Assessing the Socio-Economic Impacts and Adaptation Options for Climate Variability and Change in Mediterranean Coastal Zones

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**Assessing the Socio-Economic Impacts and Adaptation Options for Climate Variability and Change in Mediterranean Coastal Zones**

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List of acronyms

CBA  Cost Benefit Analysis
CEA  Cost Effectiveness Analysis
ClimVar & ICZM “Integration of Climatic Variability and Change into National Strategies to Implement the ICZM Protocol in the Mediterranean” Project
CVC  Climatic Variability and Change
DALY  Disability Adjusted Life Year
DIVA  Dynamic Interactive Vulnerability Assessment
EEA  European Environment Agency
EU  European Union
GDP  Gross Domestic Product
GHG  Greenhouse Gas
GVA  Gross Value Added
HTM  Hamburg Tourism Model
ICZM  Integrated Coastal Zone Management
IPCC  Intergovernmental Panel on Climate Change
IPCC AR4/AR5 IPCC Fourth/Fifth Assessment Report
MCA  Multi Criteria Analysis
NUTS  Nomenclature for Territorial Units for Statistics
PAP/RAC  Priority Actions Programme Regional Activity Centre
PESETA  Projection of Economic impacts of climate change in Sectors of the European Union based on bottom-up Analysis
RCAO  Regional Coupled Atmosphere-Ocean Model
RCP  Representative Concentration Pathway
RCM  Regional Climate Model
R&D  Research and Development
RIA  Regulatory Impact Analysis
ROA  Real Options Analysis
SKC  Šibenik-Knin County
SLR  Sea Level Rise
SRES  Special Report on Emissions Scenarios
SSP  Shared Socioeconomic Pathways
SWOT  Strengths, Weaknesses, Opportunities and Threats
UNDP  United Nations Development Programme
UNESCO  United Nations Educational, Scientific and Cultural Organization
UNFCCC  United Nations Framework Convention on Climate Change
USD  United States Dollar
1 About this document

1.1 Aims and objectives of the document

This document is part of the project “Integration of climatic variability and change into national strategies to implement the ICZM Protocol in the Mediterranean” (the ClimVar & ICZM Project) which is designed to support the implementation of the ICZM Protocol in the Mediterranean. The overall objective of the project is to create an enabling environment for the integration of climatic variability and change (CVC) coping strategies in the ICZM policies, plans and programmes of Mediterranean countries by: (i) strengthening the understanding of the impacts of CVC on the coastal zones of the Mediterranean region and (ii) establishing the needed information exchange mechanisms, capacity, and regional pilot experiences.

Central to these objectives is the need to strengthen the assessment of the environmental and socio-economic impacts of CVC and subsequent evaluation of adaptation response options. This is because the complexity of CVC has resulted at present in the absence of a common methodology for estimating these impacts. Therefore, the project includes case studies in vulnerable areas in eligible countries, using the most promising methodology to estimate the costs of CVC impacts. It is expected that the results of the assessment will provide key information for the preparation of coastal zone management plans and national ICZM strategies.

This document draws on the experience of making such assessments in the ClimVar & ICZM Project and other related assessments, to provide guidelines on assessing the costs of the environmental and socio-economic impacts of climatic variability and change, and the evaluation of response options, in the context of vulnerable coastal zones in the Mediterranean.

The aims of this document are to:

- Provide an overview of the type of concepts and methodologies used in these assessments;
- Outline the processes for making these assessments, including scoping issues, data requirements, use of assessment methods and stakeholder involvement;
- Provide further insights into these processes through examples, including how methodologies have been used; and
- Explain how these assessments can feed into sound planning and management in coastal zones.
The target readership is the policy community involved in commissioning, managing and using such assessments of CVC impacts and adaptation responses, along with interested parties in the research community, and stakeholder groups. While providing explanations of specific methodologies used in the process of assessing impacts and adaptation options, such as the DIVA model, and other analytical tools and economic techniques, it is not intended to provide in-depth practical guidance on the use of specific methodologies. Rather, it is intended to provide an understanding of processes for making the assessment, the methodologies involved and results obtained, in order to aid the design and appropriate use of such an assessment. It is recommended that the application of methodologies should draw on the expertise and experience of specialists in the relevant fields.

The document is structured as follows: Section 2 gives an introduction to the assessment of environmental and socio-economic impacts; Section 3 outlines key methodologies that can be used in these assessments; Section 4 presents an overview of the process of assessments, and Sections 5 and 6 explain how to undertake top-down and bottom-up assessments, including some demonstration cases. Section 7 discusses the integration of the results of the two approaches, to provide a basis for sound planning and management for CVC in coastal zones; Section 8 presents methods for evaluating adaption options, and Section 9 gives recommendations and lessons learned on how to assess CVC impacts and move towards developing more resilient coasts. Finally, Section 10 provides guidance on further useful sources of information, with an annotated guide to the literature.

1.2 How this document relates to the “Guidelines for Adapting to Climate Variability and Change Along the Mediterranean Coast”

This document is related to the “Guidelines for Adapting to Climate Variability and Change along the Mediterranean Coast” (UNEP/MAP/PAP, 2015), the aims of which were to provide:

- A guide to the impacts of climate variability and change (CVC) on coastal zones in the region;
- Information on how these impacts can be integrated in the Integrated Coastal Zone Management (ICZM) process; and
- Lessons learnt from the experience of handling CVC in specific locations in the Mediterranean coastal zones and elsewhere.

This current document feeds into this general guidance by providing in-depth explanations and answers regarding specific stages of integrating CVC in the ICZM process. In particular, it goes into much more detail regarding practical steps and methods for analysing the future impacts of CVC and adaptation responses per sector and issue.
1.3 What makes this assessment different?

There are a number of guidance documents available on how to estimate the socio-economic impacts of CVC (see, for example, Fankhauser (2010), UNFCCC (2011), Markandya et al., (2014)). This document differs by focussing specifically on coastal zones. It combines elements from other approaches in its scope and methodology for assessing the costs of impacts of climatic variability and change in the context of vulnerable coastal zones in the Mediterranean. The elements it includes are:

- The use of the DIVA (Dynamic Interactive Vulnerability Assessment) model for assessing the biophysical and socio-economic consequences of sea-level rise and associated extreme weather events within different physical and socio-economic scenarios, and for considering various adaptation strategies. This model, in combination with other databases, allows (i) the inclusion of a greater scope of CVC impacts (in particular, extreme sea-level events (storm surges)) than in previous assessments,\(^1\) and (ii) a more detailed local quantitative assessment of the damage expected from these impacts, measured in terms of monetary damage to assets (buildings, infrastructure) and numbers of people affected.
- The use of a flexible approach to bottom-up assessment using a number of different methods, appropriate to the available data, to estimate the significance of local impacts for a number of key sectors in the affected coastal zones.
- A combination of top-down and bottom-up assessments, enabling the more comprehensive assessment of CVC impacts and costs over a number of key sectors in the affected coastal zones. This allows a comparison of the significance of impacts per sector, and therefore feeds into adaptation planning priorities.

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\(^1\) In the Croatia study (Hinkel et al, 2015) the downscaling of DIVA methods produced an assessment that was more comprehensive than previous studies and applied different assumptions. In particular, it included less conservative estimates of the sea-level rise by considering the potential rapid melting of the Antarctic ice sheets, which has been a key concern in sea-level science in recent years.
2 Introduction to the assessment of environmental and socio-economic impacts

2.1 Why make such assessments in conditions of high uncertainty?

It is important to understand that the results of assessing the future environmental and socio-economic impacts of CVC are derived from a process that necessarily involves making assumptions about a number of key, interlinked factors, based on best available projections and expert judgement. These factors include future socio-economic development at global and national levels, the associated level of GHG emissions, and the resulting environmental and socio-economic impacts at the global level and at the level of regional, national and local coastal zones. Owing to the great uncertainties involved in estimating these factors, assessments of this type generally produce quantitative results based on a number of future emissions and socio-economic scenarios, established as standards by the research community, that give results ranging from the most pessimistic to the most optimistic. In some cases, the data limitations and high uncertainties involved mean that conclusions regarding the impacts in certain sectors can only be given in qualitative terms.

It is still, however, essential to make such assessments, even though they are inherently highly uncertain. This is because a delay in making assessments of likely impacts (until more robust results are possible), thus delaying the ability to make policy decisions on adaptation using the best current estimates, may have serious consequences in terms of future environmental, economic and social costs. The production of such assessments is therefore part of the process of understanding the most significant vulnerabilities to CVC in coastal zones, and what the priorities should be for taking appropriate adaptation action in the short, medium and long terms. This is particularly important when the significant estimated impacts from CVC on populations, assets and sectors require long-term planning and major investment in adaptation options. Indeed, existing global research indicates that in many cases (for example, appropriate infrastructure investments) there are considerable long-term net benefits in taking appropriate adaptation actions, compared to the costs of inaction. This information can be highly effective in building arguments in public and policy communities for developing and implementing coherent adaptation plans.

At the same time, limitations to making assessments of CVC impacts and adaptation priorities in conditions of uncertainly should be noted and communicated to stakeholders. Furthermore, this uncertainty necessitates periodic reappraisals of conclusions and recommendations, as and when updated research data related to emissions and socio-economic scenarios becomes available.
2.2 What to assess?

The areas covered are defined by economic and social sectors impacted by climate change. These include coastal infrastructure, tourism, agriculture, forests, health, maritime activities, fisheries, energy and transport. Sectoral coverage is discussed further in Section 4.

2.3 Past experiences

There are only a few examples of socio-economic assessments of coastal zones in the Mediterranean. Under the PAP/RAC programme, studies were carried out in the Buna-Bojana region of Albania and Montenegro, in Šibenik-Knin County in Croatia, and in Tunisia. In addition, a full assessment of the impacts of SLR and storm surges was made for Croatia. Further details can be found in Sections 4 and 5 of this document.
3 Methodologies

This section outlines some key methodological definitions, concepts and decisions relevant to the assessment of CVC impacts and adaptation options. These inform subsequent sections that describe the details of top-down and bottom-up assessments for coastal zones.

3.1 Choosing the timeframe and territorial coverage

The appropriate timeframe and territorial coverage of an assessment depend on the objectives and scope of the study in terms of the types of climate change impacts and affected sectors to be considered.

The choice of timeframes is defined by the types of impacts assessed. For sea-level rise (SLR), these are typically medium- and long-term. For example, a national-level study of the Croatian coastline (Hinkel et al, 2015) reports impacts for 2050 and 2100. The timeframes for other CVC impacts may vary according to the issue and sector. For example, some climate change impacts on agricultural crop yields, drought frequency, or forest fire frequency are already being reported in some locations, and therefore shorter time horizons may be appropriate in assessing these impacts and adaptation options.

In terms of coastal length, coverage can be at the level of a country's entire coastline, a coastal region within a country (county or province), or the coast associated with a given river basin or ecological zone. This choice will largely be defined by the overall geographical focus required by the instigators of the study.

The landward area included in a given length of coastline will depend on the required scope of the assessment. As a minimum, the study area needs to cover all areas that might be physically affected by sea-level rise. This would include, for example, all land that might be affected by storm surge over a given period (e.g. once in 100 or 1,000 years) and land that might be affected by saltwater intrusion and increased river flooding. In a comprehensive assessment, however, the choice of territorial coverage should include the wider coastal region area that might be affected by socio-economic impacts as the result of SLR and other CVC impacts. This includes impacts on people and economic sectors that might occur in an area beyond the physical impacts of SLR, for example, impacts on human settlements, tourism, fisheries, agriculture, human health and water resources. Data collection for analysing these impacts can be readily defined by existing administrative boundaries. The seaward extension of the study area should include features that may be affected by the bio-geophysical effects of sea-level rise, for example coral reefs and coastal waters used by the local fishing industry.
3.2 Selecting emission and socio-economic scenarios

Emission scenarios

The IPCC Fifth Assessment Report (AR5) adopted recently developed emission scenarios known as representative concentration pathways (RCPs). These are possible pathways for greenhouse gas and aerosol concentrations, with land use change, and are characterised by radiative forcing produced by the year 2100\(^2\). The four representative pathways are as follows\(^3\):

- **RCP2.6**: this is the most ambitious pathway, in which emissions peak early (mid-century peak radiative forcing of \(\sim 3\) W/m\(^2\)), then fall due to the active elimination of atmospheric carbon dioxide. It has no counterpart in IPCC AR4.
- **RCP4.5**: this is a medium-stabilization scenario, with stabilization at 4.5 W/m\(^2\) after 2100. It is closest to the lowest-emission scenario (B1) in IPCC AR4.
- **RCP6**: this is a medium-stabilisation scenario with stabilization at 6 W/m\(^2\) after 2100, through the introduction of a range of technologies and strategies for reducing greenhouse gas emissions. It is closest to A1B in IPCC AR4.
- **RCP8.5**: this is a high-baseline-emission scenario with a rising radiative forcing pathway leading to 8.5 W/m\(^2\) in 2100. It arises from minimum effort to reduce emissions and is closest to the highest-emission scenario (A1FI) in IPCC AR4.

In the case of the top-down DIVA modelling process, the selection of RCPs is part of modelling SLR scenarios. For example, in the study on Croatia, the three sea-level rise scenarios were based on RCP2.6, RCP 4.5 and RCP8.5 (each combined ice-melting projections not integral to the RCPs).

In bottom-up assessments of CVC impacts, the range of analysis for different issues and sectors is generally based on available studies and results relevant to a given coastal zone. This means that the assessment is dependent on the selection of emission scenarios in these studies, so estimates of impacts may be based on a number of different scenarios for different sectors. Moreover, some studies which have yielded important results in source studies may have used IPCC AR4 emmission scenarios which are not strictly consistent with RCPs (although the nearest equivalents are given in the above definitions of RCPs). It is recommended that any such inconsistencies should be noted with caveats in assessment reports. While inconsistencies are problematic in terms of accurately comparing the significance of impacts between issues and sectors, they should not compromise the assessment conclusions, since the overall aim is to provide general recommendations on the relative significance of impacts, in order to aid decisions on adaptation priorities and options.

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\(^2\) Radiative forcing is the extra heat the lower atmosphere retains as a result of additional greenhouse gases, measured in watts per square metre (W/m\(^2\)).

\(^3\) IPCC link on RCPs: [http://sedac.ipcc-data.org/ddc/ar5_scenario_process/RCPs.html](http://sedac.ipcc-data.org/ddc/ar5_scenario_process/RCPs.html)
**Socio-economic scenarios**

One of the most important drivers of coastal climate change and climate variability impacts is socio-economic development. It determines how many assets and people will be located in the coastal zone and thus at risk of experiencing coastal impacts. Future socio-economic development can be explored through the use of socio-economic scenarios. A key framework here is the shared socio-economic pathways (SSPs) that the climate change research community has developed to facilitate an integrated analysis of future climate impacts, vulnerabilities, adaptation, and mitigation (O’Neill et al. 2012). SSPs describe the alternative futures of socio-economic development as follows:

- **SSP1 (Sustainability):** relatively good progress towards sustainability, with sustained efforts to achieve development goals, while reducing resource intensity and fossil fuel dependency. Rapid development of low-income countries, a reduction in inequality (globally and within economies), rapid technology development, and a high level of awareness regarding environmental degradation. The world is characterized by an open, globalized economy, with relatively rapid technological change.

- **SSP2 (Middle of the Road):** recent trends continue, with some progress towards achieving development goals, reductions in resource and energy intensity at historic rates, and slowly decreasing fossil fuel dependency. Development of low-income countries proceeds unevenly. Per-capita income levels rise at a medium pace at the global average, with slowly converging income levels between developing and industrialized countries.

- **SSP3 (Fragmentation):** the world is failing to achieve global development goals, with little progress in reducing resource intensity, fossil fuel dependency, or addressing local environmental concerns. The world has de-globalized, and international trade, including energy resource and agricultural markets, is severely restricted. Low international cooperation and investment in technology development and education slow down economic growth in high-, middle-, and low-income regions.

- **SSP4 (Inequality):** this pathway envisages a highly unequal world, within and across countries. Vulnerable groups exist in developing and industrialized countries alike. In industrialized countries, economic uncertainty leads to low population growth. Economic growth is probably medium to high in industrialized countries, while low-income countries have low economic growth (and a rapidly rising elite at the same time), and middle-income income countries have medium growth, also driven by increasingly rich elite groups.

- **SSP5 (Conventional Development):** this world stresses conventional development, oriented toward economic growth, as the solution to social and economic problems through the pursuit of enlightened self-interest. A preference for rapid conventional
development leads to an energy system dominated by fossil fuels, resulting in high GHG emissions and challenges to mitigation.

Normally, studies use only a subset of these scenarios, enough to get a sense of the range of potential values of assets and the number of people at risk. One possibility would be to take SSP1 as indicative of a sustainable development future, SSP3 of a fragmented future, and SSP5 of a conventional future paying little attention to climate change.

It is more problematic to use these scenarios, which are at the national level, for projections in the coastal area. A common assumption is that the coastal zone will retain its relative position in the country, so for example if per capita income in the zone is 75% of the national level, it will remain so in the future. A variation may be to try to model changes in relative positions, if there is evidence that the zone is becoming relatively more or less wealthy. This would require further analysis, based on external factors.

3.3 Using baseline GDP, population and real-estate projections

GDP and population projections are inputs in the baseline valuation of a number of elements in the assessment. First and foremost is the number of people in the coastal area, derived from population projections, who will be at risk in terms of climatic impacts. Second is the value of assets, in the form of buildings and facilities for transport, communication, energy delivery, etc. GDP and population projection are inputs in estimating the volume and value of such assets. Typically, values go up in proportion to GDP per capita and the number of people. Other factors, however, may also be relevant. In the case of Croatia, for example, housing estimates also involved taking into account the construction of real estate as second homes for domestic and foreigners, and additional tourist facilities. These were based on the housing density of housing projections in other countries with developed second-home markets, which Croatia is likely to follow. This estimate was confirmed with the allowed density within Croatian coastal zone spatial plans.

Projections of per capita income can also be useful in estimating the value of impacts of climate change on ecosystems, i.e. environmental degradation. The approach normally taken is to increase estimates of damage from current levels in line with increases in GDP per capita, as a function of the increase. The function is expressed as:

\[ D_t = D_0 \left( \frac{Y_t}{Y_0} \right)^{\beta} \]

where

- \( D_t \) is the value of the service from an ecosystem in year \( t \),
- \( D_0 \) is the value in year 0
- \( \beta \) is the elasticity of value of the service with respect to income
- \( Y_0 \) is e capita income in year 0
- \( Y_t \) is per capita income in year \( t \).
Elasticity β proposed by the OECD (2012) in its guidance document is 0.8. It is noted that lower elasticities have been identified in the literature, particularly in the USA, and indeed the OECD (2012) also recommends using an elasticity of 0.4 in sensitivity analyses. However, it is also noted that some authors have expressed a preference for higher elasticities in excess of 1.0 (e.g. Hammitt and Robinson, 2012).

3.4 Top-down or bottom-up analysis?

Ideally, assessments of this type should include a combination of top-down analyses of key impacts of CVC in a given coastal zone, and bottom-up assessments of local vulnerability to these impacts. Figure 3.1 gives an overview of top-down and bottom-up tasks and how they are connected.

The top-down approach provides an estimate of the impacts of sea-level rise and coastal flooding according to a set of agreed climate change scenarios and, pursuant to that, creates an initial estimate of the desirable adaptation actions. A key tool in this approach is the Dynamic Interactive Vulnerability Assessment model (DIVA), which is an integrated global research model for assessing the biophysical and socio-economic consequences of sea-level rise and associated extreme weather events under different physical and socio-economic scenarios, and for considering various adaptation strategies (see Section 4.1).

The bottom-up assessment builds on estimates of the impacts of sea-level rise and coastal flooding, with other climate factors, and focuses on vulnerabilities at the local level in different key economic sectors. This assessment also considers CVC issues that the DIVA model does not address, such as the effects of flooding, temperature changes and precipitation on key sectors such as agriculture, fisheries, tourism and infrastructure.

The explanation regarding scoping issues in Section 4 gives more guidance on the appropriateness of top-down and bottom-up approaches for assessing different types of impacts on different sectors.
3.5 Evaluating adaptation options

The assessment of CVC impacts via top-down and bottom-up approaches should result in a set of estimates regarding the relative significance of different impacts in a given coastal zone per sector. Ideally, these estimates will be expressed in monetary terms and will inform an understanding of priorities for adaptation, in terms of where the greatest impacts will occur, by sector and by location, and the costs of inaction. The next step is to assess the adaptation options for the identified priorities.

In principle, the evaluation of adaptation options in the context of ICZM should follow the same methodological approaches as evaluating policy and investment options in other contexts. Well-developed methods, such as cost-benefit analysis, cost-effectiveness analysis and multi-criteria analysis, designed to aid the assessment of different policy options, are described below. Different methods, or combinations of these methods, may be appropriate to different sectors and types of policy, as discussed further in Section 8. The overall aim is to gain an understanding of the economic, environmental and net social benefits of a given option, along with the distributional considerations, uncertainties and feasibility risks associated with its implementation including any financial, institutional and technical risks. It is also necessary to identify any potential trade-offs and synergies between different policy measures, which may hinder or aid their effectiveness.
Some key methods for evaluating policy options are outlined briefly below.

**Cost Benefit Analysis (CBA)**
Cost-Benefit Analysis (CBA) is a key method for assessing adaptation options, and involves calculating and comparing all the costs and benefits of a given option by expressing them in monetary terms. A comparison of expected costs and benefits highlights the efficiency of a particular adaptation investment and provides a basis for prioritising possible adaptation measures. The advantage of this approach is that it compares a range of impacts using a single metric. However, a key challenge is how to include reliable estimates of non-market goods and services, for example the costs and benefits of environmental services and social or cultural values. A number of techniques for evaluating non-market costs and benefits are available. As well as producing aggregate cost and benefit values, it is also important to assess how these are distributed.

**Cost Effectiveness Analysis (CEA)**
Cost Effectiveness Analysis is used to find the least costly adaptation option, or options, for achieving a fixed level of effectiveness in meeting a given objective. This method is a useful alternative when it is difficult to quantify or monetise benefits, but it does not evaluate whether a measure is justified (e.g. by generating a benefit-cost ratio or an internal rate of return (IRR)).

**Multi Criteria Analysis (MCA)**
MCA is a method for combining monetised and non-monetised impacts in a single decision-making framework. It allows the assessment of different adaptation options according to a number of criteria. This is done by scoring each option under a number of criteria and weighting those criteria for their importance in the prioritization process, in order to arrive at an overall score for each adaptation option. Expert judgment is used in the definition of weights and in the scoring of criteria. MCA can be used in combination with CBA and CEA, and is effective when social and environmental considerations are difficult to quantify in monetary terms. The advantage of using MCA is that it allows the transparent assessment and ranking of options as an input to discussions and decisions on priorities. It is not, however, an objective process, as judgments must be made about weighting criteria. Therefore, it can be instructive to undertake a sensitivity analysis to assess how results differ when different weights are used.

**Real Options Analysis (ROA)**
Real Options Analysis originated in the financial markets, where it has been used to assess the valuation of financial options and risk transfer. It also has potential in evaluating options in other conditions of uncertainty, such as adapting to SLR and other CVC impacts. The advantages are that it quantifies the investment risk associated with uncertain future outcomes and considers the value of flexibility of investments, including flexibility regarding the timing of capital investment and the need to adjust the investment over time,
adapting, expanding, or scaling back in response to unfolding events (e.g. building a flood wall with deeper foundations than required for the initial structure, so that it can be raised in future, if necessary). It can therefore justify options (or decisions) that would not be taken forward under a conventional economic analysis (Watkins et al, 2013; Metroeconomica, 2011).

**Regulatory Impact Analysis (RIA)**

In the case of adaptation options that involve new or amended regulations, a Regulatory Impact Analysis can provide a systematic appraisal of the potential impacts, and whether the regulation is likely to achieve the desired objectives. RIAs include assessments of the effects of different policy instruments in terms of efficiency, equity, administrative ease and other relevant criteria. This tool may not be necessary at the initial stage of evaluating priority adaptation options, and may be more applicable at the stage of assessing the details of proposed regulations.

The results of evaluations using the above methods, as appropriate per type of option, should allow policy makers to understand and compare the relative net benefits, uncertainties, feasibility risks and other implementation impacts, such as those on equity and vulnerable groups, as attached to each proposed adaptation measure, in order to aid the selection and prioritization of actions. It will also provide information on no-regrets measures.

Section 7 discusses in greater detail the suitability of the different methods outlined above for evaluating adaptation options according to different CVC impacts on specific sectors, as assessed in the top-down and bottom-up approaches (outlined in Sections 5 and 6).

While it is desirable to use these methods whenever possible, it should be noted that in a number of cases, the data collected on the impacts of climate change and the information available on what adaptation measures can do to reduce these impacts are not available in a form that allows these methods to be used. The most that can be done is to provide important information on the magnitude of the impacts and risks in different sectors, and an indication of where action is needed and further information should be collected. This is in itself a useful service to policy makers, who can then decide on precisely what policies and measures should be implemented, and in what timeframe.
4 Undertaking the assessment

The process of undertaking the assessment of the impacts of CVC and associated adaptation options in coastal zones is outlined here briefly, and explained further in the following sections. Figure 4.1 summarises the stages of a typical assessment as follows:

- **Project design:** in the initial stage, the instigating organisation(s) should decide in general terms on the focus and scope given in the terms of reference. This may include geographical coverage, project timescales, the range of CVC impacts to be assessed (i.e. a comprehensive assessment, or confined to specific issues, such as SLR) and other project management issues. These details will depend on factors such as the overall objectives and obligations of the organisation(s), available resources and the views of key stakeholders on existing needs for supporting an adaptation policy in the given country or region. The exact make-up of the study team will be defined by these initial decisions, but should consist of a combination of experts on the DIVA model (if this is to be used), experts on socio-economic assessment for the selected sectors in the coastal zones, and local experts on the coastal zone under assessment.

- **Identifying stakeholders:** a key part of the process of setting up the study is identifying the stakeholders who will be involved. These may include national and local government ministries, research organisations, NGOs and local trade organisations. Consultation with these stakeholders at key stages in the study process (including scoping issues, data collection, scoping adaptation options, and communicating results) is an important way of ensuring the study is well informed on local issues, so as to improve general understanding and ownership of results and recommendations.

- **Scoping issues:** an initial review of possible CVC impacts and the vulnerabilities of different sectors and populations in the study area to these impacts will allow further refinement of the necessary scope of the study and the analysis methods required. It will also inform the data collection process. Table 4.1 gives an example framework for assessing the scope of a study, including a range of sectors and issues that may be affected by CVC hazards, the types of potential impacts, and the suitability of a top-down and bottom-up approach for assessing these impacts.

- **Data collection:** following decisions on the scope of the assessment and methods to be employed, the data collection process is undertaken by local experts in close consultation with international and national experts in the study team. A data collection plan can be used to define the types of data needed for the given methods, and likely local, national and global sources (further information on useful sources of data for specific uses is given in Section 10). It is important to stress that this is of necessity an iterative process, both with respect to both scoping issues (e.g.
it may be decided from the source data that certain issues are not relevant to the study area) and top-down and bottom-up assessments (e.g. it may be found that there is insufficient data to use the intended methodologies, or that different methods should be used, as appropriate for available data).

• **Undertaking assessments of impacts (top-down and bottom-up):** these assessments are described in more detail in Sections 5 and 6. For some issues given in Table 4.1, a combination of top-down and bottom up-assessments may be necessary. For example, in the tourism sector, downscaled DIVA results can provide data on where SLR related impacts on people and assets will occur on the coastline, while local data on key tourist locations and the economic value of tourism can inform further the analysis of economic impacts.

• **Integrating results:** the key aim at this stage is to draw together and summarise the results of top-down and bottom-up assessments, so that comparisons can be made regarding the relative significance of different CVC impacts on people, assets and different sectors. This allows prioritisation of needs for adaptations in the study area. This is described further in Section 7.

• **Evaluation of adaptation options:** this stage should build on the results of the assessment of impacts and prioritisation of needs for adaptation. An initial scoping of adaptation options per prioritised issue will result in a number of possible options for evaluation, using the appropriate methods, as outlined in Section 3.5. Further examples of the use of evaluation methods per sector are given in Section 8.

• **Communication of results:** this is a key stage in ensuring that the conclusions of the study reach the desired audience. This can help build arguments for adaptation among stakeholders and provide information on the prioritisation of adaptation policies and investments.
Figure 4.1: Overview of stages in the assessment of CVC impacts and adaptation options

- Study Design/Identification of Stakeholders
- Scoping CVC issues/sectors in the study area
- Data Collection
- Top-Down Assessment
- Bottom-Up Assessment
- Integration of Results
- Evaluation of Adaptation Options
- Communication of Results
Table 4.1: Example framework for scoping CVC impacts and sectors in a coastal zone

<table>
<thead>
<tr>
<th>Priority sector/issue</th>
<th>Climate hazards</th>
<th>Physical impacts</th>
<th>Assessment of socio-economic impacts</th>
<th>Top-down (DIVA) or bottom-up assessment?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tourism</td>
<td>Flooding, wave surges</td>
<td>Damage to tourism assets</td>
<td>Identify tourism assets on the coast and assess damage according to scenarios</td>
<td>Top-down and bottom-up</td>
</tr>
<tr>
<td></td>
<td>Changes in the Tourist Climatic Index. Impacts on attractions (e.g. biodiversity, landscapes)</td>
<td>Changes in seasonal demand.</td>
<td>Impact on the value of tourist spending for different scenarios of future seasonal demand.</td>
<td>Bottom-up</td>
</tr>
<tr>
<td>Forest fires</td>
<td>Increased fire risks</td>
<td>Damage due to fires</td>
<td>Assessment of damage according to scenarios</td>
<td>Bottom-up</td>
</tr>
<tr>
<td>Maritime activities (shellfish farming, fisheries, etc.)</td>
<td>Changes in salinity, temperature</td>
<td>Damage to catch, esp. shellfish.</td>
<td>Assessment of damage according to scenarios</td>
<td>Bottom-up</td>
</tr>
<tr>
<td>Agriculture</td>
<td>Flooding/SLR</td>
<td>Damage to the coast.</td>
<td>Assessment of damage due to direct impacts.</td>
<td>Top-down and bottom-up</td>
</tr>
<tr>
<td></td>
<td>Changes in yields</td>
<td>Change in yields due to precipitation/temperature changes. Damage due to changes in extreme weather events, diseases.</td>
<td>Assessment of changes in yields and damage due to extreme weather events</td>
<td>Bottom-up</td>
</tr>
<tr>
<td>Transport</td>
<td>Flooding/wave surges/SLR</td>
<td>Damage to shipping, road and rail infrastructure and services.</td>
<td>Adaptation costs. Assessment of lost income from</td>
<td>Top-down and bottom-up</td>
</tr>
<tr>
<td>Category</td>
<td>Issues</td>
<td>Impacts/Changes</td>
<td>Costs/Assessments</td>
<td>Approach</td>
</tr>
<tr>
<td>------------------------------</td>
<td>------------------------------------------------------------------------</td>
<td>------------------------------------------------------</td>
<td>-------------------------------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>Infrastructure (water, sewage, waste)</td>
<td>Changes in rainfall. Total and seasonal distribution.</td>
<td>Impacts on the water supply.</td>
<td>Adaptation costs.</td>
<td>Bottom-up</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Assessment of lost income from services.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flooding/wave surges/SLR</td>
<td>Impacts on water supply, sewage and waste services.</td>
<td>Adaptation costs.</td>
<td>Top-down and bottom-up</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Assessment of lost income from services.</td>
<td></td>
</tr>
<tr>
<td>Energy</td>
<td>Change in supply potential of renewables.</td>
<td>Possible changes in potential for hydro, wind, or solar energy. Increase in energy demand during hot periods.</td>
<td>Assessment of new (or loss of) potential in renewable supply.</td>
<td>Bottom-up</td>
</tr>
<tr>
<td>Other industries</td>
<td>Various</td>
<td>Impacts on other industries, e.g. shipbuilding, insurance (fires, premiums), banking (risks to mortgages on coastal property).</td>
<td>Various</td>
<td>Top-down and bottom-up</td>
</tr>
<tr>
<td>Residential properties</td>
<td>Flooding/wave surges/SLR</td>
<td>Damage to primary and secondary residential properties.</td>
<td>Assessment of damage to assets</td>
<td>Top-down</td>
</tr>
<tr>
<td></td>
<td>Inland river and flash flooding and storms.</td>
<td>Damage to properties from inland flooding.</td>
<td>Assessment of damage to assets</td>
<td>Bottom-up</td>
</tr>
<tr>
<td>Health</td>
<td>Changes in the incidence of heat or cold waves.</td>
<td>Increase in mortality and morbidity.</td>
<td>Changes in health service costs.</td>
<td>Bottom-up</td>
</tr>
<tr>
<td></td>
<td>Changes in risks of vector-borne diseases</td>
<td></td>
<td>Costs of mortality</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Changes in food-related diseases</td>
<td></td>
<td>Loss of wellbeing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Changes in water-borne diseases</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5  Top-down assessment: DIVA

In the context of assessing climate variability and change in coastal zones in the ClimVar & ICZM Project, ‘top-down’ assessment refers to the downscaling of global research models and datasets to provide estimates of the impacts of sea-level rise and coastal flooding under a set of agreed climate change and socio-economic scenarios. Specifically, this has been undertaken for coastal studies to date using the DIVA modelling framework, which is outlined below, along with a description of data requirements, stakeholders to be involved and methodological steps in the assessing the environmental and socio-economic costs of CVC impacts. This is followed by an outline of two demonstration cases, with details of how the approach has been applied in practice.

5.1  Background to DIVA

Dynamic Interactive Vulnerability Assessment (DIVA) is an integrated global modelling framework for assessing the biophysical and socio-economic consequences of sea-level rise and associated extreme weather events under different physical and socio-economic scenarios. It also considers various adaptation strategies (see Figure 5.1). DIVA was originally developed as a tool for the integrated assessment of coastal zones produced by the EU-funded DINAS-Coast consortium in 2004.

It considers impacts due to extreme water levels caused by sea-level rise during the 21st century at global and regional scales. DIVA allows the user to take future sea-level rise and socio-economic scenarios to project impacts at a global scale. Metrics include the number of people potentially exposed to flooding due to extreme water levels, the amount of land loss at extreme water levels, wetland loss due to extreme water levels, the total cost of damage due to floods, and the potential costs of adaptation to reduce flood risks.

DIVA has been used in a wide range of projects funded by NERC, DEFRA, DECC, DFID amongst others, including the impacts of sea-level rise in Africa, as part of the UNEP Climate Change Adaptation programme.

The model was co-developed with, and builds on, a global coastal database that contains information on biophysical and socio-economic coastal characteristics. The database relies on the segmentation of the world’s coasts (excluding Antarctica) into 12,148 linear segments, and associates about 100 data elements with each segment, relating to the physical, ecological and socio-economic characteristics of the coast. This approach is unique in integrating data and methods for studying coastal processes from a range of different disciplines.
5.2 Requirements for undertaking the assessment

The process of downscaling for conducting national-scale assessments involves a series of methodological steps, which are described in the next section and are also presented in detail in the studies of Croatia and Tunisia. This process relies to a large extent on the availability of spatial data on the physical and socio-economic parameters of the coast, and on input from local experts and stakeholders.

Although, as a global model, DIVA already includes data for every coastal nation in the world, the downscaling process could benefit considerably from the utilisation of national- or local-scale data. The use of larger (cartographic) scale digital coastlines and information on administrative boundaries, which are also employed by national agencies, would not only provide higher detail, but also enhance the comparability of outputs with local and regional studies. Furthermore, detailed information on parameters such as elevation, population distribution, coastal morphology and attributes would significantly enhance the outputs. Although such data are freely available for most areas of the globe, they may be subject to different types of error or uncertainty in various locations. The use of higher quality, more accurate local data may in some cases produce significant improvements at regional and local levels.

Such data can be provided by local authorities and stakeholders, who often possess the required information and knowledge and use it in studies conducted within their regions. The process of acquiring data from local actors can however present several difficulties. Issues such as data sharing ethics, data form and format, costs, metadata and licensing may constitute serious obstacles in obtaining local data to be used in the analysis. Data acquisition can therefore be a lengthy process, which depends greatly on extensive communication and establishing mutual trust between the organisations and stakeholders involved. Furthermore, the expertise and support that such organisations and individuals can supply are essential for the correct use of the data provided.

Communication is also particularly important at a later stage in the evaluation and presentation of the results of the analysis. In the cases of Croatia and Tunisia presented below, the results were communicated to groups of local and regional experts and stakeholders. Detailed presentations of preliminary results (in the form of graphs, tables and maps) proved useful in identifying emerging spatial and temporal patterns of impacts and adaptation and initiating discussions regarding the results, along with fine-tuning the model and final results.
5.3 Description of the method

The key steps of the method are described in general terms below. More details of the practical application of these steps are given in the demonstration cases for Croatia and Tunisia in the following sections.

(i) Establishing coastline segmentation and data on exposure to CVC impacts

The first step is to establish the necessary physical and socio-economic coastal data for the area of study. To achieve this aim, the DIVA model employs a linear representation of the coastline, in which information on geographic features is used to divide the coast into segments of variable length. Geographical data in the DIVA database for each segment includes administrative units, countries, rivers, tidal basins and world heritage sites. Coastal space in DIVA is structured as a meaningful expression of spatial variability in vulnerability from the national to global scales. As variations in vulnerability within the coastal zone are controlled by primary variations in the human and physical coastal interchange, several critical parameters were employed for the segmentation of the coastline. These parameters were (i) administrative boundaries, (ii) the geomorphic structure of the coastal environment, (iii) the expected morphological development of the coast, given sea-level rise, and (iv) population density. Segmentation of the coastline is therefore used as a
means of providing a series of spatial reference units for the project's modelling tool and linking it to the geographical database. The theoretical framework underlying segmentation is analytically described in McFadden et al. (2007).

The segments constitute the final reference units for the DIVA model. All the attribute data are referenced to these segments using Geographic Information Systems (GIS) and spatial processing methods described in Vafeidis et al. (2005). In downscaling DIVA for national-scale assessments in Croatia and Tunisia, a more detailed segmentation of the coastline was developed and the DIVA database was updated, where possible, using new and improved (in terms of resolution, accuracy and spatial coverage) spatial datasets on physical and socio-economic parameters, in addition to local and national datasets provided by national organisations in the countries involved. Downscaling DIVA to the national level involves a series of steps, as follows:

- **Selection of digital coastline**: the DIVA segmentation described above is based on a digital global coastline dataset with a scale of approximately 1:3,000,000. For national or local scale assessments, a finer resolution scale may be needed in order to include important coastal features. Therefore, other available digital coastline datasets may need to be used to supplement the global dataset.

- **Coastline segmentation**: the coastline segmentation is based on the use of criteria including coastal morphology and geological characteristics, population density, and administrative boundaries. The DIVA database includes global information on coastal morphology and geological characteristics, but downscaling may require additional datasets to provide greater detail for a given coastline. The combined information is then used to produce a series of linear units of variable length that represent homogeneous sections of the coast, in terms of response to SLR.

- **Assessment of exposure of area, population and assets**: exposure of an area to inundation can be assessed using Digital Elevation Models (DEM) and other information on elevation from national sources. This allows identification of the extent of areas at different elevation steps that extend inland from the coastline segments. Using population datasets, values are calculated for the population numbers exposed at different elevation steps per coastline segment. Exposure of assets per elevation step and per coastline segment can then be assessed based on spatial assets datasets for the locality.

- **Erosion parameters**: datasets on coastal morphology can also be used to characterise the degree of erodibility of different coastal types (e.g. erodible beaches, rocky coasts and urban coasts) and erosion factor values representing different coastal types can then be assigned to all segments. Based on this assessment, the total length of coastline of different degrees of erodibility can be calculated for a given stretch of coastline.
Selecting sea-level rise scenarios

The next step is to select SLR scenarios to use in assessments of CVC impacts on the coastline in the study. The generation of regional sea-level rise scenarios should follow the methodology discussed in the Fifth Assessment Report (AR5) of the Intergovernmental Panel for Climate Change (IPCC). In the demonstration cases discussed below, further scenarios were used that also took into account research in the Inter-Sectoral Impact Model Intercomparison Project Fast Track (Hinkel et al, 2014) which gives a wider range of ice-melting uncertainty and therefore slightly higher sea levels than the AR5.

Establishing the incidence of extreme water levels

Since sea-level rise is the major factor in an increase in extreme high water levels, the incidence of these extreme levels under the different selected SLR scenarios needs to be assessed, in terms of surge heights for different return periods, as part of assessing flood exposure and risk. Information on extreme water levels for different return periods is included in the DIVA database and could be supplemented by further information from national sources.

Selecting socio-economic scenarios

The analysis then needs to select socio-economic scenarios (SSPs, as described in Section 3.2) to be used for assessing the socio-economic impacts from CVC. Population growth rates and GDP per capita in the different scenarios are applied to the population and assets exposure data (from step (ii) above), in order to assess future socio-economic impacts from SLR and extreme water levels (from step (iii) above).

Assessing erosion impacts

The socio-economic impacts of SLR from the increased erosion of sandy beaches can be assessed following the approach of Hinkel et al. (2013) in terms of three metrics:

- **Land loss** (annual loss of land in km²/yr). This refers to the loss of habitable land.
- **Migration cost** (annual cost of forced migration due to land loss in millions of US$/yr).
- **Nourishment cost** (annual cost of replacing eroded sand through beach or shore nourishment in millions of US$/yr).

The first two impacts (land loss and migration cost) can be assessed with or without adaptation in the form of beach and shore nourishment, i.e. the replacement of eroded sand. This information can help decision making on adaptation options, by showing whether (and by how much) the benefits of avoided land loss, migration and the loss of tourism exceed the costs of investing in nourishment.
(vi) Assessing flood damage and sea-level rise impacts

Potential coastal flood damage and sea-level rise impacts can be assessed following the approach of Hinkel et al. (2014). This calculates the cumulative impact on a given stretch of coastline, based on aggregating impacts on coastline segments for each SLR scenario and socio-economic scenario, for the following metrics:

- **Area below extreme water level for a given return period**: for example, the area below the 1-in-100 year extreme water level [km²].
- **People below extreme water level for a given return period**: for example, the number of people living below the 1-in-100 year extreme water level.
- **Assets below extreme water level for a given return period**: for example, the value of assets below the 1-in-100 year extreme water level [billion US$].
- **People flooded**: the average number of people flooded annually through extreme water level events [people/yr]
- **Flood cost**: the average annual damage caused by coastal flooding [billion US$/yr]
- **Adaptation cost**: the annual cost of maintaining and upgrading coastal defences [billion US$/yr]

5.4 Addressing problems

Some of the most common difficulties that may arise are presented below, with proposals for handling them.

**Data availability**

The availability of data is one of the main issues that always needs to be addressed. Local data may not exist, or be simply unobtainable from local or national agencies. Data collection requires a great amount of time and provisions need to be made in advance in case local data are not available.

**Communicating methods and first results**

Considerable efforts need to be devoted to communicating the model. The possibilities of analysis and the limitations of the model both need to be communicated clearly. There may be general scepticism towards the model/methods and the outcomes, and this should be anticipated and discussed extensively with the people involved. Some results should be communicated early on, allowing local stakeholders to be involved in the analysis by expressing their expert opinions and providing further insights. This process can be used to refine and fine-tune subsequent runs, results and analysis.
5.5 Demonstration cases

5.5.1 Demonstration case 1: the Croatian coast

For this project, DIVA was downscaled to be applicable at the scales required, in order to produce information useful for developing national ICZM strategy. To this end, coastal data is represented in more detail and in reference to the specific geographical and socio-economical context.

This case study made an assessment of sea-level rise impacts on the coastal regions of Croatia using a downscaled version of the DIVA model. The assessment was based on a full representative sample of the socio-economic and sea-level rise uncertainty ranges, employing three sea-level rise scenarios (21st century sea-level rises of 0.28m, 0.49m and 1.08m) and three socio-economic development scenarios based on shared socio-economic pathways (SSP). The assessment considered the sea-level rise impacts of increased coastal flooding and coastal erosion. The impacts were assessed without and without adaptation in the form of upgrading dikes to protect against flooding, and nourishing beaches and shores to protect against erosion.

In downscaling DIVA for the national-scale assessment in Croatia, a more detailed segmentation of the coastline was developed and the DIVA database was updated, where possible, using new and improved (in terms of resolution, accuracy and spatial coverage) spatial datasets on physical and socio-economic parameters, in addition to local and national datasets provided by national organisations. Downscaling DIVA involved a series of steps, as follows:

Selection of digital coastline
The DIVA segmentation described above is based on a digital global coastline dataset with a scale of approximately 1:3,000,000. For the Croatia national scale assessment, this scale was deemed inadequate due to the loss of important coastal features (e.g. islands, enclosed bays, pocket beaches etc.). Therefore, after comparing a series of available digital coastline datasets, the Global Administrative Areas (GADM) level 01 coastline was selected. The coastline was corrected using a smoothing algorithm with a tolerance of 100m in order to remove artefacts related to the format of source data (e.g. ‘pixelisation’ of coastal segments).

Coastline segmentation
As described in Section 5.3. above, coastline segmentation was based on the criteria of coastal morphology and geological characteristics, population density and administrative boundaries, and this was extended to include river mouths. Although the DIVA database includes global information on coastal morphology and geological characteristics, for the purposes of the study, a new dataset on coastal morphology for the entire coastline of
Croatia was developed. This dataset was based on visual interpretation of Google Earth imagery, also taking into account the existing DIVA database and using location-tagged photographs from the web-service Panoramio\(^4\). For population density, all Croatian cities with a population exceeding 10,000 were considered, along with some smaller ones. By combining this information with Google Earth imagery, a new spatial dataset of coastal settlements was developed. Finally, a digital spatial dataset containing Digital Terrain Model (DTM) and administrative boundaries for Croatia provided by the State Geodetic Administration of Croatia were used.

The above information was combined for the segmentation of the Croatian coastline, producing a series of linear units of variable length representing homogeneous sections of the coast, in terms of response to SLR. Manual corrections were applied to eliminate segments shorter than 100m, as these were deemed too small for the scale of this analysis. The segmentation resulted in 1,550 segments (see Table 1), with an average length of 3.68 km (the minimum length was 100.2 metres, and the maximum length was 116.54 km).

**Exposure data – area, population and assets**

Exposure of areas to inundation was assessed on the basis of the Shuttle Radar Terrain Mission (SRTM) Digital Elevation Model (DEM) and information on elevation from the State Geodetic Administration of Croatia, through the following steps:

- Identification of land areas at different elevation increments (1m, 2m, 3m etc., up to 16m) hydrologically connected to the sea.
- Identification of buffer zones to extend coastline segments inland and calculate the extent of areas per elevation step that corresponded to these zones. These values were then stored as attributes of the coastal segments.
- Population exposure was attained by summarising the population per elevation increment, per coastline segment, and the resulting values were stored as attributes of the respective segments. Population data were obtained from the Landscan\(^5\) dataset.
- Exposure of assets per elevation was assessed using the same method as for population; assets were summarised per elevation increment, per coastline segment, and the resulting values were stored as attributes of the respective segments. The spatial assets dataset was, however, produced differently from previous DIVA assessments. Large area coastal flood impact assessments usually assess the value of exposed assets by multiplying population, GDP-per-capita and empirically attained assets-to-GDP-per-capita ratios. For Croatia, a different approach was necessary in order to take into account higher assets-to-GDP-per-

\(^4\) Panoramio provides geographically tagged photographs submitted by users for the entire coastline of Croatia, and provides useful information on coastal type and morphology, used to complement/validate the satellite imagery and cartographical information available. [http://www.panoramio.com](http://www.panoramio.com)

\(^5\) LandScan is the Oakridge National Laboratory fine resolution global population distribution dataset: [http://web.ornl.gov/sci/landscan/](http://web.ornl.gov/sci/landscan/)
capita ratios in the Mediterranean, due to substantial tourism-related secondary housing. The spatial distribution of the economic values of assets was thus derived independently from population data for each municipality/town, as described in Pascual and Markandya (2014).

**Erosion parameters**
The dataset on coastal morphology developed during the segmentation process was used to characterise the degree of erodibility of the different coastal types and to calculate the parameters for the DIVA erosion algorithm. Erosion factor values representing erodible coastal types were assigned to all segments. Based on expert judgement, a value of 1 (i.e. 100% erodible) was assigned to segments that represented erodible beaches (i.e. primarily consisting of erodible material such as sand, granular gravel, or combinations of these with stones or pebbles) while a value of 0.3 was assigned to segments that consisted of rocky coasts with pocket beaches. Altogether, 181 beaches with a total length of approximately 80 km were identified as erodible. Rocky and urban coasts were considered to be non-erodible and were assigned a value of zero.

**Sea-level rise scenarios**
For each RCP scenario, regional sea-level rise scenarios were constructed. These were based on research in the Inter-Sectoral Impact Model Intercomparison Project Fast Track, as published in Hinkel et al (2014). This takes into account a wider range of ice-melting uncertainty than in the AR5, which leads to slightly higher sea levels as compared to the AR5.

For the Croatia study, three sea-level rise scenarios were used; a lower bound scenario (RCP2.6 combined with the 5% quantile of ice-melting projections), called low SLR below, a medium scenario (RCP 4.5 combined with the median), called medium SLR, and an upper bound scenario (RCP8.5 combined with the 95% quantile), called high SLR. Local vertical land movement due to glacial-isostatic adjustment (resulting from loading and unloading of the ice sheets during the last Ice Age) were also taken into account. This contributed to the land rising (and thus the sea level falling) but was assessed as having only a small impact on total sea-level rise. The projections for sea-level rise in 2050 and 2100 are summarised in Table 5.1.

**Table 5.1: Sea-level rise in Croatia in 2050 and 2100 under three sea-level rise scenarios**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Sea-level rise 2050</th>
<th>Sea-level rise 2100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low SLR</td>
<td>0.15m</td>
<td>0.28m</td>
</tr>
<tr>
<td>Medium SLR</td>
<td>0.19m</td>
<td>0.49m</td>
</tr>
<tr>
<td>High SLR</td>
<td>0.31m</td>
<td>1.08m</td>
</tr>
</tbody>
</table>
**Extreme water levels**

Extreme water levels for different return periods used in the assessment were based on the DIVA database, and further information was provided by the National Hydrographic Service. Table 5.2 shows the extreme water levels used in the assessment of flood exposure and risk (average values over all coastline segments). H1 is the water level exceeded on average once every year, and H100 is the water level exceeded on average once every 100 years. While in 2010, H1 is about 0.83m and H100 about 1.14m, these values go up with sea-level rise. In 2100, for example, H100 will be 2.20m under RCP8.5.

### Table 5.2: H1 and H100 in 2010, 2050 and 2100, under different SLR scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>H1, 2010</th>
<th>H1, 2050</th>
<th>H1, 2100</th>
<th>H100, 2010</th>
<th>H100, 2050</th>
<th>H100, 2100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low SLR</td>
<td>0.83m</td>
<td>0.95m</td>
<td>1.08m</td>
<td>1.14m</td>
<td>1.26m</td>
<td>1.39m</td>
</tr>
<tr>
<td>Medium SLR</td>
<td>0.84m</td>
<td>0.99m</td>
<td>1.29m</td>
<td>1.14m</td>
<td>1.30m</td>
<td>1.60m</td>
</tr>
<tr>
<td>High SLR</td>
<td>0.84m</td>
<td>1.12m</td>
<td>1.89m</td>
<td>1.15m</td>
<td>1.43m</td>
<td>2.20m</td>
</tr>
</tbody>
</table>

**Socio-economic scenarios**

The Croatia analysis focused on these three socio-economic scenarios: SSP2 (Middle of the Road), SSP3 (Fragmentation) and SSP5 (Conventional Development), as they provide sufficient coverage of the full range of uncertainties (See Section X for scenario definitions). Populations and GDP per capita were estimated under these scenarios for Croatia up to the year 2100. A falling population trend was present in all scenarios, while GDP per capita tended to rise. The respective growth rates were applied to the population and assets exposure data.

**Assessment of erosion impacts**

The socio-economic impacts of SLR from the increased erosion of sandy beaches were assessed in terms of three metrics:

1. **Land loss** (annual loss of land in km²/yr). The dominant land use class per segment was used to evaluate these losses. Generally, this was an agricultural, or lower value land class (e.g. nature areas, forests or tundra).

2. **Migration cost** (annual cost of forced migration due to land loss in millions of US$/yr). The number of people forced to migrate was calculated as the product of the land area eroded and the average population density per segment, i.e. it was assumed that the population was spread evenly over the area. Following Tol (1995), emigration was valued at three times per capita income.

3. **Nourishment cost** (annual cost of replacing eroded sand through beach or shore nourishment in millions of US$/yr). The first two impacts were assessed with and without adaptation in the form of beach and shore nourishment, i.e. the
replacement of eroded sand. Nourishment is applied following a cost-benefit analysis considering the damage avoidable in terms of land loss, forced migration and tourism. Because both costs and benefits are assumed to be linear functions of the amount of nourishment, segments are either fully protected (so that no damage occurs) or not protected at all. In areas with coastal tourism, beach nourishment is the preferred adaptation option. It is applied if the combined benefits in terms of land loss, migration and tourism are sufficient. If the costs of beach nourishment cannot be justified by its benefits, then shore nourishment is evaluated to avoid land loss and forced migration. The level of tourism and tourism revenues were calculated using the Hamburg Tourism Model (HTM) (version 1), which is an econometric model of international tourism flows at a national scale (Hamilton et al., 2005a; 2005b).

**Assessment of flood damage and sea-level rise impacts**

Potential coastal flood damage and sea-level rise impacts were assessed in terms of the following:

- **Area below H100 (potential floodplain):** the area below the 1-in-100 year extreme water level [km²]
- **People below H100:** the number of people living below the 1-in-100 year extreme water level.
- **Assets below H100:** the value of assets below the 1-in-100 year extreme water level [billion US$].
- **People flooded:** the average number of people flooded annually through extreme water level events [people/yr]
- **Flood cost:** the average annual damage caused by coastal flooding [billion US$/yr]
- **Adaptation cost:** the annual cost of maintaining and upgrading coastal defences [billion US$/yr]

For each coastline segment, a cumulative people exposure function was constructed that gave the number of people living below a given elevation level. Future exposure was attained by applying the national population and GDP growth rates of the socio-economic scenarios. In the case of adaptation costs, the analysis assumed the building and upgrading of dikes based on a demand function for safety, taken from Hinkel et al. (2014). This function estimates coastal demand for safety over time, in terms of the flood return period against which protection is required.

**Estimates of SLR costs for Croatia**

The analysis showed that the impacts of SLR will be substantial for Croatia in the 21st century if no adaptation measures are taken. Coastal flooding due to current climate
variability is already an issue in Croatia. At present, 270 km$^2$ of the Croatian coastal zone is exposed to the 1-in-100 year coastal extreme water level. The predicted 21$^{st}$ century sea-level rise would increase this area to 320-360 km$^2$. If no adaptation measures are taken, sea-level rise and socio-economic development would increase flood risks substantially during the 21$^{st}$ century. The expected number of people flooded annually would increase from 17,000 in 2010 to 43,000-128,000 in 2100, and the expected annual damage from initial US$ 40 million to 0.9 to 8.9 billion US$ per year in 2100. Damage would be concentrated mainly in floodplain areas of Zadar and Šibenik. Compared to the impacts of sea-level rise on coastal flooding, coastal erosion is a minor issue in Croatia.

The analysis also shows that the impacts could be reduced significantly by applying appropriate adaptation measures. Adaptation via dikes was assessed as one possible, widely applicable strategy, which would reduce sea-level rise impacts by about two orders of magnitude. The strategy assessed in the study would require an up-front investment of US$ 11.2 billion in 2010 to build initial dikes for about 84% of Croatia's coast (when considering coastal segments with population density higher than 30 inh./km$^2$ as ones that need protection), and subsequent annual investments and maintenance costs increasing from initial about US$ 110 million per year to US$ 100-230 million by the end of the century. While these costs are substantial, they are at least one order of magnitude lower than the damage costs thus avoided, which means that the strategy would be highly cost-efficient. It must be emphasized that the proportion of the coast that requires protection (84%) is based on the assumption that entire coastal segments are to be protected if their population density exceeds 30 inh./km$^2$. However, coastal areas that are constructed or planned for construction (for both residence and tourism) according to today's spatial plans are only covering approximately 20% of Croatia's coastal length. It is therefore important to note that the actual protection length would likely be between these two values. The exact value will depend on the geographical settings (e.g. elevation, morphology, floodplain characteristics) as well as on management priorities and decisions.

5.5.2 Demonstration case 2: the Tunisian coast

In the case of Tunisia, the methods for Croatia presented in the previous sections were also employed. The results show that the impacts of sea-level rise will be substantial for Tunisia in the 21$^{st}$ century, if no adaptation measures are taken. Coastal flooding due to current climate variability is already an issue in Tunisia. Currently, 1,124 km$^2$ of the Tunisian coastal zone are exposed to the 1-in-100 year coastal extreme water level. The 21$^{st}$-century sea-level rise would increase this area to 1,666 km$^2$ (RCP8.5). The expected number of people flooded annually would increase from 140,000 in 2010 to 436,000 in 2100 and the expected annual damage could reach up to US$ 45.5 billion per year in 2100. Médenine is the municipality with the biggest potential 100-year floodplain, followed by Bizerte and Sfax;
Tunis, Ben Arous and Sfax have the highest asset values and population in the potential 100-year floodplain.

The analysis also shows that impacts can be reduced significantly by applying appropriate adaptation measures. In the present study, we assessed adaptation via dikes as one possible, widely applicable strategy. The strategy assessed here would require an up-front investment of US$ 18.8 billion to build initial dikes for about 86% of Tunisia's coastline, and subsequent annual investments and maintenance costs increasing from about US$ 169 million in 2010 to US$ 220-300 million per year by the end of the century. While these costs are substantial, they are at least one order of magnitude lower than the damage costs thus avoided, which means that the strategy would be highly cost-efficient.

Coastal erosion is expected to constitute a further issue for Tunisia. Under the high sea-level rise scenario, and without adaptation, the sea-level rise is projected to erode up to 520,000 m² of land annually by 2100, as erodible beaches constitute approximately one-third of the Tunisian coastline. Adaptation through beach nourishment would cost up to US$ 43 million annually. Nabeul, Soussè, Médenine and Bizerte are expected to be the municipalities most affected by coastal erosion. Maintaining the beaches used for tourism is therefore relatively expensive, while sand availability may pose a further challenge.
6 Bottom-up: local vulnerability assessment

The aim of a bottom-up assessment is to provide, to the extent feasible, estimates of the impacts of various CVC hazards on people, the local economy and infrastructure in a coastal zone study area. In general, the procedure is to estimate these impacts in terms of damage to the ‘business as usual’ scenario and, if possible, to quantify and monetize the impacts. The differences from the top-down assessment are that the analysis is at a scale that the top down model cannot address, and that a greater scope of impacts across different socio-economic sectors and issues is taken into account.

6.1 Scoping sectors and impacts

The initial task should be to scope CVC impacts and sectors that may be relevant to the case study area. This can be done following the approach outlined in Section 4 and Table 4.1. The following checklist can be used as a starting-point in defining which sectors may be impacted by CVC in a given case study area:

- Human health
- Transport
- Built environment and cultural heritage (including residential property)
- Agriculture
- Forestry
- Fisheries
- Biodiversity
- Water resources
- Tourism
- Energy

6.2 Data Collection

The suggested approach for data collection is to categorise data relevant to each sector and impact identified in the study area using the Impact Pathway Assessment approach, in which a pathway is followed from environmental change through climate hazards (such as SLR and increased storm intensity), to physical and socio-economic impacts and their expression in quantitative and monetary terms. Further definitions of the stages of the Pathway Assessment approach in the context of coastal zones are set out below.

Climate hazards: An overview of the most significant bio-geophysical effects of climate variability and change is provided in Table 6.1. The IPPC Fourth Assessment Report identifies the following main climate drivers (hazards) for coastal systems (ETC CCA, 2011)⁶:

⁶ In the demonstrations cases for this project, we also included other general CVC impacts that occur in the coastal zone, such as trends in temperature and rainfall that may impact tourism and agriculture.
• Change in storm frequency and intensity
• Change in wave patterns
• Sea-level rise
• Sea-water temperature increase
• CO² concentration increase and related ocean acidification
• Increase in run-off

**Physical impacts:** these are the physical damages brought about by climate hazards, such as damage from coastal flooding, coastal erosion, extreme weather events, salt-water intrusion and loss of marine habitats, ecosystems and biodiversity (ETC-ACC, 2010).

**Socio-economic impacts:** these are the socio-economic consequences of physical impacts on people, assets, economic sectors and infrastructure. For the assessment, we were interested in current and historical data on these impacts (for example, damage to different sectors resulting from storms of different intensities) so that they could be combined with information on future climate and socio-economic scenarios to enable estimates to be made of future socio-economic impacts. Of course, any existing studies of future impacts relevant to the study area are also of interest. The nature of these impacts and the resulting data to be collected will differ between sectors. It may include qualitative, quantitative or monetary valuation data on economic losses and other damage, such as that to health, habitats and cultural heritage.

In addition to the SSPs discussed above, baseline data will need to be collected from regional statistical sources. These should provide current levels of activity by sector, land areas used and, in some cases, spatial locations. Some suggested sources of information on these types of data are given in Section 10.
Table 6.1: Most significant bio-geophysical effects of climate variability and change including relevant interacting climate and non-climate stresses (source: ETC CCA, 2011)

<table>
<thead>
<tr>
<th>Bio-geophysical effect</th>
<th>Other relevant factors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Climate</td>
</tr>
<tr>
<td></td>
<td>Vertical land movement (uplift and subsidence), land use and land planning</td>
</tr>
<tr>
<td>Permanent inundation</td>
<td>Sea level rise</td>
</tr>
<tr>
<td>Flooding and storm damage</td>
<td>Wave and storm climate, morphological change, sediment supply</td>
</tr>
<tr>
<td></td>
<td>Sediment supply, flood management, morphological change, land claim</td>
</tr>
<tr>
<td>Backwater effect (river)</td>
<td>Run-off</td>
</tr>
<tr>
<td>Wetland loss (and change)</td>
<td>CO₂ fertilisation, sediment supply</td>
</tr>
<tr>
<td></td>
<td>Sediment supply, migration space, direct destruction</td>
</tr>
<tr>
<td>Erosion</td>
<td>Direct effect (open coast)</td>
</tr>
<tr>
<td></td>
<td>Sediment supply, wave and storm climate</td>
</tr>
<tr>
<td></td>
<td>Sediment supply</td>
</tr>
<tr>
<td>Indirect effect (near inlet)</td>
<td></td>
</tr>
<tr>
<td>Saltwater Intrusion</td>
<td>Surface waters</td>
</tr>
<tr>
<td></td>
<td>Run-off</td>
</tr>
<tr>
<td></td>
<td>Catchment management and land use</td>
</tr>
<tr>
<td>Rising water tables/Impeded drainage</td>
<td>Rainfall</td>
</tr>
<tr>
<td></td>
<td>Land use, aquifer use</td>
</tr>
</tbody>
</table>

6.3 Description of the method

The methods used for the bottom-up analysis are much less clearly prescribed than for the top-down assessment, due to the greater variety of impacts and sectors that may be included and the likely variability in availability of data for different impacts. For these reasons, a certain degree of flexibility in choosing approaches is necessary. It should also be borne in mind, throughout the process of selecting methods and undertaking assessments, that the overall aim is to produce results sufficient to make at least order of magnitude estimates of the socio-economic impacts of CVC that can be compared across sectors, and to aid prioritisation of adaptation planning. Therefore, to the extent possible, it is desirable to make use of the results from the existing studies, even if they use different methods and scenarios, if they provide useful detail to make order of magnitude estimates in the study area. The demonstration cases outlined below suggest possible methods on a sector-by-sector basis.
6.4 Addressing problems

The exercise of combining physical climate data with data on physical and socio-economic impacts raises several difficulties that must be addressed as they arise. Here we note some that have come up frequently in the case studies carried out.

Data issues

I. Information on the physical impacts caused by climate change is not available for the specific region. Often, estimates of how climate change affects agricultural productivity, or water availability, or how it will result in increased mortality or morbidity, are at a higher level of aggregation than the area being studied. It then becomes necessary to downscale to the zones being studied, normally by assuming these zones are similar to the aggregate region for which estimates are available. In some cases, the aggregate figures are broken down, for example, by agro-ecological zones, in which case the zones closest to those in the coastal zones are taken.

II. Socioeconomic projections are at the national level. As noted in Section 3.3, some downscaling for the region can be undertaken, either by assuming that the region will retain the same status relative to the country in the future, or by modelling possible changes in relative status based on past trends.

III. Combining socio economic and environmental/geographical data. Some relevant datasets cannot be easily integrated, since socio-economic and economic sector data are likely to be available according to administrative regions, while environmental data may be collected according to geographical definitions, for example, river basin areas. Therefore, there may be discrepancies between the two. It is possible (though time consuming) to allocate an environmental value for administrative regions by seeing what percentage of each environmental score falls within a given region. This problem arises, for example, of calculating the average elevation of an administrative region for which data on buildings are available, while geographical data on elevation have a different grid map.

Reporting results and priorities

The case studies reveal a number of issues relating to the results obtained from the socio-economic assessment.

I. How to compare results from methods using different methods. The methods applied to obtain estimates of the costs of inaction under climate change will vary across sectors, and have different degrees of reliability and precision. This makes comparison difficult between, for example, damage to buildings and damage to agriculture or fisheries. Given that each estimate is in monetary terms, with uncertainty ranges, orders of magnitude comparisons should be valid, but these can
only serve to indicate broad priorities, rather than rank specific actions across sectors.

II. How to prioritise impacts in conditions of uncertainty. Uncertainty is a key feature of climate impacts, which invariably need to be expressed as a range. The best way to evaluate options under these conditions is to use methods that attach special importance to this uncertainty, for example, by reporting the full range of possible outcomes. Furthermore, in evaluating the net benefits of adaptation actions, it is desirable to look at ‘worst case’ as well as average outcomes, and make decisions that gives some weight to actions that perform best under both types (sometimes referred to as robust decision-making).

III. Identifying hotspots. An important part of the socio-economic assessment is to provide a spatial breakdown of where the costs of inaction are the highest. Some of the methods described have a strong spatial information base (e.g. the DIVA model), which can help identify hotspots in terms of high impacts. Other potential methods are assessments of water shortages or alluvial flood risks, and areas where conditions for agriculture will improve or worsen. Such information is of high value in identifying where to prioritize actions, even if an evaluation of the impacts cannot be carried out in monetary terms. Examples of such hotspot identification are given in the case studies.

6.4.1 Demonstration case 1: Šibenik-Knin County, Croatia

The overall aim of this study in the coastal zone of Šibenik-Knin County was to assess the economic impacts of CVC and make recommendations to inform the preparation of coastal zone management plans and national ICZM strategies.

The report adopted a sector-based approach and used a number of methods to carry out the assessment with the aim of quantifying and monetize the various impacts as far as possible. For sea-level rise related damage, this bottom-up local level assessment was informed by results from the top-down assessment of sea-level rise impacts for Croatia by Hinkel et al (2015), based on the Dynamic Integrated Vulnerability Assessment (DIVA) model, and a vulnerability analysis of coastal areas of Šibenik-Knin County performed by Baučić (2014). For sectors where some or all CVC impacts were not directly related to coastal sea-level rise, other methods were used. The selection of CVC issues was based on the discussions with PAP/RAC, and took into account the priority impacts of climate change on the coastal zone of the County recognized by the stakeholders in the Climagine participatory process.

An assessment of local vulnerability to CVC was made for key sectors in the local economy. Quantitative assessments were possible for the sectors presented below. Qualitative assessments based on local data and sector and location relevant climate studies were also
made for fisheries, water management, manufacturing, maritime transport, forest fires and cultural heritage.

Tourism: the assessment of the economic impacts of climate change and sea-level rise on tourism considered the following dimensions:

- Changes in tourist visits, overnights and expenditure as a result of climate change. This followed the approaches taken in Callaway et al (2010) and Metroeconomica (2011) for the study in Buna/Bojana, by using results from both the Hamburg tourist Model (HTM) and PESETA EU studies.
  
  (i) Projections for future tourist expenditure in the absence of climate change were made for arrivals and overnights (from the SKC Tourist Board), the average daily expenditure per person (from the Institute for Tourism) and projections for percentage increases in tourism (from the Regional Development Strategy).
  
  (ii) Estimates from the Hamburg Tourist Model of percentage changes in tourist visits for a range of average annual temperature changes from the base case average annual temperature were used to calculate potential changes in tourist visits, overnights and expenditure.
  
  (iii) A second set of estimations of the impact on tourism of temperature change was made applying the EU PESETA methodology to the base case visits and expenditure data.

- Changes in expenditure and revenues from different tourism activities (such as nautical tourism and visits to national parks) as a result of climate change. These were assumed to be linked to the rate of tourist arrivals, as estimated above.

- Direct damage to tourism assets and infrastructure from sea-level rise related impacts. The study was unable to make quantitative estimates of these two impacts due to a lack of data on the likely nature and extent of damage from flooding, etc. However, data on tourist expenditure in vulnerable coastal areas was estimated to give an indication of potential revenues at risk per municipality.

Agriculture: it was not possible to make a comprehensive local estimation on the potential loss of agricultural production brought about by changes in yields caused by future climate change, due to a lack of local data. The assessment focused on wine and olive production, as these sub-sectors have been developing in the county over recent years, and have the greatest potential for further expansion under climate change. Available studies of climate change impacts on these crops were used to illustrate potential impacts in the county.

Energy: the assessment applied data from climate and hydrological models on future hydropower generating potential in Croatia to Šibenik-Knin County, to estimate a decline in
capacity in the range of 6-8 MW and a potential loss of generation of 26-35 gWh. This implies a loss of revenue for the generators in the county in the range of €2.4 million and €4.1 million. These estimates were based on a Europe-wide study undertaken as part of a research project which gave spatial estimates for different countries, including Croatia (van Vliet et al, 2013). The county-level estimates were made by a study team based on the proportion of Croatia’s hydropower produced by the county.

**Sea-level rise:** the analysis of SLR-related climate impacts gives detailed estimates of current and future damage from coastal flooding in the county, based on estimates of damage to property in the county in the Hinkel et al (2015) study of the Croatian coastline using the DIVA model (see Section 5), and the vulnerability assessment of Šibenik-Knin County to floods and other sea-level rise related climate impacts by Martina Baučić (2014). Current estimates of damage per coastal settlement, and for 2050 and 2100 (in $ million per year) are reported under three socio-economic scenarios, and under a medium climate change sea-level rise scenario.

**Health:** the study reviewed likely climate-related impacts in SKC on heat-related mortality and morbidity, increased risks of food and vector-borne diseases, and deaths and injuries from flooding. Quantitative estimates of additional heat-related mortality in SKC were made based on European data in the study by Kovats et al (2011).

The final conclusions caution against making direct comparisons between the quantitative results for different sectors, due to the diversity of methods used and the variations in climate scenarios (both SRES emission scenarios in AR4 and RCPs in AR5) used in the source material. Therefore, a general assessment was made based on scoring the relative order of magnitude of impacts on different sectors. This concluded that the greatest potential impacts on the economy of SKC from CVC arise from damage to coastal assets, including assets for nautical tourism, with other real, but less significant impacts also likely on tourism, agriculture, infrastructure and health.

### 6.4.2 Demonstration case 2: Buna/Bojana estuary and coastal zone

This case study was carried out for the coastal zone surrounding the River Buna/Bojana in Albania and Montenegro. This river is an outflow of Lake Skadar that flows into the Adriatic Sea. The main sectoral impacts of climate change include the impacts on agriculture, human health, tourism, forests, fisheries and infrastructure.

The study involved:

(i) **Identification of key climate change variables and socio-economic change** in the case study region.
Identification of key areas of impact and risks to assets and people in coastal zones using matrices to link climatic variation to impacts in sectors of interest. This led to the identification of a number of key sectors at risk, notably agriculture, health, tourism, forestry and fisheries. The study also examined the consequences of extreme weather events. For each of the above, the literature was reviewed for existing quantifications of the risk of climate change. Where relevant studies existed, these were used directly to help quantify the risks, and where there were no such studies, attempts were made to identify the potential risks through transferring the relevant results from other studies in the region.

Quantification of impacts. Initial scoping was carried out of the likely size of impacts on the sectors identified in (ii) above, drawing on expert judgments and a review of existing literature. Where possible, impacts were quantified in physical terms (taking into account socio-economic change identified in (i) above). This involved either the use of existing models (e.g. existing models of tourism) or calculations based on historical weather events (particular climate events, e.g. storms or heat waves). For some issues, it is important to note that quantification would require further modelling that was beyond the scope of the study, e.g. in the case of floods, a full river basin modelling exercise is needed to estimate the impacts on the coastal zone in question.

Monetisation of impacts. Having quantified the impacts, the study estimated these in monetary terms where possible. This allowed a better understanding of the size of the impacts and importance of adaptation options.

Identification of adaptation measures and methods of evaluating them. The study provided general guidance on how adaptation measures could be structured and, for each of the main sector impacts, indicated a broad range of adaptation measures and how they could be evaluated.

The key methods used for the key identified sectors were as follows:

Agriculture: the scoping analysis found no studies specific to Montenegro or Albania that simulated the effects of climate change on crop yields in the future. The study therefore used figures for different regions of Europe with similar agro-climatic conditions and applied them to the Buna/Bojana region as a ‘best approximate’. Two sets of estimates for percentage change in agricultural productivity, from the PESETA (Iglesias et al., 2009) study and Cline (2007), were used to estimate changes in agricultural output for the Buna/Bojana region as a result of climate change. This did not take into account any projected changes in the area harvested for different crops in the future, due to a lack of information. Based on the estimates of change in output, producer prices for different crops were used to calculate the value of changes in output in terms of monetary values, per key crop and per coastal municipality for the period 2011 to 2040 and for the 2080s. Caution is advised in interpreting the results, due to the use of regional estimates for the percentage change in agricultural yield and the lack of specific estimates per crop for these changes.
**Human health:** the analysis focused on the quantification of heat- and cold-related mortality in the Buna/Bojana region for the A2 2011-2040 climate scenario only. It did not cover changes in the burden of vector-, water- or food-borne diseases, or increases in the risk of accidents from extreme weather events. For heat- and cold-related mortality, the scoping analysis did not find studies that estimated the impacts of climate change on health for Albania and Montenegro specifically, and therefore the study followed the methodology of Callaway et al. (2010) and assumed that the distribution of high- and low-temperature deaths in the base case (1961-1990) and due to climate change in the future (A2 2011-2040 scenario) were about the same for Montenegro and Albania as for Croatia. Thus, the temperature mortality results for Croatia (in the PESETA study) were normalised for Montenegro and Albania to estimate heat-related and cold-related mortality in the Buna/Bojana region. Results are present for heat- and cold-related deaths for the period (2011-40) and for the climate change induced difference compared to baseline population and climate. This was calculated for no-acclimatisation and acclimatisation scenarios. The monetary valuation of temperature-related deaths used estimates from the literature for the Value of Life Year (VOLY) and the Value of Statistical Life (VSL) to calculate the climate change induced difference in values of heat- and cold-related deaths for 2011-2040 (in millions of EUR/year). This was done for both no-acclimatisation and acclimatisation scenarios.

**Extreme weather events:** the study reviewed regional sources on the frequency and severity of drought, flooding and storms to give an indication of the order of magnitude of impacts, but did not undertake detailed quantification of future impacts or the value of economic damage in the study area.

**Sea-level rise:** the study used the predicted SLR for Albania and Montenegro to estimate a possible range of SLR projections for the Buna/Bojana region for the 2050s, 2080s and 2100s. It outlined the range of likely impacts on coastal zones in the study area, including flooding of the coastal area, increase in the salinity of aquifers, ground-water levels, estuarine water quality natural habitats, infrastructure and coastal tourism. This was done in a qualitative way and does not include detailed modelling of coastal impacts, such as by using the DIVA model, which was not available for this study.

**Tourism:** the impact of climate change on tourism was assessed based on the Hamburg Tourism Model (HTM) and an approach developed in the PESETA project. Based on the application of HTM by Callaway et al (2010), partial elasticities were applied to the tourism and climate data in the Montenegro case, to estimate changes in future annual tourist visits and expenditure according to different scenarios for the tourism sector and climate change. The PESETA study approach, which estimates the relationship between overnights in a country and the Tourism Climate Index (TCI), was also applied by Callaway et al (2010) to Montenegro, to give simulated climate impacts on annual tourist visits and expenditure.
for different climate scenarios. These estimates from the HTM and PESETA approaches were then downscaled to the Buna/Bojana case under different tourism demand and climate scenarios.

Key findings show that the tourism impact is likely to be negative under all scenarios with the HTM model, but could be slightly positive with lower temperature increases under the Peseta model. In any event, under both models, increases in temperature of more than 3 degrees Celsius result in visitor numbers turning negative. This indicates a potential threshold effect for temperature change and tourism demand. It is also noted that climate change may also have some impact in changing the seasonal nature of tourism, with a move away from a peak in July and August towards other months.

**Fisheries:** the study noted possible changes in the distribution of fish species as waters begin to warm, and salinity is also likely to have an impact as SLR extends the reach of brackish water, but concluded that more work is needed in this area to enable an estimation of climate change impacts on fisheries.

**Forestry:** it was noted that forests are particularly important in Albania and Montenegro and that the impacts of climate change on forestry in the case study area are likely to include: coastal erosion and flooding, changes in the distribution of species, changes in pest and disease incidence, and increases in forest fires. However, due to data limitations, it was not possible to estimate the impacts of climate change on forestry in terms of economic costs.

### 6.4.3 Demonstration case 3: Tunisia

The Tunisian study was carried out in two sections: the first to estimate the effects of SLR and storm surges on coastal assets and people, and the second to estimate the effects of climate on other sectors, namely agriculture, fisheries, tourism, forests, health and energy. These reviews also included changes in fresh water and its effects on agriculture and energy.

The analysis of the effects of SLR is presented in Section 5.5.2. For other sectors, the study began by drawing on a large amount of work already undertaken by the government of Tunisia with the assistance of UNEP, GiZ and other partners. The principal reports covered the vulnerability of the coast to SLR, and two strategies on climate change in Tunisia and on the adaptation of the coastal zones in Tunisia to climate change. The key documents are listed below.

- Etude de la carte de la vulnérabilité du littoral tunisien face l’élévation accélérée du niveau de la mer »,– PNUD Tunisie -2012
While these documents provided a great deal of insight into the sectors affected, they made almost no quantitative estimates of the impacts in physical or economic terms. Thus, the challenge for the study was to use the information provided and combine it with additional material to make a set of such estimates. The main findings were as follows (Markandya and Halouani, 2015):

**Agriculture and water:** the study collected baseline data on the production of different crops by region, and projections by the government of future levels of output in the absence of climate change. The report then looked at how these levels may be affected by climate change, up to the horizon of 2030. The studies reviewed indicated that impacts on yields up to this date were very small and uncertain, so they were not considered. On the other hand, one study specific to Tunisia (Roudhane, 2013) indicated that several cereal-growing areas would suffer a major loss of water, and would in effect not be suitable for cereals. Roudhane’s estimate was that the affected coastal areas would amount to 20% of all land under cereals now. An estimate was made of the potential volume of losses resulting from this impact. As far as values are concerned, recent global studies suggest that prices will be little affected by 2030 (van Lample (2014)), so changes in value will follow changes in volume.

**Fisheries:** although fisheries account for only about 1.4% of GDP, they are important for cultural reasons and represent a higher proportion of employment, especially among lower-skilled groups. The climate projections for capture fisheries drew on global studies (Cheung, 2013), which show that fish stocks will tend to move towards higher latitudes at a rate of around 30-130km per decade in the direction of the poles and at a rate of 3.5m per decade in the direction of deeper waters. These changes were modelled and found to have serious consequences for the Mediterranean (Bosello et al., 2010). Changes in fish catches at current levels of effort by country were assessed and it was found that under scenario A1B, the catch in Tunisia could decline by 16.5% - the biggest decline in the Mediterranean. It was also found, however, that the impacts on GDP would be very small (0.02% p.a.) over the period 2001-2030. Thus the importance of this kind of loss of catch will affect the fishermen involved in the sector very specifically, and some form of support will be needed. This needs further investigation.

The other marine sector that will be impacted is aquaculture. Here, the effects include losses from higher temperatures and lower levels of dissolved oxygen, in terms of slower growth and higher mortality, less feedstock due to smaller fish populations in local waters,
and possible damage from acidification. These cannot be quantified at this stage, so further work is required.

**Tourism:** tourism is almost entirely a coastal activity in Tunisia, accounting for about 15% of GDP and a similar percentage of all employment. The models point to potentially different directions when it comes to climate change, as they do for the other studies cited. The Hamburg model indicates a decline of 10-25% per degree Celsius increase in temperature for countries like Tunisia (Hamilton et al., 2005). Other models, however, suggest little overall change in numbers, but a strong shift from the peak months of July and August to the spring and autumn (Roson and Sartori, 2012). Thus, it is difficult to make strong predictions regarding numbers, but there is good reason to believe that there will be less demand in the peak season and perhaps more in the 'shoulder' seasons.

Other impacts on tourism arise from storm surges and sea-level rise, and are discussed in Section 5.

**Forests:** forest areas in Tunisia are expanding, including in the coastal zones, and the risk of fires is already increasing. This is due to a number of reasons, including the population spreading to residential areas close to forests (a phenomenon referred to as 'californisation'). Encroachment, californisation and coastal development are becoming serious threats to forests, and with climate change, the risk of fires will undoubtedly increase. It is not possible, however, to quantify the increase for Tunisia from the current information.

**Health:** the main sources of climate impact on health are the same across all countries and include heat waves (offset by reduced losses from warmer winters), risks from food contamination, vector-borne diseases, water-borne diseases and malnutrition if food production is reduced. Recently the WHO has conducted a major assessment of the factors by region and estimated possible increases in mortality up to 2030 and 2050 for a middle (A1B) scenario. The assessment used these figures for North Africa and made estimates for Tunisia based on them. The number of additional deaths turns out to be small: 19-59 from water-borne diseases, 65-75 from heat waves, and 65-82 from malnutrition. No increases are envisaged from vector-borne diseases. The assessment did not try to quantify these impacts in money terms, although that would be possible, given we have an estimate of the value of loss of life.

**Energy:** impacts on the energy sector are divided into demand and supply. On the supply side, the main concerns are loss of efficiency in thermal power plants as temperatures increase, and potential damage to transmission and distribution power lines from extreme events. These were noted, but no quantification of damage was possible. Similarly, on the demand side, impacts were not quantified as this would require a detailed study. One impact is the extra demand for electricity for cooling (offset by lower demand for heating in
winter). Models exist for other countries, but would need to be estimated for Tunisia. Another is the extra demand for energy by pumping for irrigation and possibly desalination as water becomes scarcer. There is fragmented information on these issues, but further work is needed to obtain an estimate of additional energy needs and costs.

This assessment was used to provide indicative guidance on the key areas of action in terms of adaptation. A full cost benefit analysis could not be performed because information on adaptation costs and effects in terms of reducing climate impacts was unavailable. Nevertheless the discussion highlighted where policy measures are needed, and where further work is required. The main recommendations were:

**Agriculture and water**: more information is needed on locations where production losses occur due to water shortages, so actions can be taken. The main potential actions relate to increasing efficiency in the use of scarce water through the construction of reservoirs and other storage facilities, as well as higher water tariffs. Others include awareness-raising, adopting climate-resilient crop varieties and developing other activities in areas where agriculture is becoming less viable.

**Fisheries**: more information is needed on the groups of people who will be affected by the reduced productivity of capture fisheries predicted under climate change. There are also gaps in the information on the physical impacts of climate change on aquaculture. Support for artisan fishermen and changes in fishing quotas are adaptation measures to be considered. Support for adaptation by firms and individuals running aquaculture firms is also likely to be needed.

**Tourism**: it is important to identify centres which are likely to face water shortages and the impacts of SLR. The government needs to encourage the sector to keep informed on these impacts and to extend the tourist season as a matter of urgency.

**Forests**: we know that the risk of fires is going to increase, but more information is needed on where the risk increase is greatest so that more resources can be allocated. In addition, rural and agricultural development should be integrated with policy-making so as to reduce fire risks.

**Health**: the analysis indicates some small effects of climate change, which need to be confirmed by more local assessment. Adaptation measures that have proved successful in other countries are: (a) early-warning systems for heat waves, (b) stricter regulations on food distribution, (c) emergency planning to prevent illness resulting from flooding events and (d) social protection programmes to address cases of malnutrition caused by the loss of agricultural production.
Energy: here, the knowledge gaps are quite large. On the supply side, estimates of the loss of efficiency of power generation due to increases in temperature and possible increased damage to transmission and distribution systems are needed. On the demand side, the increased demand for energy for cooling and water pumping must be estimated. The measures to be evaluated on the supply side would then include engineering modifications to the existing thermal power systems, or increased dependence on renewable systems. Measures on the demand side would involve encouraging conservation and higher water tariffs to reflect the high costs of pumping.
7 Integrating the results of the assessments

The integration of results from the top-down and bottom-up assessments should aim to present an overall picture of the relative significance of CVC socio-economic impacts, and to the extent possible the potential costs in a ‘do-nothing’ scenario, for different issues and sectors. This could be used to inform sound adaptation planning for coastal zones. The integration of results should take into account the fact that different methodologies may have been used for assessing different issues, and therefore results may not be directly comparable. Furthermore, results may have been reported in different metrics, in monetary terms (for CBA), as a score (for MCA) or in qualitative terms. This should not be seen as a major difficulty when the aim is to present the relative significance of different impacts for the purpose of informing policy priorities, which can be done by summarising the relative order of magnitude of potential and existing impacts of CVC on different sectors and issues, using a simple rating system.

Table 7.1 shows a simple format for illustrating the likely significance of impacts without adaptation on (i) sectors/issues and (ii) the whole economy of the study area (i.e. taking into account the current relative contribution of the sector to GDP). The chosen rating is from -3 (most negative) to +3 (most positive) for both the medium and long term. This type of a rating should be made by project experts, based on the results of the top-down and bottom-up assessment, and reviewed by the project team for plausibility.

Table 7.1: Example of summary of CVC impacts per sector and issue

<table>
<thead>
<tr>
<th>Priority sector/issue</th>
<th>Climate hazards</th>
<th>Potential economic impacts</th>
<th>Significance of impacts on the sector in the medium term (up to 2050)</th>
<th>Significance of impacts on the sector in the long term (up to 2100)</th>
<th>Significance of impacts on the whole of local economy in the medium term (up to 2050)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea-level Rise</td>
<td>Flooding and other SLR related effects</td>
<td>Damage to coastal assets caused by sea floods</td>
<td>Score -3 to +3</td>
<td>Score -3 to +3</td>
<td>3 to +3</td>
</tr>
<tr>
<td>Tourism</td>
<td>Change in seasonal temperature</td>
<td>Changes in total tourist visits and expenditure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SLR</td>
<td>Damage to assets and infrastructure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Category</td>
<td>Effects of CVC on ecosystems and water flows.</td>
<td>Changes in attractiveness and expenditure for national parks</td>
<td>Agriculture</td>
<td>Change in temperature, precipitation, and weather extremes</td>
<td>Change in agricultural yields and incidence of disease</td>
</tr>
<tr>
<td>----------</td>
<td>-----------------------------------------------</td>
<td>-------------------------------------------------------------</td>
<td>-------------</td>
<td>---------------------------------------------------------</td>
<td>---------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>Changes in frequency and severity of extreme weather events</td>
<td></td>
<td>Fisheries</td>
<td>Warmer sea temperatures</td>
<td>Change in the distribution of fish species and number of invasive species may affect fishing catch</td>
</tr>
<tr>
<td></td>
<td>Increasing salinity</td>
<td>Impact on shell-fish farming</td>
<td>Health</td>
<td>Increased temperature and incidence of heat waves</td>
<td>Increases in morbidity and mortality</td>
</tr>
</tbody>
</table>
8 Evaluating adaptation options

This section presents a review of possible adaptation options per sector/issue and suitable evaluation methods that could be applied. It should also be noted that adaptation options can be defined as autonomously adjusted or needing strategic action.

**Agriculture:**

For the agriculture sector, adaptation options mainly consist of:

(i) Farm-level measures, such as adjustments in planting dates, crop diversification, or in the intensity of input use such as fertilisers

(ii) Public-level interventions, such as stimulating R&D, disseminating information on climate change and adaptation possibilities, and making market and policy conditions conducive for efficient and sustainable adaptation.

To evaluate the options, a Cost Benefit Analysis (CBA) may be possible for this sector, given the availability of relevant studies. These assess the benefits of adaptation using crop impact models that look at how changes in management might avoid decline in crop yields, or spatial analogues that examine the relationship between climate factors and agricultural production. Estimating the costs of adaptation is difficult in this sector, given the complexity of agriculture and the multiplicity of decisions and actors involved. So the literature on the cost side is relatively limited. As noted for other sectors, a multi-criteria analysis (MCA) can also be undertaken to capture elements of the assessment not included in the estimated costs and benefits.

It is also important to note that adaptation decisions for agriculture do not focus exclusively on coastal zones. Hence, any assessment of adaptation measures should be undertaken as part of a wider review of agriculture in the region or country as a whole. Crops that need to be located in the coastal areas should be given due attention in the national strategy. An important indirect effect could be achieved through changes in national agricultural imports and exports affecting coastal port activity. Such impacts can be evaluated through computable general equilibrium models for the country, or more widely.

**Health**

Adaptation options for the health sector fall into two main categories:

(i) Preventive measures. These include (a) improving and expanding vector and disease surveillance systems and early warning systems for infectious diseases, (b) maintaining and improving environmental health regulatory systems and standards (e.g. water, sanitation, air quality), (c) improving occupational health
by introducing measures to prevent the adverse impacts of increased heat on the health and productivity of workers, (d) hot and cold weather warning systems, improved heating and ventilation in housing stock (e.g. for the elderly and infirm), (e) improving health system infrastructure to cope with the increased frequency of extreme weather events and the additional disease burden associated with them.

(ii) Reactive measures: these include actions such as (a) treating additional cases of diseases not prevented through adaptation upstream and improving the provision of medication to reduce the impact of potential increases in infectious diseases, (b) economic instruments to encourage heating use (e.g. cold weather payments to help the vulnerable with heating costs).

In terms of the need for CBA analysis in the health sector, the benefits of adaptation could be calculated in the form of reduced loss of life and reduced morbidity, but there is only limited data available in current studies. Furthermore, while the cost of action has been estimated in existing studies, it is generally at the global and regional level. Therefore, depending on the availability of studies relevant to the specific coastal zone being assessed, the appropriate methodology may be to conduct a cost effectiveness analysis, rather than a cost benefit analysis. This involves a comparison of different measures in terms of cost per life saved, or per Disability Adjusted Life Year (DALY). Such measures are widely used to evaluate other health interventions.

As in the case of agriculture, adaptation issues for health in coastal zones should be considered in the wider national and regional context. However, coastal zones may be exposed to increased risks from some CVC impacts, such as extreme weather events, and therefore special measures should be developed and implemented to address them.

Extreme weather events
Policy options for extreme weather events can be grouped as follows (Mechler, 2011):

(i) Ex ante risk management options. These can be grouped under (a) risk assessment (e.g. hazard assessment, vulnerability assessment, risk assessment, hazard monitoring and forecasting), (b) risk reduction (e.g. physical and structural risk reduction works, land-use planning and building codes, economic incentives for proactive risk management, education, training and awareness raising), (c) preparedness (e.g. early warning systems and communication systems, contingency planning, networks of emergency responders, shelter facilities and evacuation plans), and (d) risk financing (e.g. risk transfer, alternative risk transfer, national and local reserves, calamity funds).

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7 The Disability Adjusted Life Year takes life years and assigns weights for different conditions according to their relative impact on wellbeing.
(ii) *Ex post* disaster management options. These can be grouped under, (a) response (e.g. humanitarian assistance, clean-up, temporary repairs and restoration of services, damage assessment, mobilisation of recovery resources), and (b) construction and rehabilitation (e.g. rehabilitation/reconstruction of damaged critical infrastructure, revitalisation for affected sectors, macroeconomic and budget management, incorporation of disaster mitigation components in reconstruction activities).

Cost-Benefit Analysis (CBA) can be used to appraise options for extreme weather events, and there is evidence of the great benefits resulting from disaster risk reduction in many contexts. However, Mechler (2011) notes that there have been only a few systematic CBA studies analysing prospective investments in disaster risk reduction.

Due to the diversity of impacts of extreme events (economic, social and environmental), and the difficulties in monetizing some of them, alternative approaches are often used. One is to set the level of risk at which protective measures will be taken. For example, if the present arrangements are designed to protect against an extreme flood currently assessed as a 1 in 100 year event, and under climate change this is estimated to become a 1 in 10 year event, then adaptation measures would be undertaken to provide the same level of protection as at present. These measures can be evaluated using a MCA framework such as that developed by Mechler (2011) for extreme weather events.

**Sea-level rise**

Adaptation options related to SLR impacts for coastal zones may be classified as follows:

(i) Protection – manage the hazard by reducing the probability of occurrence. This includes (a) hard structural options such as, dikes, levees, floodwalls, seawalls, groynes, detached breakwaters, floodgates and tidal barriers, and saltwater-intrusion barriers, and (b) soft structural options such as periodic beach nourishment, dune restoration and creation, and wetland restoration and creation.

(ii) Accommodation – manage the hazard by reducing its impacts. This includes elevating buildings on piles, growing flood- or salt-tolerant crops, hazard insurance, modifying building styles and codes, strict regulation of hazard zones, and improving drainage, desalination and evacuation systems.

(iii) Planned retreat – manage the hazard by reducing exposure in a planned or managed manner. This includes land-use planning/hazard delineation, increasing or establishing set-back zones, relocating threatened buildings, phased-out or no development in susceptible areas, presumed mobility, rolling easements, managed realignment, creating upland buffers etc. The establishment of set-back zones under ICZM rules can make a major contribution to promoting such important measures.
In addition to the above measures proposed for coastal zones, there are also a number of ‘no-regrets’ or ‘low-regrets’ options available for this sector, which yield significant benefits in terms of reducing risk, and are not sensitive to climate change uncertainties (Hallegatte, 2009). Examples of such options include setting up early warning systems, and undertaking risk-averse land-use planning by avoiding new buildings in high risk areas, etc. Some options are also identified as ‘win-win’. An example is mangrove/wetlands rehabilitation that can reduce flood risk and enhance ecosystem adaptation.

Another issue is that of changes in the knowledge base. We can expect to be better informed about the magnitude of sea-level rise and its impacts over time. So it is necessary to make informed judgements about whether (and how long) to wait until better information is available before making decisions that involve resources. This is especially relevant to sea-level rise, where high sunk-costs and long lead-times are involved in investment decisions.

For SLR adaptation options, it is usually possible to conduct a CBA to evaluate the costs of the options against the benefits in terms of damages avoided, especially in the case of hard structural options. However, some elements of the assessment will not be captured in the estimated aggregate costs and benefits, including distributional considerations and impacts not quantifiable in monetary and physical terms (some social and environmental impacts). Thus, the use of MCA and Real Options Analysis for evaluating adaptation options should be used alongside CBA.

Tourism

The most important adaptation actions for tourism can be categorised as follows:

(i) Tourist capacity focused actions: raising awareness of private sector investors and financing institutions regarding likely CVC impacts on tourism can result in investments to improve facilities during shoulder seasons, to take advantage of the changing seasonal climate and put less emphasis on tourism capacity investment in July and August.

(ii) Infrastructure focused actions: these should ensure that public and private sector infrastructure investments also take into account possible developments brought about by CVC. This includes waste disposal, water and energy provision, with a view to changes in seasonal tourist demands, where peak demand in the high season currently determines the required capacity. Facilities for activities such as eco-tourism and agro-tourism may also be in greater demand in the shoulder seasons, and the corresponding infrastructure should be provided.

In addition, it should be noted that adaptation related to extreme weather events, sea-level rise and human health also has a tourism dimension. For example, options to improve
infrastructure resilience against extreme weather events and SLR may be particularly relevant to some tourist resorts and marina locations, while food facilities in tourist areas may need stricter standards appropriate to higher temperatures.

In addition to CBA and MCA, evaluating tourism options will benefit from the application of the ‘robust’ approach of Real Options Analysis. This involves:

i) Selecting measures that are effective over the widest range of possible future scenarios and entail low costs, including supplying information to all stakeholders on the impacts of climate change on tourism

ii) Building flexibility into adaptation measures so that they can be adjusted in the future. Thus, there may be a case for investment in tourist infrastructure with a shorter lifespan, that can be replaced or modified as new information becomes available

iii) Building flexibility into the decision process itself, through waiting and learning. This could take the form of delaying costly investments, where new information on climate impacts could change the nature of the investment without imposing significant additional adaptation costs.

**Fisheries**

Categories of actions related to fisheries are given below. Most of the measures listed are ‘no-regrets’ options for promoting sustainable fisheries, and would need to be assessed further for the significance of their contribution to CVC adaptation. In the case of actions under points (i) and (ii), Regulatory Impact Analysis tools to assess the overall effects of different policy instruments could be adapted to include the impact of adaptation to climate change for the fisheries in the relevant location.

(i) Market-based instruments: tradable quota fisheries management policies, fishing capacity buyback and tax incentives (or disincentives) to address overfishing, polluter-paid scheme and sustainable certification schemes to address habitat degradation /destruction, ecosystem services payment scheme to address unsustainable activities/ climate change

(ii) Regulatory instruments: ecosystem and environmental standards, integrated marine spatial planning, legislation for the conservation of threatened species, fishing input and output control

(iii) Public investment programmes: sewage treatment facilities, investment in marine protected areas, investment in marine ecosystem management research, development of alternative livelihoods for fishing communities, elimination of ‘bad’ subsidies

(iv) Information-based instruments: illegal, unreported and unregulated (IUU) fishing monitoring networks, vessel monitoring systems, integrated assessment of marine ecosystems, public education. International cooperation programmes:
international agreement on fisheries, shipping, biodiversity and dumping, regional fisheries management organisation, international research collaboration, international agreements on technological transfer.

**Forestry**

Options for reducing the vulnerability of forests to climate change impacts include the following:

(i) Increased forest conservation and biodiversity conservation
(ii) Expansion of protected areas
(iii) Promotion of the regeneration of native species through protection and natural regeneration in degraded natural forest lands, to reduce vulnerability to changing climate conditions
(iv) Sustainable logging and management of forests
(v) Promotion of multi-species plantation forestry incorporating native species, instead of monoculture plantation of exotic species, to reduce vulnerability
(vi) Adoption of short rotation species in commercial or industrial forestry, to enable adaptation to any adverse impacts of climate change
(vii) Anticipatory planting and assisted natural migration through transplanting plant species
(viii) Incorporation of several silvicultural practices, such as sanitation harvests and increased thinning to reduce the occurrence of pests and diseases
(ix) Incorporation of better fire protection measures to reduce the vulnerability of forests to fire hazards due to warming accompanied by droughts
(x) Incorporation of soil and water conservation measures to reduce the adverse impacts of drought on forest growth.

Many of these actions are likely to be ‘low-regrets’, such as better fire protection measures. For others, the focus is mainly on changes in forest and conservation practices, so some form of MCA may be the most appropriate approach. The criteria to take into account will include cost, impact on forest resources (possibly in monetary terms), ecological benefits, benefits to local communities and other distributional factors, impact uncertainty and the flexibility of the approach, if and when new information becomes available.
9 Recommendations and lessons learned

The following points are worth noting:

- **Existing estimates of impacts are based on a number of emissions scenarios** and are not necessarily consistent. In particular, caution is needed in using estimates of climate change impacts from source material that may employ differing Greenhouse Gas Emissions scenarios in the Special Report on Emissions Scenarios (SRES) used in the IPCC 3rd and 4th Assessment, and the range of scenarios called Representative Concentration Pathways (RCPs) introduced in the IPCC 5th Assessment Report (AR5).

- Due to the lack of data on some impacts, it is often necessary to make best approximations based on study results from other studies in comparable regions. It is important, therefore, that the basis for estimates is transparent, and the necessary caveats are given about interpreting the results in these cases. In particular, the need should be stressed for revising the results of existing assessments, as and when new and improved sources of data become available, so that adaptation priorities can be modified as appropriate.

- **Impacts are generally in the mid to long term.** While this is true, certain aspects of coastal development have long life – e.g. transport networks, coastal defences, and areas for residential construction. If these are constructed without taking climate scenarios into account, then commitments may be made which will entail high future adaptation costs.

- **Socio-economic change is often more significant than climate signals.** It is hard to say how the tourism sector, for example, may develop over the next 50 years. The history of tourism in the case study areas presented here is not very extensive, so modelling future scenarios may be more difficult than in developed markets.

- **The most important impacts are likely to be: (a) sea-level rise, (b) extreme events and (c) tourism.** Sea-level rise is likely to be significant, particularly for coastal lagoons and estuaries. With increasing salinity, there may be shifts in the nature of the ecosystem. Coastal zone management plans need to take these factors into account. Extreme events are likely to increase, resulting in significant damage if no action is taken. Hence, adaptation to such events needs to be planned now, including future infrastructure design and changes in land use. Finally, tourism changes merit planning for the forseen changes in demand. In all cases, there are great uncertainties, but this does not mean action should be avoided.
10 Annotated Guide to the Literature

This section presents some of the key literature and websites relevant to assessing the costs of the environmental and socio-economic impacts of climatic variability and change, and the evaluation of response options, in the context of vulnerable coastal zones. The sources are grouped according to a number of different sub topics relevant to the overall aim of these guidelines. As such, there is some overlap between the sources given under each sub topic and referenced in the general reference section.

Key Documents in the ClimVar & ICZM Project


Case study for application of a methodology that attempts to quantify the risks associated with climate change in this region. The five main steps were (i) Identification of key climate change variables and socioeconomic change, (ii) Identification of key areas of impact and risks to assets and people, (iii) Quantification of impacts, (iv) Monetisation of impacts, (v) Identification of adaptation measures and methods to evaluate impacts.


This Local Vulnerability Assessment report of CVC in Šibenik-Knin County in Croatia supports the overall project objective to “strengthen the understanding of the impacts of CVC on the coastal zones of the Mediterranean region, which aims to assess environmental and socio-economic impacts and evaluate response options in vulnerable sites.” It assesses the economic impacts of CVC in Šibenik-Knin County and makes conclusions and recommendations to inform preparation of coastal zone management plans and national ICZM strategies.

The purpose of this report is to assess the socio-economic impacts of CVC on coastal areas. Specifically, it aims to deepen the study of the impact assessment on specific economic sectors (tourism, agriculture, etc.). The study covers the Tunisian coastal areas. The method used in Tunisia was the one adapted from the one implemented in ClimVar & ICZM project in the Šibenik region of Croatia and the Buna-Bojana area of Albania and Montenegro.

Website: www.pap-thecoastcentre.org/

Sources on use of the DIVA Model for assessments of sea-level rise impacts, vulnerability and adaptation


Website: [www.diva-model.net](http://www.diva-model.net)

**General sources for assessing coastal vulnerability to climate change**


**Assessing Adaptation Options**


A number of briefing notes on Decision Support Methods for Climate Change Adaptation have been produced under the European Commission FP7-funded MEDIATION project (Methodology for Effective Decision-making on Impacts and AdaptaTION). These include briefing notes on Multi Criteria Analysis, Cost Effectiveness Analysis and real options analysis available at: [http://www.mediation-project.eu/platform/pbs/home.html](http://www.mediation-project.eu/platform/pbs/home.html)

General international data sources on climate change

UNDP Climate Change Country Profile
http://www.geog.ox.ac.uk/research/climate/projects/undp-cp/

World Bank Climate Risk and Adaptation Country Profile
http://sdwebx.worldbank.org/climateportalb/home.cfm?page=country_profile

Maplecroft Corp. Global Climate Change and Vulnerability Atlas
http://maplecroft.com/themes/cc/

National Communications Support Program
http://ncsp.undp.org/

IPCC 5th Assessment Report 2014 – Impacts, Adaptation and Vulnerability
11 References


Caesar, J. and N. Golding (2011). Meteorological factors influencing forest fire risk under climate change mitigation, Report by Met Office Hadley Centre for AVOID research programme.


