



# **Study on Adaptation Modelling**

## *Comprehensive Desk Review: Concise Summary*

**CLIMA/A.3/ETU/2018/0010**  
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Directorate-General for Climate Policy  
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Unit A3 — Adaptation

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## Introduction

This document provides a concise summary of the comprehensive desk review of climate adaptation models and tools for the “*Study on Adaptation Modelling*” on behalf of the Directorate General for Climate Action (DG CLIMA) (CLIMA/A.3/ETU/2018/0010). This work was undertaken by a consortium led by Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC) and includes Deltares, the Institute for Environmental Studies (IVM) and Paul Watkiss Associates (PWA).

## Aim of the study

This comprehensive desk review aims to address the European Commissions’ requirement to support better-informed decision making on climate adaptation at multiple governance levels: it provides a comprehensive, up-to-date and forward looking overview of the range of technical, financial, economic and non-monetary models and tools for hazards, risks, impacts, vulnerability and adaptation climate assessments. This therefore aims not only to collate current knowledge on climate adaptation assessment methodologies, but to highlight research gaps in each field. This review subsequently informs a recommended approach for adaptation modelling, detailed in further reports.

## Structure of the comprehensive desk review

The comprehensive desk review constitutes a report overviewing the key groups of model and tool methodologies, which provides a reference guide to the supporting annex detailing greater specific use of individual models and tools.

In order to support policy decision-making, the review considered the requirement for assessment tools and methodologies to support each stage of the adaptation policy cycle<sup>1</sup> (figure 1).

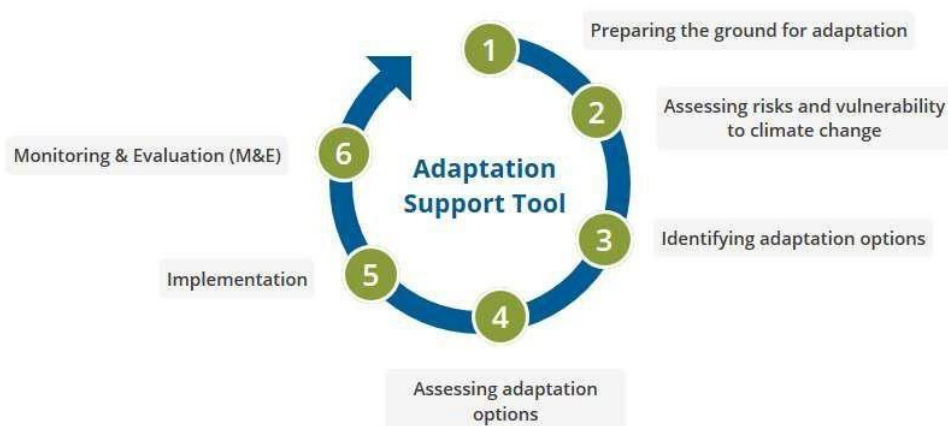


Figure 1: Climate-ADAPT Adaptation Policy Cycle (European Environment Agency).

<sup>1</sup> <https://climateadapt.eea.europa.eu/knowledge/tools/adaptation-support-tool>

As such, the consortium developed an **adaptation modelling typology** to reflect this, as well as the range of models and tools for both environmental and socio-economic assessments (figure 2).

| Climate system   |  | Env. system  |   | Social-Ec. system  |  |
|--|--|--|---|--|--|
| Models   |  |  |   |  |  |
| Climate modelling (for adaptation)   | Hazard, exposure and vulnerability modelling   | Sectoral models for impact and adaptation assessment   | Economic models for impacts and adaptation assessment   | Other techniques   | How to use the information (principles and methods)  |
| Climate models which provide inputs for risk, impact and adaptation assessments. | Models and techniques which utilise climate variables to develop climate risk assessments. These provide inputs further processed by impact models, such as crop and energy models, detailed under 'sectoral models for impact and adaptation assessment'. | These models process 'hazard, exposure and vulnerability modelling' outputs to quantify the impact of climate change on sectors that provide essential services to society, the environment and the economy. These can support identifying adaptation options. | Top-down macro-economic models inform the choice of adaptation measures, or mix of measures and policies, often under substantial and non-reducible, deep uncertainty. Other economic assessments test strategies to support the uptake of adaptation measures. | Further analysis, using qualitative or semi-qualitative techniques, that can support adaptation assessments. | Scrutiny of analytical "conceptual frameworks" and of methodologies that substantiate them in adaptation analyses. |

Figure 2: Climate adaptation modelling typology.

Due to the emphasis of developing understanding regarding climate *adaptation* assessments and methodologies, climate modelling, the first column of the typology, was excluded from the compendium. A compilation of climate tools to access climate data has been compiled by Copernicus' Climate Data Store and toolbox.<sup>2</sup>

Therefore, the comprehensive desk review is structured according to the remaining model categories:

1. Hazard, exposure and vulnerability modelling
2. Sectoral models for impact and adaptation assessment
3. Economic models for impact and adaptation assessment
4. Other techniques
5. How to use the information (principals and methods)
6. Future research

### 1. Hazard, exposure and vulnerability modelling

When developing climate adaptation measures, the aim is to address one or more components of risk (UNDRR, 2016)<sup>3</sup> which is commonly defined as the product of hazard, exposure and vulnerability. Climate hazards constitute agents of disaster based on their impact on humans and the environment (Hobbs, 1987) and models typically utilise weather and climate data as inputs as, for example, can be found at the Copernicus Climate Data Store. Exposure refers to the elements located within the area of a hazard occurrence, while vulnerability describes the propensity of these elements, such as people, livelihoods and the environment, to the impacts of these hazard events (Cardona *et al.*, 2012). Therefore, the first chapter examines hazard, exposure and vulnerability modelling to support the establishment of climate risks to be addressed within climate adaptation strategies. The identification of extreme climate events, changes in their spatial and temporal occurrence, and the

<sup>2</sup> <https://climate.copernicus.eu/what-we-do>

<sup>3</sup> UNDRR (2016). Report of the open-ended intergovernmental expert working group on indicators and terminology relating to disaster risk reduction. Retrieved from <http://www.preventionweb.net/drr-framework/open-ended-working-group/>



compounding impact of multiple hazards are also paramount in identifying risk (de Ruiter *et al.*, 2020), and therefore methods to examine these factors are also included in this chapter.

## **2. Sectoral models for impact and adaptation assessment**

Climate hazards can impact multiple sectors that provide essential services to society, the environment and the economy. Modelling the impact and response of these sectors to climate events, such as the impact of flooding on urban areas, supports the tailoring of adaptation strategies to reduce the resulting negative consequences. The model groups detailed in this section typically use outputs from the previous chapter on hazards, their extremes, exposure and vulnerability as inputs. Examples of these sectors include, but are not limited to, tourism, agriculture, and ecosystems and biodiversity.

## **3. Economic models for impact and adaptation assessment**

An assessment of the efficiency of adaptation measures requires an understanding of economic models. Macro-economic models, including IAMs and CGEs, provide top-down, economic-oriented models to inform the choice of adaptation measures or mix of measures and policies, often under substantial and non-reducible, deep uncertainty. Other economic assessments include insurance impact assessments and behavioural economic experiments, which are important for assessing smaller-scale economic strategies to promote the uptake of adaptation measures.

## **4. Other techniques**

Under a range of different settings in which climate adaptation decisions are required, further analysis may be necessary to provide a holistic assessment that further inform impact assessments detailed in chapter 2. This chapter presents qualitative and semi-qualitative techniques of agent-based models, stakeholder and multi-criteria analyses where the interests of multiple stakeholders need to be considered.

## **5. How to use the information (principals and methods)**

This chapter presents methods which can use information from the previous four chapters to support decision making based on different requirements and situations, for example, when decision makers are operating under high degrees of future uncertainty or comparing the effectiveness of different identified adaptation strategies.

## **6. Future research**

A sixth and final chapter "Future research" is included which appraises the literature within this comprehensive desk review, conducting a gap analysis to provide recommendations for future research.

Typical questions that can be addressed using the model groups described within this desk review are highlighted in figure 3. Here, answering initial questions such as which hazards are present, whether there are multiple and compounding events, what is the severity and frequency, who is vulnerable and where is exposed, can inform questions regarding which sector(s) are impacted and what adaptation measures could reduce this impact. A sector-specific user should also start with hazard, exposure and vulnerability modelling before applying sector-specific models and tools. Subsequently,

wider economic analysis, in conjunction with any further analyses (if applicable) and use of decision support systems can develop on sector impact modelling to inform holistic climate adaptation strategies. Table 1 highlights which chapters of this review may be relevant to identified key end users operating at the European, national and local or project spatial scales. These key end users include policy and public decision makers; investment, finance and insurance; business and industry (private sector); research and civil society and NGOs.

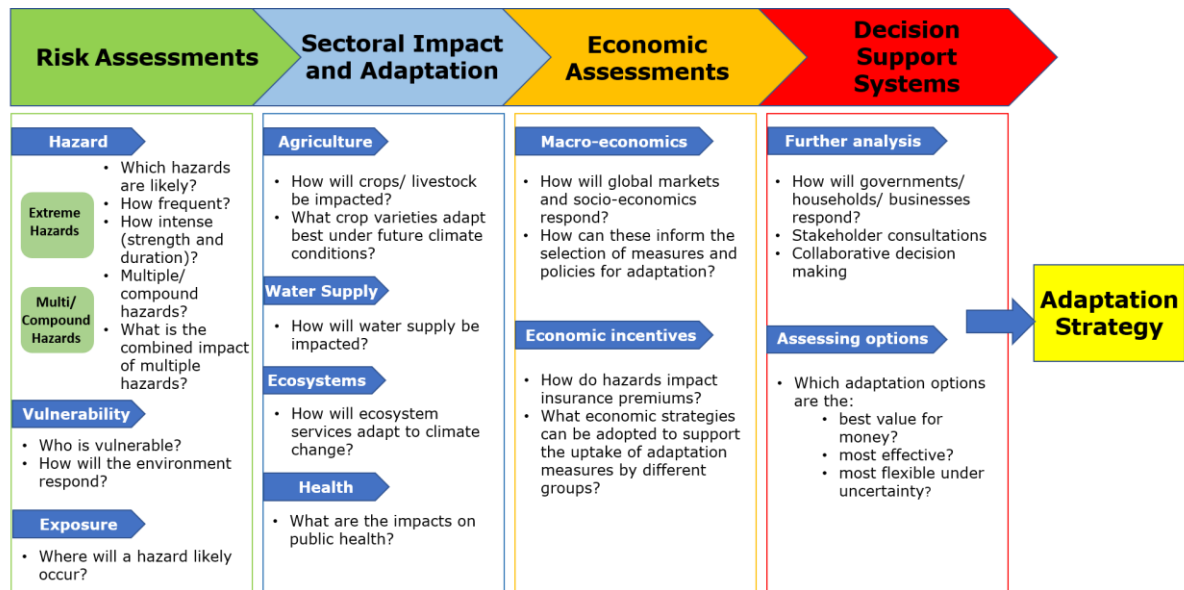


Figure 3: Key example questions that can be examined and used to support the development of climate adaptation strategies.

It should be noted that multiple hazards can impact multiple sectors and, as such, table 2 highlights some of the overlaps in topics between chapters 1 and 2 which may be relevant to consider. Given that economic models (chapter 3), other techniques (chapter 4) and decision support systems (chapter 5) are not hazard or sector-specific, with the exception of chapter 5.7 'Urban adaptation tools and models', these have not been included in table 2. Therefore, it may be useful for users to consider these other chapters, dependent on the individual case or project.

### What specific information does the review present?

The discussion within each chapter, which provides an overview of the key groups of model and tool methodologies, follows a set template:

1. An initial short overview is provided to guide the reader on the aims of the model groups described.
2. Each chapter identifies the main users or applications and their scale: local/project, national, European. These users include the following: policy and decision makers; investment, finance, and insurance sector; private sector; research; and civil society and NGOs. However, it should be noted that while there are some groups of models that operate at a specific spatial scale, such



- as urban models, generally the scale of the analysis is often highly dependent on the scale of the available input data.
3. The step(s) of the adaptation policy cycle (as shown in figure 1) which can be supported by the model groups are identified, along with the general model outputs and how they can support adaptation policy or decision making. This supports the user to identify the applicability of the model groups for their specific case or project.
  4. A short technical summary of the key modelling methodologies, their assumptions and methods to test the quality of the models are provided. This provides more in-depth information regarding the model groups and some examples of specific models within these groups. This can support users to identify which model methodologies are most appropriate and guides towards relevant specific models which can be used, as detailed in the annex.
  5. The required climate, socio-economic and other input data of importance to the model are outlined.
  6. The outputs, in conjunction with examples of how these model groups have been previously applied, are outlined to demonstrate how these model groups have successfully been used. This assists the user in justifying the selection of a model group.
  7. The main strengths and weaknesses of the model groups are summarized in a table. This assists the user to identify under which situations the model groups are best applied.
  8. To assist in the identification of whether certain groups of models or tools can be used for rapid assessment, a short discussion is provided to highlight whether and how the models can be used in for this.
  9. Finally, existing research gaps in terms of data availability, research regarding the use and application of the tool are discussed. A summary of the research gaps across climate adaptation modelling can be found in chapter 6 'Future research'.

Overall, the desk review covers a wide range of topics within the process of developing adaptation strategies, which aims to provide a bridge in understanding between the technicalities of adaptation modelling and decision making. It is hoped that the desk review will represent a guide for users to progress information accessibility beyond academia. Together, not only could the review promote understanding of what is currently possible but guide our future efforts to develop our knowledge further.







Table 2: Models from multiple chapters can inform impact and adaptation analyses in a number of other hazard, exposure, vulnerability and sectoral investigations. Such potential overlaps are highlighted in orange.

|                               | Hazards                    |         |              |                      |                     |            |            |                     |                           |                            | E. c. events   |                        |                          |                         | Exp       |                |           | Vuln.               |              |                    | Sectors  |               |                           |        |         |                        |                         |           |           |                 |                  |  |
|-------------------------------|----------------------------|---------|--------------|----------------------|---------------------|------------|------------|---------------------|---------------------------|----------------------------|----------------|------------------------|--------------------------|-------------------------|-----------|----------------|-----------|---------------------|--------------|--------------------|----------|---------------|---------------------------|--------|---------|------------------------|-------------------------|-----------|-----------|-----------------|------------------|--|
|                               | Heatwaves                  | Drought | Forest fires | Land desertification | Heavy precipitation | Windstorms | Hailstorms | Flow and river flow | Landslides and avalanches | Coastal and sea level rise | ETCCDI indices | Extreme value analysis | Spatio-temporal patterns | Multi-risk, compound... | Scenarios | Socio-economic | Ecosystem | Resilience analysis | Water supply | Agriculture/ crops | Forestry | Fish dynamics | Ecosystems & biodiversity | Energy | Tourism | Cities and urban areas | Critical infrastructure | Buildings | Transport | Health and heat | Health and other |  |
| <b>Hazards</b>                | Heatwaves                  |         |              |                      |                     |            |            |                     |                           |                            |                |                        |                          |                         |           |                |           |                     |              |                    |          |               |                           |        |         |                        |                         |           |           |                 |                  |  |
|                               | Drought                    |         |              |                      |                     |            |            |                     |                           |                            |                |                        |                          |                         |           |                |           |                     |              |                    |          |               |                           |        |         |                        |                         |           |           |                 |                  |  |
|                               | Forest fires               |         |              |                      |                     |            |            |                     |                           |                            |                |                        |                          |                         |           |                |           |                     |              |                    |          |               |                           |        |         |                        |                         |           |           |                 |                  |  |
|                               | Land desertification       |         |              |                      |                     |            |            |                     |                           |                            |                |                        |                          |                         |           |                |           |                     |              |                    |          |               |                           |        |         |                        |                         |           |           |                 |                  |  |
|                               | Heavy precipitation        |         |              |                      |                     |            |            |                     |                           |                            |                |                        |                          |                         |           |                |           |                     |              |                    |          |               |                           |        |         |                        |                         |           |           |                 |                  |  |
|                               | Windstorms                 |         |              |                      |                     |            |            |                     |                           |                            |                |                        |                          |                         |           |                |           |                     |              |                    |          |               |                           |        |         |                        |                         |           |           |                 |                  |  |
|                               | Hailstorms                 |         |              |                      |                     |            |            |                     |                           |                            |                |                        |                          |                         |           |                |           |                     |              |                    |          |               |                           |        |         |                        |                         |           |           |                 |                  |  |
|                               | Flow and river flow        |         |              |                      |                     |            |            |                     |                           |                            |                |                        |                          |                         |           |                |           |                     |              |                    |          |               |                           |        |         |                        |                         |           |           |                 |                  |  |
| <b>Extreme climate events</b> | Landslides and avalanches  |         |              |                      |                     |            |            |                     |                           |                            |                |                        |                          |                         |           |                |           |                     |              |                    |          |               |                           |        |         |                        |                         |           |           |                 |                  |  |
|                               | Coastal and sea level rise |         |              |                      |                     |            |            |                     |                           |                            |                |                        |                          |                         |           |                |           |                     |              |                    |          |               |                           |        |         |                        |                         |           |           |                 |                  |  |
|                               | ETCCDI indices             |         |              |                      |                     |            |            |                     |                           |                            |                |                        |                          |                         |           |                |           |                     |              |                    |          |               |                           |        |         |                        |                         |           |           |                 |                  |  |
|                               | Extreme value analysis     |         |              |                      |                     |            |            |                     |                           |                            |                |                        |                          |                         |           |                |           |                     |              |                    |          |               |                           |        |         |                        |                         |           |           |                 |                  |  |
| <b>Exposure</b>               | Spatio-temporal patterns   |         |              |                      |                     |            |            |                     |                           |                            |                |                        |                          |                         |           |                |           |                     |              |                    |          |               |                           |        |         |                        |                         |           |           |                 |                  |  |
| <b>Vulnerability</b>          | Multi-risk, compound...    |         |              |                      |                     |            |            |                     |                           |                            |                |                        |                          |                         |           |                |           |                     |              |                    |          |               |                           |        |         |                        |                         |           |           |                 |                  |  |
|                               | Scenarios                  |         |              |                      |                     |            |            |                     |                           |                            |                |                        |                          |                         |           |                |           |                     |              |                    |          |               |                           |        |         |                        |                         |           |           |                 |                  |  |
|                               | Socio-economic             |         |              |                      |                     |            |            |                     |                           |                            |                |                        |                          |                         |           |                |           |                     |              |                    |          |               |                           |        |         |                        |                         |           |           |                 |                  |  |
| <b>Sectors</b>                | Ecosystem                  |         |              |                      |                     |            |            |                     |                           |                            |                |                        |                          |                         |           |                |           |                     |              |                    |          |               |                           |        |         |                        |                         |           |           |                 |                  |  |
|                               | Resilience analysis        |         |              |                      |                     |            |            |                     |                           |                            |                |                        |                          |                         |           |                |           |                     |              |                    |          |               |                           |        |         |                        |                         |           |           |                 |                  |  |
|                               | Water supply               |         |              |                      |                     |            |            |                     |                           |                            |                |                        |                          |                         |           |                |           |                     |              |                    |          |               |                           |        |         |                        |                         |           |           |                 |                  |  |
|                               | Agriculture/ crops         |         |              |                      |                     |            |            |                     |                           |                            |                |                        |                          |                         |           |                |           |                     |              |                    |          |               |                           |        |         |                        |                         |           |           |                 |                  |  |
|                               | Forestry                   |         |              |                      |                     |            |            |                     |                           |                            |                |                        |                          |                         |           |                |           |                     |              |                    |          |               |                           |        |         |                        |                         |           |           |                 |                  |  |
|                               | Fish dynamics              |         |              |                      |                     |            |            |                     |                           |                            |                |                        |                          |                         |           |                |           |                     |              |                    |          |               |                           |        |         |                        |                         |           |           |                 |                  |  |
|                               | Ecosystems & biodiversity  |         |              |                      |                     |            |            |                     |                           |                            |                |                        |                          |                         |           |                |           |                     |              |                    |          |               |                           |        |         |                        |                         |           |           |                 |                  |  |
|                               | Energy                     |         |              |                      |                     |            |            |                     |                           |                            |                |                        |                          |                         |           |                |           |                     |              |                    |          |               |                           |        |         |                        |                         |           |           |                 |                  |  |
|                               | Tourism                    |         |              |                      |                     |            |            |                     |                           |                            |                |                        |                          |                         |           |                |           |                     |              |                    |          |               |                           |        |         |                        |                         |           |           |                 |                  |  |
|                               | Cities and urban areas     |         |              |                      |                     |            |            |                     |                           |                            |                |                        |                          |                         |           |                |           |                     |              |                    |          |               |                           |        |         |                        |                         |           |           |                 |                  |  |
|                               | Critical infrastructure    |         |              |                      |                     |            |            |                     |                           |                            |                |                        |                          |                         |           |                |           |                     |              |                    |          |               |                           |        |         |                        |                         |           |           |                 |                  |  |
|                               | Buildings                  |         |              |                      |                     |            |            |                     |                           |                            |                |                        |                          |                         |           |                |           |                     |              |                    |          |               |                           |        |         |                        |                         |           |           |                 |                  |  |
|                               | Transport                  |         |              |                      |                     |            |            |                     |                           |                            |                |                        |                          |                         |           |                |           |                     |              |                    |          |               |                           |        |         |                        |                         |           |           |                 |                  |  |
|                               | Health and heat            |         |              |                      |                     |            |            |                     |                           |                            |                |                        |                          |                         |           |                |           |                     |              |                    |          |               |                           |        |         |                        |                         |           |           |                 |                  |  |
| Health and other              |                            |         |              |                      |                     |            |            |                     |                           |                            |                |                        |                          |                         |           |                |           |                     |              |                    |          |               |                           |        |         |                        |                         |           |           |                 |                  |  |

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