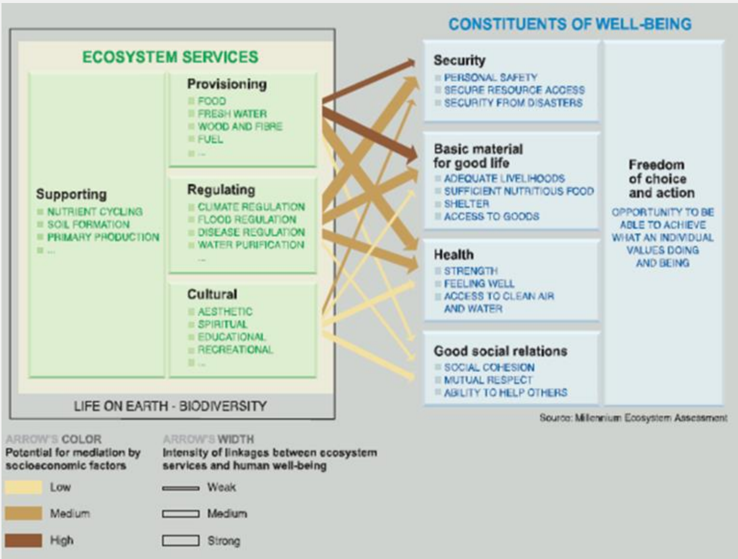
Canal deepening	Flood	87,00%	0	nil	100%	0	1	0	nil	no	ECA Barisal
Canal widening	Flood	81,00%	0	nil	100%	0	1	0	nil	no	ECA Barisal
Rain water infiltration	Flood	96,00%	0	nil	100%	0	1	0	nil	no	ECA Barisal
Regular embankments	Flood	70,00%	0	nil	100%	0	1	0	nil	no	ECA Barisal
River erosion control	Flood	82,00%	0	nil	100%	0	1	0	nil	no	ECA Barisal
Additional ponds for infiltration	Flood	98,00%	0	nil	100%	0	1	0	nil	no	ECA Barisal

TIP: POTENTIAL PITFALLS WHILE INTRODUCING COSTS

The Measure Entity allows input of costs and indirect benefits of a measure, but you can only provide one number as an input. In addition, the Measure Entity does not provide an option for inserting the precise yearly timing of costs and impacts (phasing of the measure, its costs and impacts). More specifically, it is not possible to gradually over time implement a measure (which is needed with, for example, a support programme on resilient buildings, where measure implementation is gradual over time). Also it is not possible to specifically enter the yearly timing of costs and impacts (sometimes a measure will need time to generate impacts). These drawbacks are to be taken into consideration while parameterising your measures.

Ecosystems provide natural services that can be beneficial in a disaster reduction context. As stated in the Millennium Ecosystem Assessment report (2005a) one approach to categorising ecosystem services is to distinguish between supporting services, provisioning services, regulating services and cultural services. As can be seen in the illustration below, regulating services of the ecosystem may comprise climate regulation, flood regulation, and disease regulation.

Strong arguments which are in favour of the application of ecosystem-based disaster risk reduction (green CCA measures such as promoted by the Nature Conservancy in a white paper (The Nature Conservancy, 2013)) is beyond their capacity to act as natural buffers to mitigate hazardous events, their installation and maintenance is in some cases less expensive and more effective than engineered solutions (grey CCA measures) (Sudmeier-Rieux & Ash, 2009) and their implementation is also associated with additional positive benefits (Estrella & Saalismaa, 2013).



Categories of ecosystem service (Source: Millennium Ecosystem Assessment 2005a: 28).

The linkage of the services which are provided by ecosystems and the reduction of disasters is now being described as ecosystem-based disaster risk reduction (Eco-DRR) or as ecosystem-based adaptation (EBA), depending on the context of application (UNEP, 2015). Those terms refer to “the sustainable management, conservation and restoration of ecosystems to reduce disaster risk, with the aim of achieving sustainable and resilient development” (Estrella & Saalismaa, 2013).

Hence, ecosystems can either contribute to a reduction of physical exposure to hazardous events or to a reduction of socio-economic vulnerability to such events (Pedr, 2010). Their use is often underestimated and should be promoted in climate adaptation context. An ecosystem with a hazard mitigation value can be for example wetlands, floodplains, mangroves or coral reefs.

Step 4: Simulate and validate results with historical observation for different scenarios

Once you have parameterised your CCA measures into climada, it is important to validate your results (as for other Phases) against historic data. In order to validate your results, you should first “run” your climada simulation, including assets, hazards and damage functions previously validated. You will include CCA measures in them and have a look at how these CCA measures influence the total damage to your asset. Based on the information you might have collected during the workshop, but also on literature review and on expert knowledge, you will be able to judge if these simulations results (in terms of averted damage) are in the right order of magnitude. You should repeat this step as long as you think that your CCA measures are too optimistic. For instance, it is quite likely that you have overestimated the effect of one CCA measure on an asset category if this CCA measure reduces hazards impact by 90% or 100%.

TIP: THE IMPORTANCE OF MODEL VALIDATION

Validation is a time-consuming process because extensive analysis is needed to verify the results. Without validation, modellers build less knowledge on the sensitivity of the inputs. Through ‘playing around with the model’, knowledge is obtained on which areas, inputs and/or measures are most important. This would benefit the optimisation process, building knowledge on where to reduce uncertainty and, more importantly, when measures are most effective.

With the experience in Barisal, several approaches were developed for the validation exercise. One can compare the expected hazard damage (Annual Expected Damage, AED) with the total value of assets at risk (Direct Exposure Value, DEV) in the baseline scenario and under implementation of the measures:

- For the baseline scenario, check for each grid cell and asset class whether the AED/DEV ratio is higher than one. The related intuition is that an asset can only be damaged once. If the ratio is higher, the baseline damage is overestimated.
- For the baseline scenario, check whether the simulated AED/DEV ratios already occur somewhere in the project area. The related intuition is that when an asset gets damaged very frequently, the asset owner will likely stop rebuilding/repairing the asset. The AED/DEV ratio shouldn’t significantly exceed the ratios currently observed in practice. Otherwise, the baseline damage is overestimated.
- Check whether the AED/DEV ratio as realised through implementing a measure is realistic: is it possible to completely negate all damage? How does this relate to what can be observed in practice?

Step 5: From the short list to the feasibility analysis

Cost efficiency of CCA measures from the short list have been now carried out in climada. These calculations are based on estimates with a margin of limited but sufficient accuracy to allow for a comparative analysis between CCA measures. You will be able to select the most cost-effective CCA measures and exclude the least cost-effective CCA measures from your analysis. In addition, climada allows an evaluation of the relevance of CCA measures selected. The priority actions are considered most profitable and most relevant. Figure 22 shows adaptation bar charts for selected CCA measures in San Salvador. These measures are analysed against different scenarios with regards to their respect costs and benefits. Cost benefit for the whole period is presented on the right axis. The upper axis presents costs or number of affected persons. The lower axis presents the net averted value. This bar chart allows a multidimensional comparison of measures, including a differentiation between different economic and climate scenarios.

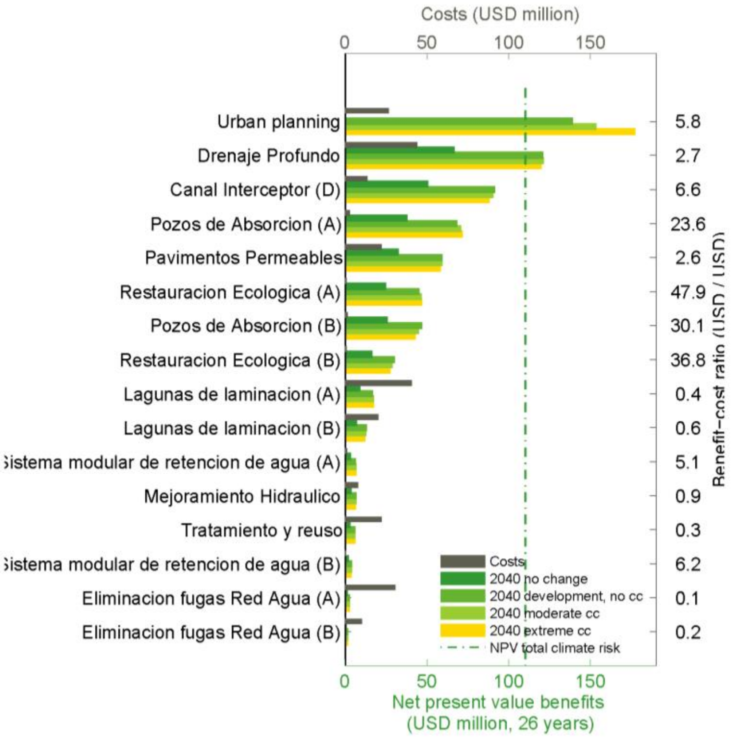


Figure 22 Adaptation Bar Chart for inundation (USD) for CCA measures in San Salvador

However, technical CCA measures analysed in climada have different legal, institutional and organisational requirements, i.e. they need preparatory studies as well as environmental and socioeconomic studies. These requirements may facilitate or hinder the implementation of the CCA measures. The best CCA measures are indeed those offering a high profit and high impact as well as being easily executable in the local context, preferably based on practical local experience.

The objective of the feasibility study is therefore to examine in greater detail the CCA measures from the short list tested in climada. In the feasibility study, the analysis of priority CCA measures focuses on the following aspects:

- ✓ Which level of investment is suggested for each CCA measure within the framework of the project?
- ✓ Which level of investment is viable at various implementation levels (national, local, community)?
- ✓ Which implementation modalities are recommended for each CCA measure: institutional responsibility, requirements for tenders and for implementation contracts, participation of the target group?
- ✓ Which technical or institutional support is required for efficient implementation and sustainability?
- ✓ Which technical, social and environmental risks must be considered during implementation of the CCA measures?
- ✓ Which CCA measures can be implemented in a complementary manner or collectively (packages of CCA measures)?

Thus, the definitive inclusion of CCA measures into the final project proposal is a further result of the feasibility phase. The feasibility of implementation is a criterion that can only be assessed qualitatively on the basis of expert opinion. The quality criteria we have incorporated for this purpose are as follows:

- ✓ Policies:
    - o Alignment of CCA measures with national policies
    - o Studies: Extensive technical studies required or not
- ✓ Environmental impact studies required or not:
    - o Previous experience exist in the country
    - o Skills and entrepreneurial capacities exist in the country
    - o Technical supervision capacity exists in public administration
    - o Technical standards for the CCA measure in the country are in place
- ✓ Risks:
    - o High risk of socio-cultural or community resistance to the CCA measure
    - o Technical risks

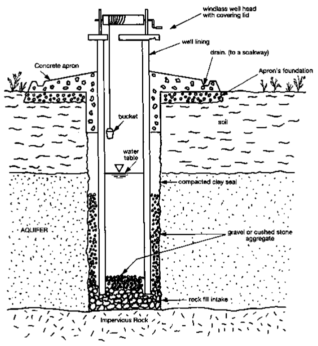
Best practice in your feasibility report shows that a good structure is key to later communication of your findings. Below, we provide an example of a structure for your feasibility report:

In your feasibility study, the following sections should be integrated:

1) Context
    i. Regional
    ii. Socio-economic

iii. Focus Group
iv. Risk and vulnerability
v. Selected CCA Measures
2) Project design
i. Focus Group and other beneficiaries
ii. Detailed description of CCA Measures
iii. Institutions involvement and capacity
iv. Financial and operative sustainability
v. Monitoring concept
vi. Implementation plan
3) Executive entities
4) Costs and financing
5) Impacts and Risks

In addition, it is essential that your feasibility report includes a detailed and concise description of your final measures. In *Table 9* we provide an example from the San Salvador feasibility study. This table provides all relevant information to make a decision about an investment in this particular measure. We recommend following this structure for inclusion in your report.

CCA Measure	Infiltration Well
Description / Design Type	Infiltration wells are a special design in permeable ground that channel runoff rainwater underground for groundwater enrichment. We suggest wells of 2m in diameter with a depth of 25m with brick wall trench, built under the sidewalk. Operatively connected to the drainage system of rainwater. A total of 300 wells (approx. 94,000 m³ capacity in total) is proposed. 
Utility / Benefits	Solve small local flooding and contribute to reducing the level of water in streams. The protection expected to amount 523.6 m³ per well water stopped during an event 2 hours. A total of 300 wells could stop up to about 150,000 m³ during rains 2 hours.
Beneficiaries	Direct: It protects populations in areas affected by small or local flooding near wells and those on the banks of rivers and streams, by reducing tight or depth of water in the natural course. There are more than 30 communities in the area Rio Acelhuate with about 13,500 households and 50,000 inhabitants. Indirect: All the San Salvador Metropolitan Area (AMSS) because the decline in flooded areas results in roads improvement (the movement of people and goods during the rains).
Location	San Salvador volcano north of Santa Tecla, Northwest San Salvador, Antiguo Cuscatlan residential. They can be accommodated on the sidewalks should be close to the net rainwater.
Costs	Construction cost: Approx. USD 17.630/well; 300 wells for a total of USD 5.28 million. In addition: approx. previous studies. USD 160,000. Bidding and supervision of works needed, in charge of the execution unit.
Previous applications	Private development Honeysuckle, Antiguo Cuscatlán. Other wells in private areas approved by ANDA and OPAMSS.
Risks	• Failure operation and maintenance • Aquifer Pollution • illegal connections

	• Rejection of the community • Infiltration slower than projected • Decreased life by collapse, earthquake, etc. • Liquefaction of the land by earthquake and generation of a gully (fairly remote risk).
Responsibility for implementation	Responsibility not clear. ANDA could be, MARN, MOPTVDU. MARN and OPAMSS set the rules.
Other actors involved	ANDA, MARN, ADESCO of surrounding communities, NGOs, social organisation management and community groups in the process of social reintegration.
Responsible Maintenance	Review and periodic maintenance: Implementing entity (MOPTVDU); participation of municipalities and communities. Low operation and maintenance costs.
Norms	Regulation of the Law Development and Territorial Planning of the Metropolitan Area of San Salvador (AMSS) and the surrounding municipalities (2012)
Prerequisites	Coordination with other projects and water projects in selected areas Coordination with municipalities and OPAMSS. Implementation on publicly owned land, possibly under sidewalks, streets, parks or sidewalks that are already municipal.

Table 9 Example of feasibility summary table for measures implementation in San Salvador

PHASE 8: Illustrating Your Results

DESCRIPTION OF THE PHASE

You will learn how to present the findings of your analysis. To do so it is important to keep in mind whom these results are targeted at. According to your scope and objectives, what were the target audience, who are the stakeholders and the beneficiaries or your CCA assessment? Which outcomes are important for subsequent tasks (for instance adaptation planning or strategy development)? What is the best format to convey your results? And what possibilities exist within climada or using a GIS package?

KEY STEPS

Step 1: Identify your audience

- ✓ *Who is your target audience?*
- ✓ *What are your take home messages?*

Step 2: Plan your CCA assessment report

- ✓ *How do you structure your report?*
- ✓ *What are the outputs you find most relevant for the objective of your assessment?*

Step3: Illustrate your findings

- ✓ *How can you illustrate your findings?*
- ✓ *What tools are available in climada to illustrate your findings?*

INPUT NEEDED

To present your CCA assessment results you will need:

- ✓ *Outcomes from previous Phases such as hazard and asset maps and cost benefit results*
- ✓ *Information on your target audience and the policy processes your CCA assessment will be supporting (cf. Phase 1)*
- ✓ *Standard Office software, geographical information systems (GIS), MATLAB®, climada*

EXPECTED OUTCOMES

After completing Phase 8, you will have:

- ✓ *A CCA assessment report, findings and method of presentation*
- ✓ *Visualisation of your findings*
- ✓ *A vision about what formats are best appropriate*

TOOLS AND ADDITIONAL INFORMATION

- ✓ *climada integrated illustration tools*

Getting Started

There are numerous ways to present the outcomes of a CCA assessment. One of the most important conveyors of your output will be your CCA report. This report should provide a clear description of the objectives, the methods as well as the key findings. Ideally, this document will give your audience a comprehensive overview, with all necessary background information needed to understand your outputs. Illustrating your results is also paramount to communicating your outputs. The right figure or diagram can be used in many different ways and is potentially an efficient mean of communication. In this regard, climada offers a unique spatial approach which enables possibilities in illustrating results, therefore beneficial to the decision process.

Before compiling your report, it is important to consider a few aspects regarding your audience (Step 1) and to plan carefully your report (Step 2). Finally, in Step 3, we will explore what illustrations serve best your objectives while targeting your audience.

Step 1: Identify your audience

It is important to adapt your report to those who will support the CCA assessment. The language level, style and content of your report should be appropriate to your audience. If you are targeting external decision makers, it is important that you consider their own objectives and how they interact with your assessment. Equally, it is essential that you tailor the technical level of your report to your target audience: technical jargon should be avoided or explained in a glossary if not avoidable.

In general, decision makers and/or policy makers are used to contained, well-structured documents with the most important information and final results delivered in key points. Professional or scientists, on the other hand, require a higher level of details, and are often interested in details about the methodology or the data you have used. In any cases, a summary is mandatory, and if you address a mixed audience, it is advisable to provide a summary tailored for decision and policy makers at the beginning.

Take-home messages?

Very often, you will find your assessment to provide a plethora of outputs. It is important to select the one you want your audience to “take home”. In the same vein, you are likely to produce ones which you didn’t expect at the beginning of the assessment – sometimes they are even counterintuitive. Don’t miss the opportunity to convey those as well. Challenges in an assessment are always an important source of knowledge and potentially have a high learning effect, if presented adequately.

Step 2: Plan your CCA assessment report

Stetting the right structure

Once you have reflected on your target audience, the next step is to focus on the structure of your report. In general, you should make sure you include the following parts in order to secure a rigorous structure:

i) Introduction
ii) Context and objectives
iii) Methodology and data
iv) Main findings and cost benefit analysis of CCA measures
v) Conclusions and outlook

An assessment report thus provides information on all the factors which have influenced your findings, defines underlying assumptions while supplying any additional information the reader needs to interpret the results. This level of details is very important, because it ensures the reproducibility of your results, therefore strengthening their credibility.

Introduction, context and objectives

At the beginning of your report, you should clearly state the overall context, the objective but also the assumptions associated with your assessment. You will have already gathered this information during Phase 1:

- ✓ What is the context in which the CCA assessment was conducted? Was it part of a programme, was it funded by an international institution?
- ✓ What are the overall and specific objectives of your assessment? What approach have you chosen to reach them?
- ✓ What are the institutions and key stakeholders or target groups involved?
- ✓ What is the geographical scope and timeframe of your assessment?

Presentation of your methodology and data

In the next sections, you will outline the methods you have used as well as the data you have gathered. It is essential, as it will ensure that others can reproduce your results. It is also paramount to the interpretation of your findings. You will have already all necessary information gathered during Phase 2. You should keep in mind that this part of your report should offer an extensive description of the methods, with detailed information about data transformation, hazard modelling, field survey and modelling decisions of different hazards. If you addressed a particularly technical audience, you might also consider drafting a technical document in addition to your assessment report. Your chapters/sections on methodology on data should focus on the following points:

- ✓ A description of your scenarios and hazards
- ✓ How were assets selected, methods to determine their value?

- ✓ What was the impact of selected hazards on your assets?
- ✓ How were damage functions created, for what hazards and for what categories of assets?
- ✓ What was the long list of CCA measures?
- ✓ What primary and secondary data have been used?

Discuss your findings and outcomes

The findings, i.e. the cost benefit analysis of your short list of CCA measure are the central information of your report. They should be presented clearly and concisely. They should include, ideally differentiated for different hazards or target groups, the following points:

- ✓ Cost and benefits of CCA measures
- ✓ Main impacts on selected assets and target groups
- ✓ Main impacts on environment, cultural heritage and health
- ✓ Institutional assessment
- ✓ Challenges and opportunities encountered at the various stages of the assessment

Conclusions

In this chapter you should also describe the uncertainties included in your assessment transparently and – if possible – quantify them. Knowing about the knowledge gaps on climate variability and climate change and its impacts due to. for example, scale and model effects will promote your audience's understanding of your findings.

Outlook

In this part, you have the opportunity to think ahead and make recommendations to your audience. The following guiding questions could be helpful: What are the starting points for action? What obstacles need to be overcome? What knowledge gaps still remain?

Step 3: Illustrate your findings

climada offers a unique spatial approach which enables possibilities in illustrating results. Illustrated outputs are powerful at conveying ideas and are therefore beneficial to the decision process. While there is always a danger of misinterpretation, maps, graphs and charts, when correctly put into context with detailed legends, can contribute to a better understanding of your outputs. In this step, we will present you with integrated illustration possibilities (using climada) and "ex-situ" illustration presentation option using GIS software packages (mainly for mapping illustrations).

climada illustration tools

Within climada, several figures and charts are available. We will describe the most powerful ones to convey your results, along with examples of existing studies. However, if you feel that you need tailored illustrations for your study, climada offers the possibility (via MATLAB® or Octave) to program your own graphics (Please refer to the climada manual and MATLAB®/Octave respective manuals). The following illustrations are embedded in climada:

- ✓ The Waterfall histogram
- ✓ The Adaptation cost curve
- ✓ The Adaptation bar chart

Waterfall Histogram

The waterfall histogram is a function of climada and can be called using MATLAB®/Octave functionalities (please refer to the climada manual for further information). The Waterfall histogram is very useful for representing annual expected damage (AED) today, compared to AED in the future, for different climate and economic scenarios. It also offers an aggregated visualization of the so-called total climate risk, combining economic and climate risk for your region. It is a useful illustration to present your general findings. In Figure 23, waterfall histograms have been used to present AED in San Salvador for different climate scenarios. Different bar colours are used to emphasise the difference between today's and future AED in the metropolitan area. Different waterfall histograms are used for monetary and non-monetary (persons) assets.

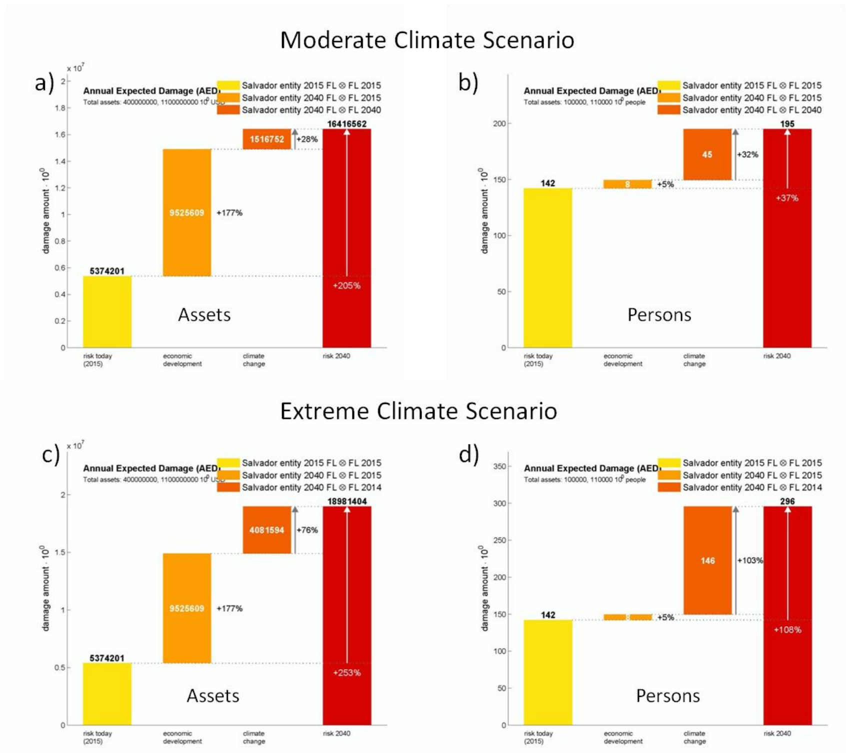


Figure 23 Example of waterfall histograms for the San Salvador Assessment study (Source: KfW (2015a))

In Figure 24, a waterfall histogram was used to present aggregated risk for cyclone and monsoon in the region of Barisal. This view is very useful if your hazard has aggregated impacts and if you want to present CCA measures mitigating different hazards in the same region.

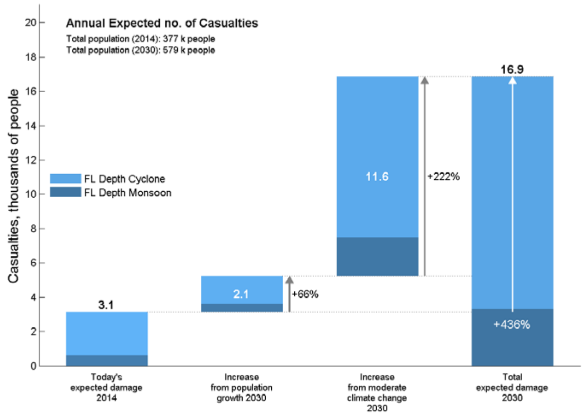


Figure 24 Example of waterfall histogram for aggregated hazards in Barisal (Source KfW (2015b))

Adaptation Cost Curve

The so-called adaptation cost curve offers an innovative representation of the main outcomes of your cost benefit analysis. Each CCA measure is represented by a colour bar. The main objective of this chart is to differentiate between cost-effective and less cost-effective CCA measures. It presents on the x axis (horizontal axis) the value in USD of the net averted damage until your time horizon (i.e. if your baseline is 2015 and your time horizon is 2040, then you will look into 26 years). The width of each column therefore represents the capacity of each CCA measure to avoid/reduce damage from a particular hazard or set of hazards. On the y axis (vertical axis), the ratio between benefit and cost for a particular CCA measures is depicted. The height of a column therefore represents cost-effectiveness of your CCA measures. The higher a column, the more effective your CCA measure. A ratio of 10 means that a CCA measure provides benefits 10 times higher than its costs. A ratio of 1 means that for a particular CCA measure, for one USD invested, you avoid one USD of damage. This ratio represents the border between cost-effective and non-cost-effective CCA measures. A ratio below one applies to CCA measures, where the averted damage for a CCA measure is lower than its costs.

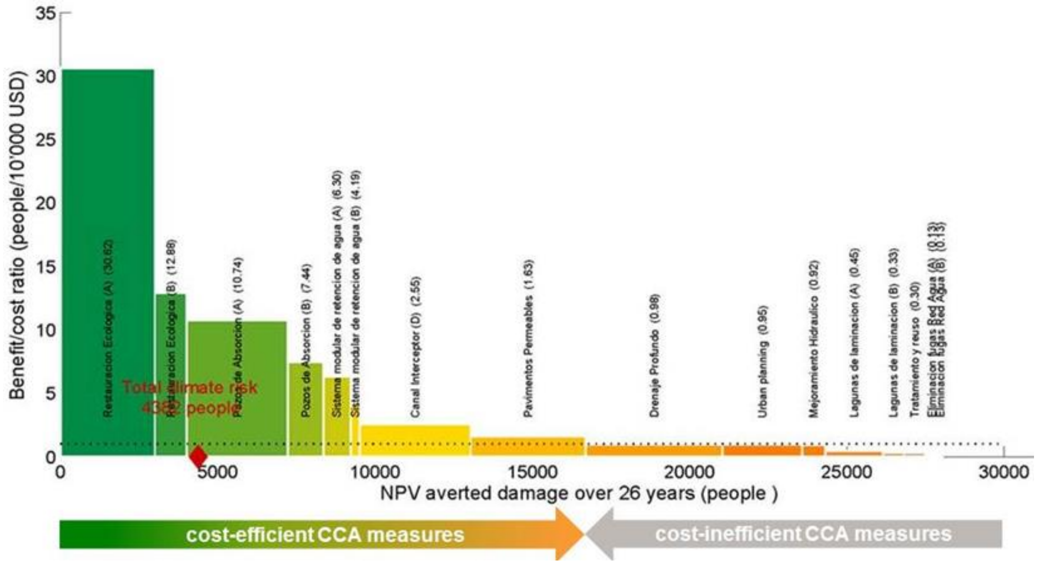


Figure 25 Adaptation Cost Curve for people in San Salvador over a period of 26 years (Source modified after KfW (2016)

In Figure 25, we present an example of adaptation cost curve for San Salvador for people. In total, eight (8) CCA measures are found to be cost effective allowing for a total of 15,000 persons not affected over 26 years. Some CCA measures are more effective than others at reducing risks, but with higher costs. This chart allows you to sort them and show the most effective ones.

Adaptation Bar Chart

Adaptation bar charts are a useful alternative to adaptation cost curves as they represent the CCA measures ranked in terms of benefits. Costs and efficiency ratio are also presented, but you will rather emphasise the benefit of particular CCA measures, considering different scenarios. This representation is very useful when you want to look into CCA measures that were already on a political agenda and compare them in terms of benefits for different scenarios. In Figure 26 we present an example of an adaptation bar chart for San Salvador. In this particular case, urban planning (the first CCA measure) has the largest benefit (although its cost-efficiency ratio is not the highest). The dashed lined represent the total climate risk over the 26 years (depending on the time horizon), meaning that urban planning alone (as modelled in the study) could account for the total risk in the region. Nevertheless, it is always best practice to diversify your CCA measure portfolio.

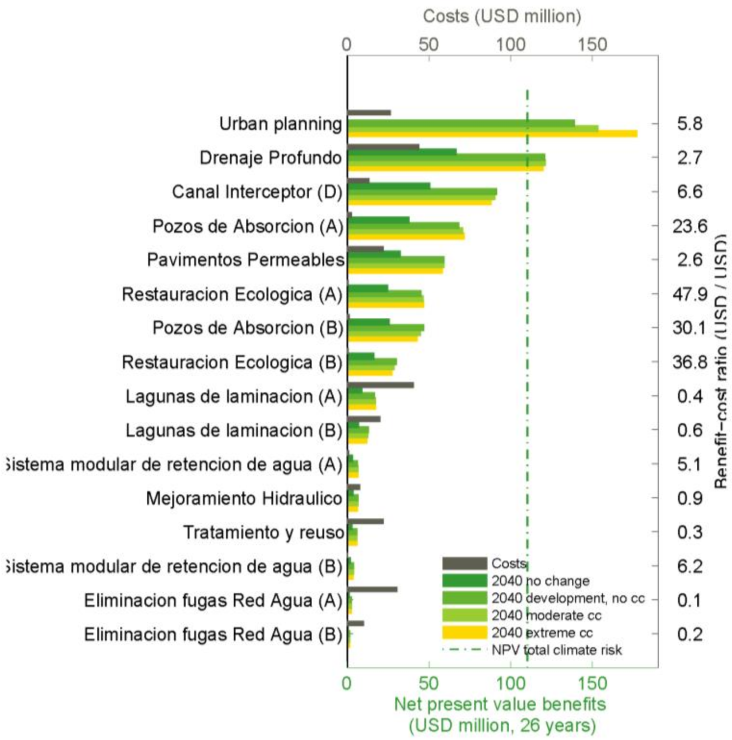


Figure 26 Adaptation Bar Chart for the San Salvador urban area (Source: KfW (2015a))

Illustration not included in climada

Beyond figures and charts embedded in climada, spatial representation using the GIS software package can be useful to convey your output to your audience. The spatial quality of your results offers many possibilities such as:

- ✓ Benefit distribution maps
- ✓ Damage distribution maps
- ✓ Asset distribution maps
- ✓ Hazard intensity/frequency maps

We will present these figures shortly in the section below.

Benefit distribution maps

As stated earlier, climada offers a unique distributed approach of climate risk. Because of its spatial approach for hazards and assets, it is possible to present your results in a geographical manner. Using raw output from climada, you can draw as in Figure 27a a spatial illustration of benefit for different CCA measures. This map offers the advantage of emphasising which areas in your region are responding positively to certain types of CCA measures.

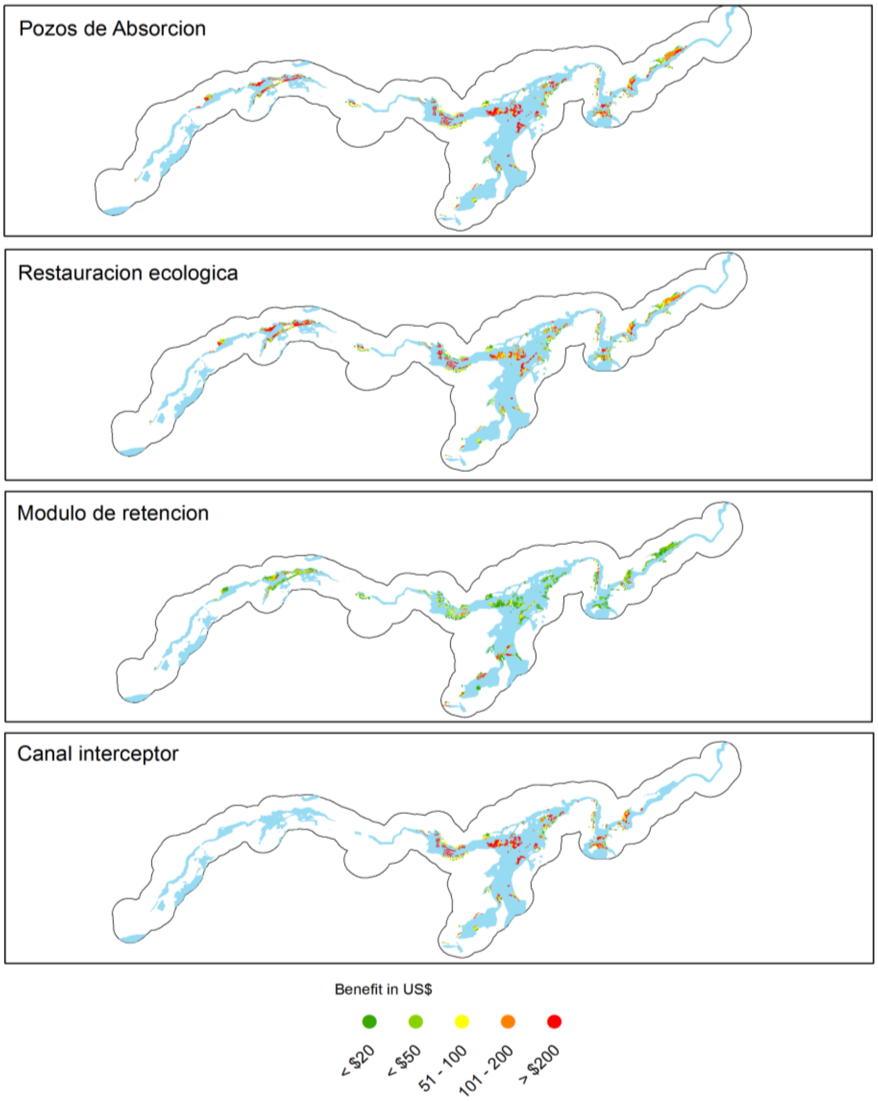


Figure 27 spatial distribution of benefits in USD in San Salvador (KfW, 2015a)

Damage distribution

The same raw output can be used to show, as in Figure 28, the area and intensity of expected damage in a particular region. For instance, in Barisal, the expected number of casualties is concentrated in certain areas of the city only, which might guide the decision in terms of location of CCA measures.

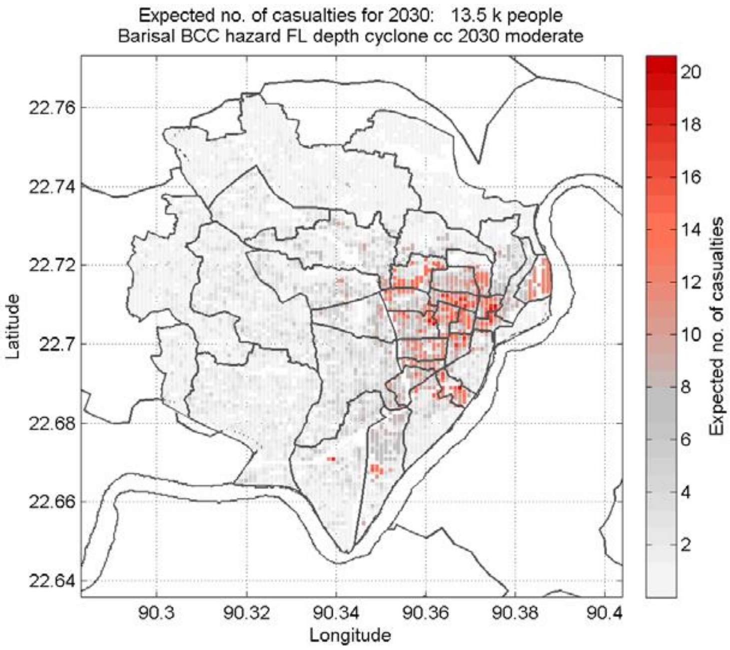


Figure 28 Expected damage for persons in Barisal for the time horizon 2030 (KfW, 2015b)

Asset or CCA measures location maps

In the following example (Figure 29), maps were used to show where a particular set of CCA measures was applied, therefore informing the audience about the methodology applied. A text description would have been confusing and a spatial representation was in this case the best solution. In the same vein, inputs of the model such as assets can be depicted using maps informing the readership about both location and resolution (See Figure 30).

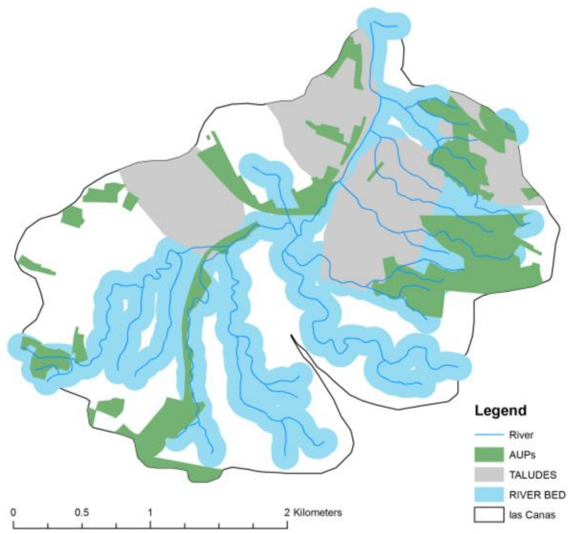


Figure 29 spatial location of CCA measures (KfW, 2015ª)

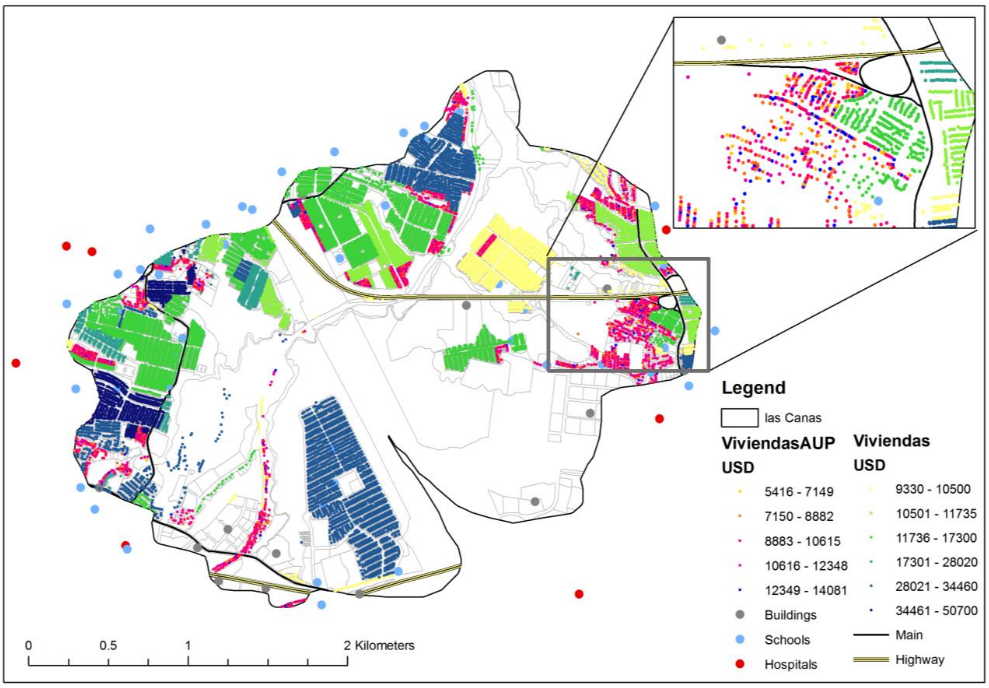


Figure 30 Spatial location of monetary assets in San Salvador (KfW, 2015a)

Hazard Maps

Hazard and risk maps are also a good conveyor of your message. Your audience will often wish to visualise where the main hazards are concentrated and a hazard map constitutes an important asset in your report. These maps are made based on input data for climada either directly in MATLAB® or using GIS packages such as in Figure 31.

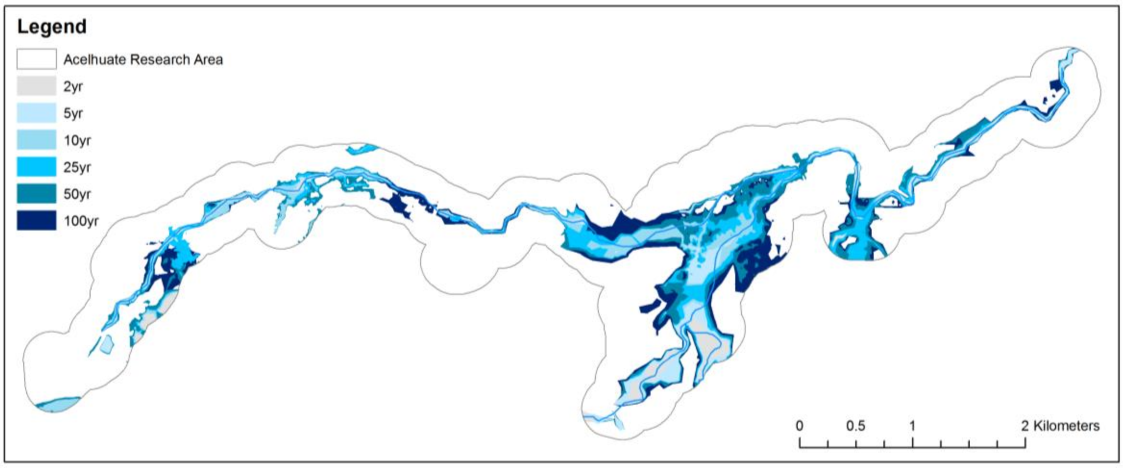


Figure 31 Hazard map for flood risk in San Salvador for selected return periods (KfW, 2015a)

Glossary

Adaptation (to climate change) *IPCC AR5 definition: The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate harm or exploit beneficial opportunities. In natural systems, human intervention may facilitate adjustment to expected climate and its effects. (EUFIWACC, 2016)*

Adaptive Capacity *Adaptive capacity is the ability or potential of a system to respond successfully to climate variability and change, and includes adjustments in both behaviour and in resources and technologies. The presence of adaptive capacity has been shown to be a necessary condition for the design and implementation of effective adaptation strategies so as to reduce the likelihood and the magnitude of harmful outcomes resulting from climate change. Adaptive capacity also enables sectors and institutions to take advantage of opportunities or benefits from climate change, such as a longer growing season or increased potential for tourism. (EUFIWACC, 2016)*

Baseline Period *The baseline (or reference) is the state against which change is CCA measured. It might be a 'current baseline', in which case it represents observable, present-day conditions. It might also be a 'future baseline', which is a projected future set of conditions excluding the driving factor of interest. Alternative interpretations of the reference conditions can give rise to multiple baselines. For example, the Intergovernmental Panel on Climate Change (IPCC) recommends a baseline of 1961 – 1990, and the World Meteorological Organisation (WMO) recommends a baseline of 1981 – 2010. (EUFIWACC, 2016)*

Capacity building *In the context of climate change, the process of developing the technical skills and institutional capability in developing countries and economies in transition to enable them to address effectively the causes and results of climate change.*

Climate change *IPCC AR5 definition: Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcing such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use. (EUFIWACC, 2016)*

UNFCCC definition: A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.

Climate change adaptation assessment (CCA) *The process of identifying options to adapt to climate change, and of evaluating them in terms of criteria such as availability, benefits, costs, effectiveness, efficiency and feasibility. (EUFIWACC, 2016)*

Climate change signal *Observed and simulated climate change is the sum of the forced (signal) and the natural variability (noise). (EUFIWACC, 2016)*

Climate model *A numerical representation of the climate system based on the physical, chemical and biological properties of its components, their interactions and feedback processes, and accounting for all or some of its known properties. The climate system can be represented by models of varying complexity, that is, for any one component or combination of components a spectrum or hierarchy of models can be identified, differing in such aspects as the number of spatial dimensions, the extent to which physical, chemical or biological processes are explicitly represented, or the level at which empirical parameterisations are involved. Climate models are applied as a research tool to study and simulate the climate, and for operational purposes, including monthly, seasonal and inter-annual climate predictions. (EUFIWACC, 2016)*

Climate prediction *A climate prediction or climate forecast is the result of an attempt to produce an estimate of the actual evolution of the climate in the future, e.g., at seasonal, inter-annual or long-term time scales. (EUFIWACC, 2016)*

Climate variability *Climate variability refers to variations in the mean state and other statistics (such as standard deviations, statistics of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system*

(internal variability), or to variations in natural or anthropogenic external forcing (external variability). (EUFIWACC, 2016)

Damage *replaceable damage [ersetzbarer Verlust], e.g. damage of property (can be repaired/rebuilt), consequential damage, like business interruption (can be monetarily compensated). Damage can be repaired or rebuilt at a cost. The full scale of risk management options can be employed: avoidance, prevention, intervention and risk transfer. Therefore, an economic analysis provides a suitable framework to assess the damage and to determine the most effective combination of avoidance, prevention, intervention and risk transfer measures to address damage (climada manual, 2016)*

Damage function *A damage function describes the relation between the intensity of a specific hazard and the typical monetary damage caused with respect to either a single structure (microscale) or a portfolio of structures (macroscale).* *http://www.nat-hazards-earth-syst-sci.net/15/769/2015/nhess-15-769-2015.pdf*

Discount rate *A mathematical operation making monetary (or other) amounts received or expended at different points in time (years) comparable across time. The operator uses a fixed or possibly time-varying discount rate (>0) from year to year that makes future value worth less today. In a descriptive discounting approach one accepts the discount rates people (savers and investors) actually apply in their day-to-day decisions (private discount rate). In a prescriptive (ethical or normative) discounting approach the discount rate is fixed from a social perspective, e.g. based on an ethical judgement about the interests of future generations (social discount rate) (IPCC, 2014)*

Fifth Assessment Report (AR5) *The Fifth Assessment Report of the Intergovernmental Panel on Climate Change, released in 2014.*

Hazard *A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage. (UNISDR 2009: 17).*

Loss *irrevocable loss [unersetzbarer Verlust], e.g. loss of glaciers (due to warmer climate) or loss of coastal land (due to sea level rise) or loss of precipitation (due to changed weather patterns). Losses can only be compensated for, not re-stated or re-placed. A risk management approach to loss does strongly suggest avoiding*

such losses due to their irrevocable nature. Risk management options such as intervention or sharing of risk can only deal with some of the consequences of the loss, not the loss itself. Irrevocable losses are uninsurable - still, some of their consequences can be insured (e.g. glacier melt is not random, hence cannot be insured, but the risk of a glacier lake bursting can be insured, since it's a random event. Likely: sea level rise and the loss of coastal land cannot be insured, since it's not random - but storm surge risk can be insured, since it's a random event) (climada manual, 2016)

Loss and damage *Loss and damage refers to negative effects of climate variability and climate change that people have not been able to cope with or adapt to. This includes the inability to respond adequately to climate stressors and the costs and adverse effects associated with the adaptation and coping measures themselves. Such costs and adverse effects can be both economic and non-economic. Loss and damage is also related to mitigation, as the potential costs of future climate change depend to a large extent on the intensity of climatic disruptions, which in turn depend on mitigation efforts globally. (Warner & van der Geest 2013: 369). http://www.inderscienceonline.com/doi/pdf/10.1504/IJGW.2013.057289*

National adaptation programmes of action (NAPAs) *Documents prepared by least developed countries (LDCs) identifying urgent and immediate needs for adapting to climate change. (EUFIWACC, 2016)*

Reference Period *Climate 'normal' are reference points used by climatologists to compare current climatological trends to that of the past or what is considered 'normal'. A normal is defined as the arithmetic average of a climate element (e.g. temperature) over a 30-year period. A 30-year period is used, as it is long enough to filter out any inter-annual variation or anomalies, but also short enough to be able to show longer climatic trends. The current climate normal period is calculated from 1 January 1961 to 31 December 1990. (EUFIWACC, 2016)*

Resilience *The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions. (UNISDR 2009).*

Risk *The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability or likelihood of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. In this report, the term risk*

is often used to refer to the potential, when the outcome is uncertain, for adverse consequences on lives, livelihoods, health, ecosystems and species, economic, social and cultural assets, services (including environmental services) and infrastructure. (EUFIWACC, 2016)

Risk assessment *A methodology to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that could pose a potential threat or harm to people, livelihoods and the environment on which they depend. (Source UN-ISDR: http://www.unisdr.org/eng/library/lib-terminology-eng%20home.htm)*

Sensitivity *Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise). (EUFIWACC, 2016)*

Temporal average *The temporal mean is the arithmetic mean of a series of values over a time period. Assuming equidistant measuring or sampling times, it can be computed as the sum of the values over a period divided by the number of values. (EUFIWACC, 2016)*

Uncertainty *An expression of the degree to which a value (e.g., the future state of the climate system) is unknown. Uncertainty can result from lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from quantifiable errors in the data to ambiguously defined concepts or terminology, or uncertain projections of human behaviour. Uncertainty can therefore be represented by quantitative measures, for example, a range of values calculated by various models, or by qualitative statements, for example, reflecting the judgement of a team of experts. (IPCC, 2015)*

Vulnerability to climate change *The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including changes in climate variability and extremes. Vulnerability to climate change is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity. (EUFIWACC, 2016)*

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ANNEXES

ANNEX 1……………………………………………………Data and Input Needed Check List

https://www.ethz.ch/content/dam/ethz/special-interest/usys/ied/ied-dam/text/edu/climrisk_ANNEX_1.pdf

ANNEX 2 ……………………………………………………Template Data Gathering for Asset Value

https://www.ethz.ch/content/dam/ethz/special-interest/usys/ied/ied-dam/text/edu/climrisk_ANNEX_2.pdf

ANNEX 3 ……………………………………………………Example of Flood Risk Adaptation Measure Parameters

https://www.ethz.ch/content/dam/ethz/special-interest/usys/ied/ied-dam/text/edu/climrisk_ANNEX_3.pdf

ANNEX 4 ……………………………………………………Catalogue of Standard Measures

https://github.com/davidnbresch/climada/blob/master/data/entities/catalogue_of_standard_measures.xlsx

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Photo
An aerial view of the flooded houses in the aftermath of the tropical storm "Hanna"
Source: UN Photo / Marco Dormino 2008