EUROPEAN COMMISSION
European Research Area
SEVENTH FRAMEWORK PROGRAMME
Funded under Socio-economic Sciences & Humanities

WP 4a - Management of environment and natural resources

Adaptation to Climate Change in the Southern Mediterranean

A Theoretical Framework, a Foresight Analysis and Three Case Studies

Daniel Osberghaus and Claudio Baccianti

with contributions by Aurélie Domisse, Beyhan Ekinci, Christian Hengesbach, Max Pohl and Daniel Ruhnow

MEDPRO Technical Report No. 26/February 2013

Abstract

Adaptation to climate change in southern and eastern Mediterranean countries is particularly relevant because of the strong expected effects on the region and the sensitivity of important sectors like agriculture and tourism to climate change. This work analyses qualitative scenarios with the support of insights from the theoretical literature and information collected from case studies about Tunisia, Egypt and Turkey. We deal with several dimensions of adaptation, including the role of the government, equity, uncertainty and linkages with mitigation. In general, we conclude that inaction is not a viable option and this report shows how adaptation policy should be designed. We identify major areas of intervention, from removing barriers to private adaptation to the fostering of international cooperation.

This paper was produced in the context of the MEDPRO (Mediterranean Prospects) project, a three-year project funded under the Socio-economic Sciences & Humanities Programme of DG Research of the European Commission's Seventh Framework Research Programme. MEDPRO Technical Reports give an indication of work being conducted within MEDPRO thematic Work Packages (WPs) and aim at stimulating reactions from other experts and academics in the field.

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ISBN 978-94-6138-273-3

Available for free downloading from the MEDPRO (www.medpro-foresight.eu) and CEPS (www.ceps.eu) websites

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1. Introduction and outline

According to reports by the Intergovernmental Panel on Climate Change (IPCC) and other international and national studies, southern and eastern Mediterranean countries (SEMCs) are particularly vulnerable to global warming because of their geographical position and their dependence on climate-sensitive economic sectors. Sea level rise endangers the living conditions of millions of people living on the Mediterranean coast. Important economic sectors like tourism and agriculture depend heavily on weather conditions, and the increase in temperature and the frequency of extreme events calls for comprehensive preventive measures to avoid future economic costs. Water scarcity – already affecting the eastern Mediterranean region – is likely to become more severe in the future and a major cause of regional conflicts.

Therefore, measures to adapt to climate change should be a priority for national governments in the area. Like mitigation, adaptation to climate change is a complex economic concept that is characterised by several issues relevant for policy-making. This report addresses the main policy relevant questions about adaptation and provides answers based on a theoretical framework applied to the case of three Mediterranean countries, namely Turkey, Egypt and Tunisia.

In the first sections we deal with adaptation to climate change from a theoretical viewpoint. The perspective is not limited to strictly economic issues (such as investment timing, public intervention and uncertainty), but also covers fairness and international agreements on mitigation and adaptation. In the second part we make use of the conceptual framework developed in the theoretical discussion to analyse the adaptation-related situations of 11 SEMCs[1] along the scenarios suggested by Ayadi and Sessa (2011). The analytical tools we outline are a valuable means to tackle various dimensions that characterise each future adaptation scenario. The current adaptation policies in the country case studies are found to be slightly different but eventually broadly inadequate. Even if optimistic future projections might mitigate some aspects of the problem, an increase in the current long-term effort is necessary to face climate change without critical economic and social costs, as shown in the country case studies.

Using the contributions of the theoretical framework, we explain important directions of policy intervention for adaptation in the 11 SEMCs, paying particular attention to the specific socio-economic conditions of these countries.

* Daniel Osberghaus and Claudio Baccianti are researchers at the Centre for European Economic Research (ZEW) in Mannheim; Aurélie Domisse, Beyhan Ekinci, Christian Hengesbach, Max Pohl and Daniel Ruhnow are interns and research assistants at ZEW.

[1] The 11 countries are Algeria, Egypt, Israel, Jordan, Lebanon, Libya, Morocco, Palestine, Syria, Tunisia and Turkey.

2. Role of the government in adaptation

2.1 Private adaptation

Many adaptation measures are planned, implemented and financed by private firms or households without any necessary governmental intervention. The literature speaks of "private", "autonomous", "market" or "decentralised adaptation" (Fankhauser et al., 1999; Mendelsohn, 2000, 2006; OECD, 2008; Osberghaus et al., 2010).[2] In this respect, the role of the government is generally more limited in adaptation processes than in mitigation. There are, however, a number of important preconditions for private adaptation: first, the benefits of adaptation have to accrue to the decision-maker, at least to some non-negligible extent. This is the case with many adaptation measures taken within a firm, e.g. installing an air conditioner in company-owned buildings or purchasing a technical irrigation system at the farm level.[3] Another precondition for private adaptation is the availability of information about climate impacts and feasible coping measures. This precondition also includes the openness of the decision-maker to new techniques, which sometimes are unusual and contrary to traditional customs. Third, private adaptation has to be financed. A well-functioning capital and insurance market will guarantee the availability of finance for those actors who can afford adaptation in the long run, even for large-scale and capital-intensive projects, e.g. a desalination plant. Fourth, the policy environment has to remove other barriers to autonomous adaptation (for example legal, institutional or societal). Summing up, "individuals have to have the right incentives, resources, knowledge and skills to adapt efficiently" (Fankhauser et al., 1999, p. 74).

2.2 Public adaptation

At the same time, there is also a role for the government in adaptation. Exploring the reasons and rationales for governmental intervention in adaptation is the aim of this section. Again, the literature provides a number of terms – "planned", "government", "centralised", "collective", "joint" and "public adaptation" – all pointing in the same direction, each highlighting certain nuances of broadly the same issue (Smith et al., 2009, same sources as above).

We discuss the various arguments for government intervention by exploring the neoclassical approach, which leads to a rather minimalistic concept of governmental interference. According to the neoclassical foundations of economic theory, public intervention in adaptation is efficient if and only if there is some kind of market failure. In contrast, there are complementary and sometimes contradictory concepts of public intervention, based upon particular objectives of public policy (such as equity or security of supply). These complementary approaches are discussed in section A4 in the appendix.

In addition, Smith et al. (2009) identify tasks for public adaptation that cannot be easily integrated into one of these two areas – the reason being that most of them refer to the means through which adaptation policies should be implemented rather than to the policies themselves. They mention the following phenomena:

- *Political leadership*. Sometimes a strong and visible commitment of a chief political leader is needed to overcome obstacles, e.g. bureaucratic resistance and risk aversion.
- *Institutional organisation*. This refers to the mainstreaming and coordination of adaptation efforts at the various governmental levels and departments.
- *Stakeholder involvement*. Without the involvement of non-political stakeholders, it will be difficult to develop practical and accepted policies.

[2] For sake of simplicity, we will mainly use the term "private adaptation".

[3] Mendelsohn (2006) analyses the functioning of private markets in the sector of water supply. Private water markets do not exist in many places of the world – so the assignment of (tradable) water rights to private actors would foster efficient adaptation in the water sector. It may not always be just, however, nor provide a constant secure supply; these issues are tackled in section A4.2 in the appendix and section 3.

- *Appropriate use of decision-analysis techniques*. The deep uncertainty about adaptation decisions may cause decision-makers to wait for more information. Yet, this can result in an inappropriate paralysis in the policy process. The usage of decision analysis tools as a means of informing decision-makers, rather than a means of prescribing decisions, can facilitate policies on adaptation despite the deep uncertainties.
- *Explicit consideration of barriers to adaptation*. Some existing policies are too inflexible to account for a changing climate and thereby hamper private adaptation – e.g. subsidies for specific crops at specific localities, building norms or flood insurance regulation. Adaptation policy would seek to identify and remove these barriers to private adaptation.
- *Technology development and diffusion*. If market conditions are not supportive of climate-resilient technologies, the government may step in to foster their development.

Apart from these phenomena, they mention the task of informing the public about climate change, adaptation research (these two are dealt with in this section) and the funding of adaptation.

In the neoclassical concept, the key rationale for public policy intervention in private decisions is market failure; in these cases the government can enhance economic efficiency by specific regulation. In contrast, where markets work, by the first and second theorem of welfare economics they provide Pareto-efficient allocations of goods and services (Mas-Collel et al., 1995).

The provision of public goods is a typical case of a market failure (Bator, 1958): as their consumption value is not limited to a single consumer, free-riding leads to under-provision by private investors, in particular in the case of perfect public goods that are non-excludable and non-rival. A dyke sheltering a human agglomeration from flooding is the central example: no individual in the agglomeration can be excluded from the increase in security provided by the dyke. This makes a tax-financed public investment in coastal protection socially efficient. Other examples of adaptation measures that have public good properties are early-warning systems for floods, droughts and heat waves.

Another example of adaptation in the form of a public good is the generation and dissemination of information about climate change impacts. The efficiency of autonomous adaptation hinges on the assumptions of full information on climate change and competitive markets. Take the following example: under changing precipitation and temperature patterns, a farmer will efficiently plan and invest in an irrigation system, but basic hydrological research on the development of water flows should be conducted by public research institutes. The reason is that information has public good properties. In practice, it is not sufficient to just provide climate projection data; it must be done in a way that makes it be easily accessible and understood by local and private decision-makers. Education falls into the same category of enabling people to adapt, having similar public good properties as general information. Educating private decision-makers about the consequences of their usual behaviour under a changing climate and about more suitable alternatives to new environmental conditions – without actually prescribing them – plays a key role in facilitating efficient private adaptation (Fankhauser et al., 1999).

A similar argumentation is valid for the case of basic research and development. If new coping technologies have to be developed (e.g. vaccination serums and drought-resistant crops), basic research may be necessary, which has similar public good properties, such as climate science information. Therefore, these kinds of research programmes need support from public sources – which forms an important pillar of adaptation policy.

Not only does the state produce and distribute information, support basic research and care for coastal protection and early warning, it also provides public goods in terms of the existing infrastructure, such as roads, railway systems and energy networks, which have to be adapted to endure climatic changes. Along with the public water supply, this is probably one of the main cost drivers of public adaptation in the 11 SEMCs. Many authors also mention the conservation of important natural habitats, ecosystems, biodiversity and cultural heritage as a public adaptation good (e.g. Adger et al., 2005; Mendelsohn, 2006). General education (not only climate-specific) is another example of a public good already provided by the government. Along with its manifold positive effects, it is often seen as one of the most effective measures the government can take to increase the adaptive capacity of a society. Thus, education is not a new public task posed by climate change, but its benefits and relevance are increased in the face of climate risks.

An important question for economic research concerns the optimal degree of the provision of public goods in times of climate change. Theory provides us with Samuelson's rule (Samuelson, 1954): the sum of all marginal benefits from public adaptation should equal the marginal costs of public investment. Two points are important to note: first, the provision of a public good can become too costly in some cases, e.g. it may be socially preferable to give up a settlement if the adaptation to floods or sea level rise exceeds reasonable cost limits. We return to this point in section A4.1 in the appendix. Second, in spite of the general notion of non-rival consumption of public goods, in the real world public goods often have a local or regional character. For instance, a dyke usually protects a certain community, not a whole country – the beneficiary is the local, not the national, population. According to the theory of fiscal federalism (Oates, 1999), it is efficient to assign the task of providing the local public good to the local authorities and tax-payers: the construction of a dyke providing shelter to one city only accrues to municipal authorities and local taxpayers. This view of local public goods can be altered by negative externalities. In the case of local public goods, if their provision in one locality (i.e. the collective adaptation of one group) has a negative impact on other localities (i.e. the adaptation measures by other groups), uncoordinated actions by the localities (or groups) will be socially inefficient. As an example, just consider the case of a dam upstream a river. If the upstream community does not take the effects in the downstream community into account, the outcome will be most probably less than optimal from a social planner's perspective. In that case, planning by a central government (or even across governments in the case of transboundary river systems) can ensure the socially efficient outcome.

The case of integrated river management is a standard example of an externality – a further main rationale for governmental intervention in private adaptation processes. Adger et al. (2005) point to the fact that the "success" of a certain adaptation measure greatly depends on the spatial and temporal scale considered: through the effect on the person who adapts and by his/her generation, an adaptation measure may be perceived as successful, but taking into account the effect on other parties or even future generations, the same measure may be judged as too costly, ineffective or counterproductive. This is because of negative externalities. The existence of negative (and positive) externalities is a main reason for governmental intervention. In the neoclassical framework, the government would optimally internalise the externalities by prices and thereby facilitate an efficient outcome by market mechanisms.[4]

A final important role of a central government in the neoclassical perspective is the establishment of an institutional framework of property rights. Clearly, without a functioning system of property rights, long-term investments that are crucial for several adaptation strategies will not take place, endangering both public and autonomous adaptation. An example here is the property rights to a water source that are the prerequisite for the construction of an agricultural irrigation system. The provision of a legal system is considered the most elementary and indispensable public service. While the necessity of property rights may seem like a trivial point at this stage, it becomes apparent that contentious issues may arise when we discuss the equity principle in section 3.

[4] An example of negative externalities of adaptation would be the CO_2 emissions of a desalination plant if they are not internalised by any tax or emissions trading system. Positive externalities may arise from forestry strategies that respond to climate threats by mixed stands and thereby also provide improved air quality and recreation value.

3. Equity issues in adaptation

3.1 Introduction

The failure to prevent an increase in the atmospheric concentration of greenhouse gases would result in severe macro climate changes and entire societies would bear the costs. Yet it would be far from anything like a fair punishment of humans for not respecting the ecosystems in which they live. Climate change will indeed affect human societies very differently and regardless of individual responsibility for past emissions. Inevitably, equity issues arise in several areas. Even within the same community, benefits and costs will not be homogeneously distributed and not all parties involved are able to influence the political decision process. Resources for adaptation and the cost of adapting to a changing climate are two aspects that raise concerns about unfairness in adaptation. Equity issues are usually one of the pillars of policies and they are central in the political debate.

In general, the identification of *vulnerable groups* helps to clarify the important points. These are people who would particularly suffer from the effects of climate change because they have either fewer resources or higher costs for adapting and they may not have sufficient access to the decision-making process to influence it. In developing countries, farmers represent a large share of the population and if changing weather conditions reduce their land's productivity, only some of them would have the resources to adapt their production to the new climate. Moreover, poor people living in cities or in the countryside (being net consumers or suppliers of food) are alternatively sensitive to upward or downward trends in basic commodity prices because of climate change. Thus, poor households in both the countryside and urban areas would be vulnerable.[5] More precisely, countries or poor households are not the only potentially vulnerable groups. Future generations cannot actively lobby in the present for their interests. They will very likely bear the effects of climate change, but their influence on current policy is low. Adaptation projects may be postponed to the future and regarded as unnecessary because the local climate has currently shown little or no change (sections 4 and 5 deal extensively with the timing of investment and uncertainty). As a result, the next generations will carry the adaptation costs, which are likely to be higher if implemented too late.

Plenty of articles have been written about equity issues in mitigation (Azar, 2000; Cazorla and Toman, 2000; Rose et al., 1998), a topic that has some inevitable overlaps with the discussion about adaptation. The effects of climate change on countries and communities are the starting point for any discussion about responsibility and burden sharing in mitigation policy, but also in relation to adaptation. For instance, at the international level some countries will be hit harder by weather variation and they will not necessarily be those more responsible for climate change. In both cases, the parties involved should be able to participate in the decision process and defend their rights and needs.

Following Paavola and Adger (2002), the discussion has a pluralist approach, going beyond the common concept of distributive justice to include another important point of view, namely procedural justice. Indeed, even if the utilitarian approach (focusing on the distributive aspect of justice) has always had a leading role in the political economy, several different points of view have sprung up in the literature. The extension to procedural justice enriches the presentation of crucial points and analysis of the case of the Mediterranean area.

3.2 Stakeholders in adaptation

Adaptation plans may be conceived at different levels and the higher the level at which the decision takes place, the more complicated it is to involve all stakeholders. Starting from single individuals and households, their response to climate change has a basically private nature. Paavola and Adger (2002) identify three types of responses to climate change: proactive, reactive and inactive adaptation. For individuals, a proactive response is a set of measures that would allow them to keep living in the same location but adapt to the new environmental conditions (exploiting benefits or preventing damages). Behavioural changes in livelihood and investment in human and physical capital are two examples.

[5] See Jacoby et al. (2011) for a modelling study about the vulnerability of poor urban households in India.

The adaptation investment is in this case a private good, as there is little room for the possibility of others to benefit from it. A reactive response is instead the other available option besides inaction (no response). Migration to another area after experiencing adverse climate impacts would make the individual better off, assuming improved weather conditions in the new location.

On a slightly larger scale, local communities are among the main parties involved in promoting and carrying out adaptation projects. Climate change would indeed affect areas in the same country very heterogeneously and local authorities would have different incentives to invest in adaptation to climate change. For instance, in Egypt the Nile Delta is the most populated area of the country and a location sensitive to flooding events because of sea level rise and low-lying coastal zones. Nevertheless, the western coast, where Alexandria is located, will be more at risk than the central region because of different ground levels. Within the Alexandria area, the construction of sea gate protections has the nature of a public good because each individual is protected and it is not possible to exclude anyone from it. From the perspective of the region, however, the project is closer to a private good; hence local communities may cooperate little. Competition would even arise in applying for national or international funds for local infrastructure investment (e.g. groundwater recharge, irrigation and flood protection). Such infrastructural intervention is clearly a proactive response to expected climate change, but as we mentioned earlier, communities may also react less actively and choose internal schemes to mutually insure themselves from potential damage or simply leave individuals without any additional protection.

At the regional level, the differentiation between climate change winners and losers becomes neater and important. For instance, in Turkey the south-western coast is expected to see its total precipitation level reduced and it will likely be affected by desertification. Large parts will be too arid for agriculture and the altered climate will probably be less attractive for tourists. On the other hand, the northern coast along the Black Sea could benefit from an increase in precipitation.

A proactive response at the national level mainly relies on coordination and centralised adaptation planning to improve local cooperation and to collect resources for distribution among internal regions for realising proactive measures at lower levels (e.g. regional governments, urban areas or individuals). A government could also just prepare a buffer against potential negative effects. In the 11 SEMCs, low-income households are a vulnerable group in terms of food provision during adverse climate conditions. Facing insufficient agricultural production internally, the central government may intervene through tariffs (e.g. lower tariffs on food imports), fiscal policy or direct food aid to relieve food shortages and economic distress.

On a worldwide scale, national governments interact to coordinate and strengthen the internal adaptation policies discussed so far. In this case, vulnerable groups are countries that expect high damages relative to their economic strength, which can only address their appeals for support to the international community. Yet at this level, climate change winners and losers do not belong to the same political institution or national identity. The weakness of international institutions makes it harder for these countries to raise external support, but nowadays a minimum level of permanent support is ensured through some institutions belonging to the United Nations, as we explain in more detail below. For a proactive response at a global or macro-regional level, international cooperation is necessary. The EU is an example of how strong political relationships among countries can favour close coordination on adaptation strategies and the mutual funding of adaptation investment. On the other hand, the failure of multilateral and bilateral agreements would push countries to downgrade the targets of the international policy agenda to some reactive – or even no – response (e.g. *ex post* foreign aid, contingent on disastrous events already experienced).

With or without cooperation, countries are all responsible for another vulnerable group: future generations. Some cultures may be more sensitive than others to the conditions of people living in the future but in general their needs are not represented in the political decision process. One of the main challenges in terms of justice in adaptation, regardless of the definition, is to account for future generations in the current design of adaptation policies. As Paavola and Adger (2002) point out, "[t]he analysis of justice implications becomes complex when all levels, timing and types of adaptive responses are considered simultaneously". That is the major challenge in the design of international rules for participating countries. Before going into the details of what has been achieved so far, some definitions of equity are presented.

3.3 Concepts of equity in adaptation

We discuss equity issues following two different approaches: *distributive* and *procedural* justice. Distributive justice concerns how the benefits and costs of adaptation are distributed among individuals and groups of interest. The possibility for stakeholders to influence adaptation plans and the importance of legitimacy in the decision-making process is related to procedural justice instead.

3.3.1 Distributive justice

Fairness is often a synonym of equal distribution and this approach (particularly in the form of welfare theory) is central in economics as well as in the international and national political debate. Numerous public policies are intended to support vulnerable individuals in facing climate change, raising funds from the well-off groups.

National cohesion is a reason for centralised fundraising from internal regions to support the areas suffering the most from changing climatic conditions. Especially in countries where the territory is large enough to have different climate regions, this is an effective form of redistribution. Funds may be used not only to finance specific local needs but also by central monitoring and coordination agencies to address the danger of flooding, water resource management and health conditions. Governmental agencies are particularly useful in this preliminary phase of climate change because prevention can reduce expected future costs. Poorer areas can receive technical and scientific support from these agencies for preparing effective adaptation plans. For instance, Turkey is planning to set up a Coastal Zone Department for Environmental Impact Assessment and an Authority for the Protection of Special Areas to provide an early-warning system for flooding events and undertake special monitoring of areas that are highly at risk of environmental degradation.

At the international level the same applies, but the decision process is made more complicated by the lack of political cohesion and the high number of participants. Also, there are winners and losers, countries that will benefit and others that will be mostly damaged by climate change, regardless of their level of development. Under global warming, southern countries are likely to be more affected by severe degradation because of high temperatures, desertification and more drastic climate variability, while northern countries will probably experience a mitigation of their current cold weather (IPCC, 2007). Such uneven distribution of climate change effects calls for developed economies to make an additional effort in supporting other countries.

Developed countries are not only economically stronger, but they are also more responsible for past emissions of greenhouse gases in the atmosphere. Concerning mitigation, developing countries argue that it would not be fair to threaten their own fast growth period with emission cuts to redress the side effects of rich economies' development. Concerning adaptation, this is an additional argument for poorer countries to ask for support. International aid from north to south would be justified, not only in terms of solidarity, but also as compensation for damages for which they are not responsible.

As explained in the UN Framework Convention on Climate Change (UNFCCC), the support that should be provided for developing countries is not solely financial. Articles 4 and 9 clearly state that technology transfers are crucial for these economies to follow a path of sustainable development, for both reducing their impact on the environment and improving their resilience to a changing climate.

3.3.2 Procedural justice

Another perspective on justice in adaptation emphasises fairness and legitimacy in the decision-making process. According to procedural justice, all stakeholders of climate change effects and adaptation plans should be involved and transparency guaranteed. Moreover, institutional bodies taking decisions on funding and regulation must be recognised by all parties in order to ensure full legitimacy of the policy.

At the national level, whether procedural justice is guaranteed or not depends on the specific institutional and internal legal organisation. At the international level, the decision-making process on adaptation mostly benefits from the institutional framework designed for climate policy agreements, where procedural justice is carefully considered. The UNFCCC ensures that all countries, whether rich or poor, are involved equally in the decision-making process. Beyond ethical concerns, developed countries cannot achieve any substantial result without the collaboration of other economic areas.

3.4 Overview of the key issues

The main concerns are about the political decision process on adaptation and its outcome for each stakeholder. According to Paavola and Adger (2002), the "crucial dilemmas" for international adaptation policy involve both distributive and procedural justice issues. First of all, the responsibility of developed countries to assist the rest of the world in adapting to climate change has to be grounded and identified in order to choose a fair amount of aid. The group of developed economies has in turn to decide how to share these costs and to commit each other to the plan. On the other side, the choice of the distributive criterion for allocating funds to developing countries is crucial. If funding is based on present or future vulnerability, some countries and areas would have high priority but the ranking is likely to change if a different criterion is adopted (e.g. ability to adapt).

To guarantee procedural justice in adaptation, the stakeholders have to be identified first (in particular if they are vulnerable groups). For international agreements it is standard to involve only national governments as the representative of all internal interests. Yet, the possibility for local communities to participate in the primary decision about international aid would increase the level of legitimacy and justice of the final agreement. Even if formal participation is not possible (a prime example is future generations), the decision-making process should be designed in a way to account for all vulnerable groups during the planning of adaptation policies and agreements. The possibility of informal participation in meetings and conferences, as is usually the case with non-governmental organisations and local communities, could reduce such a gap.

4. Timing of adaptation

4.1 Concept of net present value

If private actors as well as governmental authorities have to make decisions on adaptation measures, there are different issues of interest, such as costs, responsibilities, type and quantity. Moreover, they take the timing of the adaptation into account, because it remarkably affects the present value costs of a measure. Fankhauser (2006) proposes a framework for estimating the adaptation costs according to the timing of realisation. For this purpose, he differentiates between the present value costs of adaptation now and at a later stage. Furthermore, the present value of climate damages at each point in time is relevant (under the case of adaptation as well as non-adaptation). This comparison between the costs enables us to determine the date of realisation at a minimum cost level.

The notation used in Fankhauser (2006) indicates that the decision on the timing of adaptation is dependent on three factors:

- *Differences in adaptation costs over time*. Adaptation costs can be either less or more cost-intensive at a later date. Waiting leads to cost reductions if the costs of measures strongly depend on technological progress, such as power plant cooling systems that are more efficient. The opposite is the case with respect to long-term adaptation measures, for instance in the infrastructure sector. When building a bridge, it turns out to be cheaper to include the adaptation measures directly in the new construction, considering that retrofitting costs in this sector are very high.
- *Short-term benefits of adaptation*. If an adaptation measure is designed so that its immediate benefit is very high or shows significant additional effects, as applies in the case of health investments for example, an immediate realisation is more justified.

- *Long-term effects of early adaptation*. Immediate realisation is reasonable if an adaptation measure leads to a significant decrease of the expected damage costs in the long-term. For example, preventing irreversible damages of the entire ecological system is justified because future damage costs could be relatively high and the residual costs may remain high even after the realisation of the adaptation at a later stage. On the other hand, technological developments may lead to a greater degree of effectiveness of adaptation measures that are realised later. This could occur in the domain of early-warning systems, which may increase in efficiency through an increase in the coverage of communication devices throughout the vulnerable population.

Considering these three factors, decision-makers should be capable of determining the most cost-effective date to realise an adaptation measure. This calculation, however, is based upon the assumption of certainty or constant uncertainty. The case of learning and diminishing uncertainty is tackled in the next section.

4.2 Investment under diminishing uncertainty: Using real options

The purpose of the real options theory is to model rational investment decisions under specific conditions. It was first developed and presented by Dixit and Pindyck (1994). For application of the real options theory, the following requirements are the most important:

- uncertainty, which will diminish or decrease at a later date;
- the irreversibility of investments; and
- the possibility of delaying the investment or extending it at a later date.

Decision problems with regard to adaptation to climate change exhibit these characteristics (especially uncertainty and irreversibility) in many cases. That is why closer consideration of this theory in combination with adaptation could be interesting.

The term 'option' indicates the right (not the obligation) to perform a certain economic action. These options not only exist on financial markets, but also in many parts of the real economy (Arrow and Fisher, 1974). The 'real option' indicates the possibility to perform a 'real' (and not only a financial) action. For example, this could be the new construction of an infrastructure system or the extension of an existing structure. The crucial point is that the decision-maker is able to make the investment now or at a later stage with the advantage of an improved state of information (Beare and Szakiel). Hence, one of the main features of the real options theory is the evaluation of different counteracting values: the value of waiting (for new information that improves the knowledge basis of decisions) versus the cost of waiting (because of profits or reduced losses achieved by an early investment).

There are many application possibilities, for example in the energy industry (Blyth et al., 2007). Also, in the context of climate policy the real options theory might be an aid for making decisions. The fictive example in section A5 in the appendix on the real options theory and adaptation demonstrates the application of the theory in an adaptation context in the 11 SEMCs and additional examples taken from different literature sources. There is also an elaboration on the possible constraints of a real options approach in relation to adaptation issues.

5. Uncertainty and adaptation

In this section, more general topics about uncertainty and adaptation are discussed. Uncertainty is a delicate issue for economic theory and it can generate limit cases that can call standard theories into question. Adaptation and mitigation give rise to similar concerns to some extent with respect to uncertainty and most of the debate presented here is borrowed from the more general economic literature about climate change and other fields of economic theory.

5.1 Sources of uncertainty

Earlier, in section 3.2, future generations are considered a vulnerable group because in the present people who are not yet born cannot mobilise political pressure in favour of adaptation measures. They would have several reasons for doing so: it is not clear how the global climate will change, how regional climates will vary or how severe the economic and health effects will be. Moreover, even if there was consensus about future catastrophic events, there is uncertainty about the effectiveness and future development of technologies: future adaptation techniques may be far more effective than existing ones, such that postponing investments could be optimal (as explained in section 4).

There are several sources of uncertainty pertaining to adaptation decisions:

- *Probability of catastrophic scenarios*. The major concern calling for adaptation responses is the occurrence of catastrophic climatic events, such as desertification or a low level of precipitation, sea level rise, increasing climate variability or frequent storms. Theoretical models handle these harmful scenarios as realisations of random variables for climate change. A random variable associates a probability distribution with a set of all possible (future) states of the world. If the random variable is defined based on temperature variation, it usually has a bell shape with one or two side tails (depending on whether only positive or both negative and positive temperature variations are considered possible). The thickness of these tails is crucial for any analytical enquiry (Figure 1). Extreme climate changes are considered very unlikely if the probability density function approaches zero very fast for high temperature variations (Figure 1, panel a). Under such an assumption, extreme events are in fact ruled out from the analysis and the model can give finite and nice predictions. In the opposite case, with ‘fat tails’, probabilities associated with very high temperature variations are large enough to enable extreme events to drive the results. The issue of the probability of catastrophic events is related to what Heal and Kriström (2002) label as scientific uncertainty, the extreme difficulty of predicting some key climate mechanisms as the response of the carbon cycle to human-induced emissions and the sensitivity of the climate to changes in the carbon cycle.

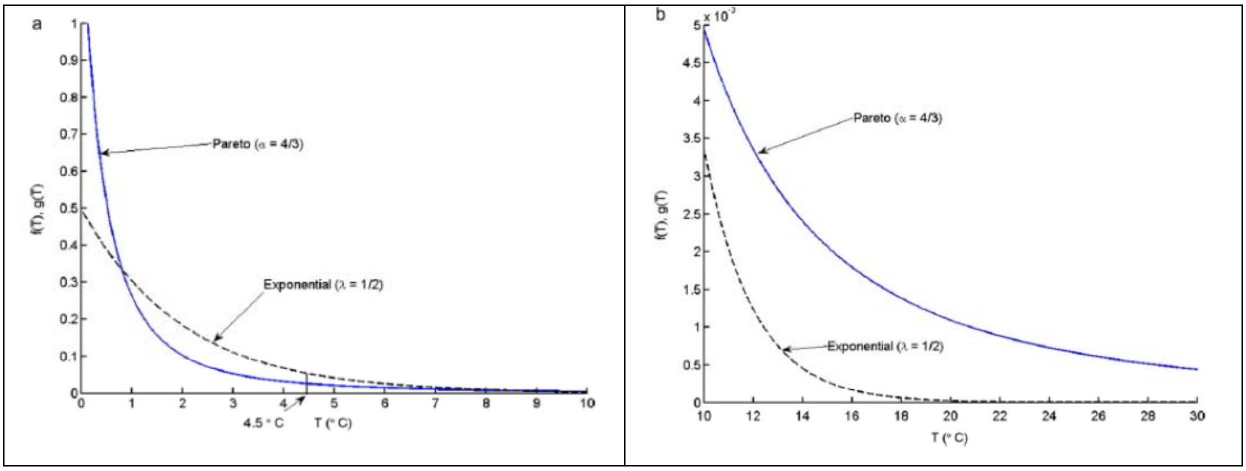
- *Impact uncertainty.* Besides scientific uncertainty, Heal and Kriström (2002) identify the scarce knowledge about the impact of potential climate-change scenarios on human systems as one of the main sources of uncertainty. While the former affects the probabilities of catastrophic events, the latter determines the costs and definition of *catastrophic*. Whether a given temperature increase is ‘catastrophic’ depends on the economic (welfare) implications deriving from all the effects of the temperature rise, for instance changing weather, the spread of diseases and sea level rise. Economists are likely in charge of this impact evaluation, mostly using modelling tools that are also affected by some degree of scientific uncertainty. Section 5.2 sketches some controversies among economists on the *right* theory, which is not surprising given that economics is usually considered a more quarrelsome field than any natural science.

- *Uncertainty about technology*. Many commentators advocate geo-engineering as a reliable response to climate change, but these projects are yet to be tested. Current technologies give hints about potential directions in future discoveries, but a policy relying on what is not yet available would be hardly acceptable. Therefore, adaptation policies are designed based on available technologies, and the costs and benefits are calculated using the technical details provided by the scientific community. Some degree of uncertainty still affects the decisions, however. Some techniques may entail significant level of uncertainty about their effectiveness. Moreover, there are unknown side effects of the implemented technology. That is true in particular for large-scale projects, which are usually justified by model simulations and need a trial period before being fully adopted. For example, a barrier system against sea level rise has some ecological and economic side effects that are only partly known and the adoption of such technology implies these additional risks.[6]

[6] Fontini et al. (2010) explain the costs and benefits of the MOSE system recently built in Venice.

- *Uncertainty about future resources for adaptation*. Another source of uncertainty comes from the future pattern of income, prices and financial conditions. Future economic scenarios influence current decisions, in particular the development of personal or national income. Households and individuals may change their adaptation decisions (cancel an adaptation investment) because of a negative change in expectations about future personal income or they may prefer to migrate to proactive measures because of negative expectations about the future state of the local or national economy. Governments may start ambitious adaptation projects backed by optimistic expectations of future economic growth. These variables do not directly depend on technology or climate change, but they are inevitably affected by patterns in the technological and climatic environment.

Figure 1. Example of distribution with fat tails



Notes: The blue line is the Pareto probability density function (pdf); the dashed line is the exponential function. In panel a, the Pareto pdf has a thin tail, because for high temperature increases (x-axis) it approaches zero faster than the exponential function. In panel b, the Pareto pdf has a thick tail, because for high temperature increases the associated probabilities are not close to zero.

Source: Pindyck (2011).

The benefits and costs of adaptation are influenced by all these sources of uncertainty. Finally, Pindyck (2007) points out that in the calculation of benefit and cost functions, high non-linearity amplifies the uncertainty discussed so far. Such non-linear functions may have some (unknown) thresholds associated with dramatic changes in the behaviour of the function. For a +3°C temperature increase, the related damages to the agricultural sector may be moderate, but at +4°C some cultivations could begin to suffer heavy distress and the expected benefit from the adaptation plan would rise sharply. Furthermore, the shape of curves is usually unknown and the mathematical representation with popular probability functions is just an approximation. As a result, the cost–benefit analysis may be extremely sensitive to changes in underlying variables and robustness can hardly be guaranteed.

5.2 Theoretical disputes

Adaptation measures are evaluated based on future uncertain outcomes. The economic analysis of adaptation encounters the same difficulties that economic theory has always had in handling this concept. The distinction of Knight (1921) between risk and uncertainty introduced one of the first methodological disputes into the field. Economic models use the concept of 'risk' because knowledge of future possible states of the world and associated probabilities is necessary to use random variables and other statistical tools in numerical models. In contrast, the Knightian definition of 'uncertainty' refers to the case in which future outcomes are completely unknown and no statistical measurement is considered reliable. It is clear how cost–benefit analysis requires the use of the former instead of the latter definition. Indeed, the choice between the two concepts has major methodological consequences. Under Knightian 'uncertainty', data about past events are not reliable information from which to infer regular properties of future outcomes; the only possible forecasts are made out of subjective probabilities that may be collected from expert surveys, for example (Dobes, 2012).

In policy-making, the adoption of the Knightian uncertainty concept implies the use of alternative frameworks to the pure cost–benefit analysis. The use of scenarios is a popular example. In section 7.3, Figure 2 shows four potential scenarios for the future that are used to develop four policy outlooks. Notice that no probabilities are associated with any of the quadrants in the graph of Figure 2, and thus the policy-maker would frame the policy plan according to some subjective weighting of the scenarios. A cost–benefit calculation for an adaptation plan would have needed a probability distribution defined for each dimension in order to calculate the overall expected costs and benefits. For example, if one of the 11 SEMC governments wants to calculate the feasibility of a coastal protection project under 'riskiness', the expected costs are dependent on the level of sustainable development and international collaboration. The higher the probability of having strong economic development in the next decades, the higher are the expected tax revenues and the lower is the need for external capital. Additionally, the closer the cooperation in the EU–MED region, the more abundant the EU funds will be, expectedly. After assigning probabilities to future long-run growth rates and degrees of political integration, and together with all information about costs and benefits, a precise net expected return from the coastal protection project could be calculated. Under an 'uncertain' setting, however, the project evaluation should rely on alternative decision criteria. With a conservative criterion, the total costs in the worst-case scenario may be the critical value to consider and if it transgresses a predetermined 'dangerous' threshold then the project should be rejected.

Nevertheless, even when using the 'risk' assumption about knowledge of the future, some controversial issues may still arise. In section 5.1, the probability associated with catastrophic events is regarded as a sensitive criterion for the choice of adaptation. The presence of fat tails is troublesome here because cost–benefit analysis is an application of expected utility theory (EUT), which generally suffers the same problem. In an influential paper, Weitzman (2009) demonstrates the so-called "Dismal theory", a serial flaw in the EUT applied to the case of extreme events. The cost–benefit analysis breaks down because if the probability of an extreme event is not sufficiently small, sufficiently high costs associated with the event would make the expected value explode. As a result, the individuals' willingness to pay for preventing the catastrophic damage is infinite, which is quite an unrealistic theoretical prediction. The implications of the theorem are rather strong for such a popular economic tool and the result stimulated wide discussion among economists on the subtle assumptions behind the theorem (Pindyck, 2011; Nordhaus, 2011).

Anyway, even before the publication of Weitzman's paper other theories were emerging besides the EUT. Prospect theory is one example of an explanation of decision-making under risk departing from the standard EUT. A main idea proposed by Kahneman and Tversky (1979) is that the EUT assumes people give the same weights to gains and losses, while in reality this is not the case. Individuals tend to repel losses and to weigh negative outcomes more than potential gains. As a result, the decision is not based on the final net outcome but on a separate evaluation of benefits and costs. Additionally, probabilities are replaced by 'decision weights' depending on probabilities.

This short illustration of the theoretical disputes surrounding the theory of adaptation and mitigation to climate change shows how careful policy-makers should be in relying on policy recommendations, not only because of the uncertainty in natural and economic phenomena, but also that associated with the soundness of economic theory.

6. Adaptation and mitigation

This section focuses on the linkages, interdependencies, synergies and conflicts of mitigation and adaptation. We define mitigation as the abatement of greenhouse gases, thereby combating the cause of climate change. In contrast, adaptation refers to the adjustment to actual or expected climate change, thereby reducing the adverse impacts of climate change and yielding potential benefits. Both strategies are pillars of a comprehensive climate policy, which will be used as the generic term for both strategies. How adaptation and mitigation are connected with each other and what implications are to be expected for the 11 SEMCs is the topic of this section. The more theoretical topics of the major differences, the optimal policy mix, the role of uncertainty and whether the two policies are rather seen as substitutes or complements, are tackled in section A7 in the appendix.

6.1 Synergies and conflicts

The interdependencies of climate policies at the theoretical level (discussed in section A7 in the appendix) can be broken down at a lower level with concrete illustrations. There is a strand of literature that examines synergies and conflicts between concrete adaptation and mitigation measures. Synergies are defined as the positive impacts of one policy measure on the effectiveness of another. Sometimes they are also referred to as co-benefits. Conflicts, on the other hand, imply negative side effects of one policy on the objectives of another. These are adaptation options that come with a high amount of CO_2 emissions or mitigation measures that increase climate vulnerability.

Synergies of mitigation and adaptation can be identified in many concrete policy options, most of them strengthening the role of natural resources in environmental management. Examples taken from Paterson et al. (2008) and Moser (2012) include reforestation with native and diverse tree species, coastal wetland restoration, urban greening and soil conservation. Table 1, reproduced from Moser (2012), lists some measures that work in favour of adaptation and mitigation simultaneously.

Table 1. Examples of measures that enhance adaptation and mitigation goals simultaneously

Measure or Option	Positive Implications for Mitigation	Positive Implications for Adaptation
Coastal wetland restoration	Increased carbon storage	Storm buffer, species habitat, fish nursery
Building insulation	Reduced energy consumption for heating and cooling	Protection from heat, human health benefits, comfort
Reforestation with native and diverse tree species	Carbon storage	Habitat and species protection, flood control, soil preservation
Reduction/cessation of off-shore oil production	Reduction in liquid fuel-related GHG emissions	Reduced risk of oil spills, reduction of multiple stresses on marine/coastal ecosystems
Energy demand management	Reduced energy use and energy-related GHG emissions	Cost savings for energy user, system-wide lowered peak demands may avoid black-out
Soil conservation, e.g. through changed tillage or cover cropping practices	Potentially increased carbon storage and nitrogen fixation	Improved nutrient and water retention, increased soil biodiversity

Source: Moser (2012).

Many of the synergies are found in the agricultural sector, due to the dual role of soil and vegetation in terms of vulnerability and carbon sequestration. Rosenzweig and Tubiello (2007) review these synergies and conclude that "many positive interactions have been identified", but still

> it is important to note that synergies will not be possible under all climate and socio-economic scenarios, and across regions. Adaptation strategies will likely often take precedence over mitigation, as climate changes are already underway and farmers will adapt (as they have always done), in order to maintain production systems and thus their own incomes and livelihoods.

This lack of incentives for mitigation might also be a reason why they rather speak of *potential* synergies of adaptation and mitigation strategies in agriculture.

At the same time, there are also clear conflicts between mitigation and adaptation activities. They are present especially in the field of technical adaptation solutions (energy-intense cooling devices, built infrastructure and energy supply). But they also occur in the forestry sector, as presented by Geijer et al. (2011) for Sweden. The climate mitigation objective calls for a high usage of wood as an alternative to fossil fuels. On the other hand, the adaptation objective makes the case for increased forest conservation. Although the study by Geijer et al. focuses on a northern European country, in general the aspect of competing objectives (mitigation vs. adaptation) in the forestry sector may also become relevant in the SEMCs.[7] Regarding energy supply, Kopytko and Perkins (2011) highlight the adaptation–mitigation dilemma inherent in the mitigation strategy of an increased usage of nuclear power. Although nuclear power plants emit less greenhouse gases, they are more vulnerable to climate change than alternative energy sources, and further objectives like safety and an interruption in security have to be considered very carefully too. In essence, the authors' view of nuclear power as a mitigation policy is very sceptical, not just for the adaptation considerations.[8]

Moser (2012), reviewing synergies as well as conflicts, concludes that the latter have to be analysed very carefully as they often occur more directly and imminently than positive side benefits. Although synergies with the respective counterpart are often identified as justification for some policy implementation, the harmonies between the two strategies should not be overestimated. This contribution, according to the author, should not be misunderstood as a negation of synergies, but rather as advice for realistic expectations towards climate policies.

Finally, it should be mentioned that synergies and conflicts of climate policies not only occur within the climate debate, but also in connection with other policy fields. As one of many examples, Paterson et al. (2008) examine the impact of both types of climate policies on biodiversity. The authors present a framework for analysing the policies with regard to their impact on adaptation, mitigation and the third objective of biodiversity. They place some possible options for climate policy in a diagram that illustrates this multi-objective perspective. Optimal solutions should be "win-win-win solutions", such as "[u]rban tree planting" or "[f]orest conservation".

6.2 Adaptation and international mitigation agreements

The effect of adaptation on international mitigation negotiations and agreements is an issue frequently tackled in the literature. The key question here is whether and how national adaptation is able to influence the probability of global mitigation. In general, there are three theoretically possible answers: first, adaptation has no influence on mitigation agreements. Second, the introduction (or increase in levels) of national adaptation lowers the global mitigation level agreed upon in international negotiations, e.g. by higher incentives to leave a mitigation coalition. Third, national adaptation helps to achieve higher levels of global mitigation. Both the latter two possibilities (which contradict one another) are present in the current literature.

Antweiler (2011), using a dynamic optimisation model in a theoretical framework, shows that the presence of multiple countries – compared with a single country case – increases the overall attractiveness of adaptation relative to mitigation. This is just because adaptation, by reducing climate damages, decreases the attractiveness of contributing to mitigation, particularly for countries that already have low emission levels. This finding proposes a negative effect of national adaptation for international mitigation efforts.

[7] Three of the eleven SEMCs have forest areas that are greater than 10% of their total land area: Turkey (14.7%), Lebanon (13.4%) and Morocco (11.5%). Data from the World Bank, "Forest area (% of land area)" for 2010 (http://data.worldbank.org/indicator/AG.LND.FRST.ZS).

[8] Although nuclear power is not currently used in the 11 SEMCs, this topic is essentially relevant for the future after 2018. Except for Lebanon and the Palestinian Autonomy, all 11 SEMCs have plans for establishing a nuclear energy supply. Four of them (Egypt, Israel, Jordan and Turkey) have already made concrete plans or proposals for the construction of nuclear reactors. Data from the World Nuclear Association (2012) (http://www.world-nuclear.org/info/inf102.html).

On the other hand, there are a number of theoretical papers that raise expectations of a favourable role of adaptation in global mitigation agreements. One way adaptation increases the probability of such agreements is the strategic employment of adaptation. If a subgroup of countries invests in adaptation *ex ante*, this credibly commits them to a lower mitigation level in the future. Given the lower mitigation level of some countries, the remaining countries are willing to mitigate more in order to keep their optimal climate policy mix.[9] In the end, this may enhance the probability of a global agreement, even though the remaining countries are more or less forced to cooperate (Auerswald et al., 2011; Farnham and Kennedy, 2010).

Another argumentation is based on the convex cost structure of adaptation. Presuming that one country free-rides and increases its own emissions, the other countries have the possibility to increase adaptation efforts to keep their climate damage constant. In this case, the free-rider also has to increase its adaptation level to keep climate damage constant. Yet, the costs of adaptation are convex in the level of adaptation and hence the costs of each individual country, including the free-rider, increase if cooperation fails. In effect, the higher the adaptation level, the higher are the gains of cooperation and the lower the incentives to leave coalitions (Benchekroun et al., 2011).

The few literature sources presented here show that the debate on the nexus of national adaptation and global mitigation agreements is still underway and definitely deserves more thorough examination than is possible here. Most contributions model climate policy in an abstract, theoretical way and many quite important empirical inputs are still missing. This possibly leads to the conclusion that without clearer quantitative knowledge of marginal adaptation as well as mitigation costs and benefits in the different world regions, this debate will continue. A second, policy-relevant conclusion is drawn by Lecocq and Shalizi (2007), who state, "mitigation policies and adaptation policies should be negotiated jointly, and not separately as is essentially the case today".

7. Qualitative foresight analysis of adaptation policy

The theoretical framework is now used to provide sound foundations for a qualitative foresight analysis of adaptation in the 11 SEMCs under the scenarios defined in Ayadi and Sessa (2011).[10] What follows relies on the arguments discussed in the first six sections of this report and on the adaptation needs/adaptation cost data available at the moment. As empirical information about adaptation measures in the region is limited, most of the analysis is qualitative. For the three transition scenarios we identify opportunities and potential critical issues regarding adaptation policies for national governments in the SEMCs, with particular attention given to the cooperation between the EU area and these countries.

7.1 Literature review on adaptation in the 11 SEMCs and case studies

This section reviews current available information about adaptation at the sector level for the SEMCs. In section A8 in the appendix, we also present the few cost estimates for adaptation found in the literature. More details about the expected impact of climate change on these countries and the adaptation measures implemented to date are included in the country case studies in the appendix (A1, A2 and A3).

To identify the available studies on climate impacts and adaptation in the SEMCs, a literature review has been performed. Studies and reports have been included if they focus on one or several of the 11 SEMCs and on regional or local climate impacts or adaptation measures. All the studies reviewed are listed in section A8 in the appendix. To identify which countries are well covered by the literature, the studies have been grouped by the countries and sectors analysed (see section A8.1 in the appendix). The results reveal two features of the literature base:

[9] According to Auerswald et al. (2011), they are even forced to do so.

[10] For a detailed description of the four scenarios and the methodology, refer to Ayadi and Sessa (2011). An illustrative graph is depicted in Figure 2.

- It is relatively scarce in the sense that adaptation is not always covered and the number of region- or country-specific studies is very limited. Studies concentrating on affected aspects or sectors, such as biodiversity or fisheries, are almost absent in all countries.
- It is quite heterogeneous across the countries, e.g. the climate impacts in Egypt are relatively well researched in comparison with Libya or the Palestinian Autonomy (where no specific study could be identified).

These results served as the basis for the selection of the three case studies: we found that Egypt, Turkey and Tunisia have the best literature base, even if it is still quite fragmentary. Moreover, they represent three broad regions of the southern Mediterranean (west, south-east and north-east) and somewhat different socio-economic backgrounds. These country case studies are thus the empirical backing for the analysis of adaptation futures in the rest of the report.

7.2 The Reference Scenario

The 11 SEMCs currently have a similar level of cooperation with the EU and a quite heterogeneous per capita GDP and income distribution. The EU has established an important channel of cooperation and aid to the southern neighbourhood through its Annual Programmes South, which complements other bilateral activities with single countries and is part of a more general Euro-Mediterranean Partnership framework. The programme has a wide variety of objectives. Adaptation to climate change is – if at all – only a sub-target besides promoting general economic development and reducing poverty. The cooperation plan is the result of a full consultation of potential stakeholders and the projects to be adopted are targeted at civil society, national and local governments. During the programme definition phase, several meetings between EU officials and groups of stakeholders helped to guarantee a good level of transparency and participation.

Since the establishment of the UNFCCC, many funding bodies have been set up under the supervision of UN institutions. These are the operating channels for providing grants, loans and technical support to adaptation projects all around the world, mostly directed at developing countries as established in the UNFCCC. So far, four of these funds have financed adaptation projects in the 11 SEMCs. Two of them are bilateral funds managed by national governments in Europe. The *International Climate Initiative* is a German fund that has the special feature of being financed by the national emissions trading scheme. It has recently supported a project in Turkey with a contribution of €1.35 million. The *MDG Achievement Fund* is a Spanish fund in cooperation with the UN Development Program (UNDP), which has "Environmental and Climate Change" among its programme areas. The fund allocated €4 million for a project in Jordan and €4 million for one in Egypt. The other two funding bodies are the *Special Climate Change Fund* and the *GEF Trust Fund – Climate Change Focal Area*, both managed by the UNDP Global Environment Facility (UNDP-GEF). The UNDP-GEF is an independent financial organisation that operates in a multilateral setting in collaboration with 182 national governments and several UN institutions. Among the 11 SEMCs, one project in Morocco received €4.35 million and one in Egypt €4 million, while €2 million was allocated to Jordan and €0.7 million to Tunisia.[11]

Moving to the current economic conditions of the 11 SEMCs, national resources for adaptation vary quite widely. The GDP per capita ranges from more than $28,000 in Israel to less than $5,000 in Syria, the Palestinian territories and Morocco. Looking at income inequalities as an additional indicator of individual resources for adaptation by households, all countries have a moderately unequal income distribution, with a Gini coefficient[12] between 0.35 and 0.41. Poverty rates, using national poverty lines,[13] are 27% for Turkey and 22.6% for Algeria, while Tunisia, Jordan and Egypt have lower shares

[11] See the website of Climate Funds Update (www.climatfundsupdate.org), last accessed on 15.02.2012.

[12] Data derived from the CIA's "World Factbook". In general, recent data are not available and values are used here to refer to different years in the 2000s (1995 is the last year for Algeria).

[13] These are based on the United Nations' data published for the "Human Development Indices" referring to 2006. National poverty lines are the values considered appropriate by each country's authorities.

of the population living in poverty. There are no data available about the income distribution for Libya or Lebanon. As a result, the presence of a large share of the population having an absolutely and relatively low income in all countries raises concerns about adaptation policies. Together with these vulnerable groups, many governments in the 11 economies (e.g. Algeria, Egypt, Jordan, Morocco and Tunisia) may not have enough resources to finance effective adaptation plans even if an urgent response to desertification and coastal erosion is needed.

The first signs of climate change have already appeared in the 11 SEMCs, as also shown in the country case studies in the appendix (A1, A2 and A3) to this report and in other deliverables of this MEDPRO Work Package. Their most important vulnerabilities regard health, water supply, coastal erosion, agriculture and tourism, and hence these are the priority areas for intervention. At the same time, the current situation in the region is mostly portrayed by political inaction. Only very recently have some central governments prepared national strategies concerning adaptation and specific sectoral plans to tackle issues like coastal erosion, water scarcity and agricultural vulnerability to climate change. One positive example is Tunisia, which has developed national policies in most of the critical areas (see the case study in section A3 in the appendix). Still, even recent improvements are not sufficient to make a satisfactory long-run trend. The persistence of the current low level of political involvement will leave the 11 SEMCs inadequately prepared to face the future effects of climate change in their territories.

7.3 Analysis of future scenarios

7.3.1 Green Transition (Q II)

In the 'Green Transition' scenario, a process of political integration between the 11 SEMCs and the EU would take place in some form of EU–MED union, most likely as an extension of the EU to the 11 SEMCs (Figure 2). As is required by EU treaties, the latter countries would need to adopt many features of the European legal system on human rights, labour, environmental and health protection law. Internal inequalities may be reduced and improved social cohesion would be a step towards stronger resilience to climate shocks. Newcomers would have full access to EU funding and the possibility to use a number of resources that directly and indirectly facilitate adaptation policies and investment. Less developed regions would largely benefit from such financial support and avoid lagging behind in the implementation of effective adaptation measures. Moreover, the level of procedural justice could be improved because both sides of the Mediterranean Sea could discuss and negotiate all possible cooperation actions for adaptation in a fully legitimate and equal environment – European institutions.

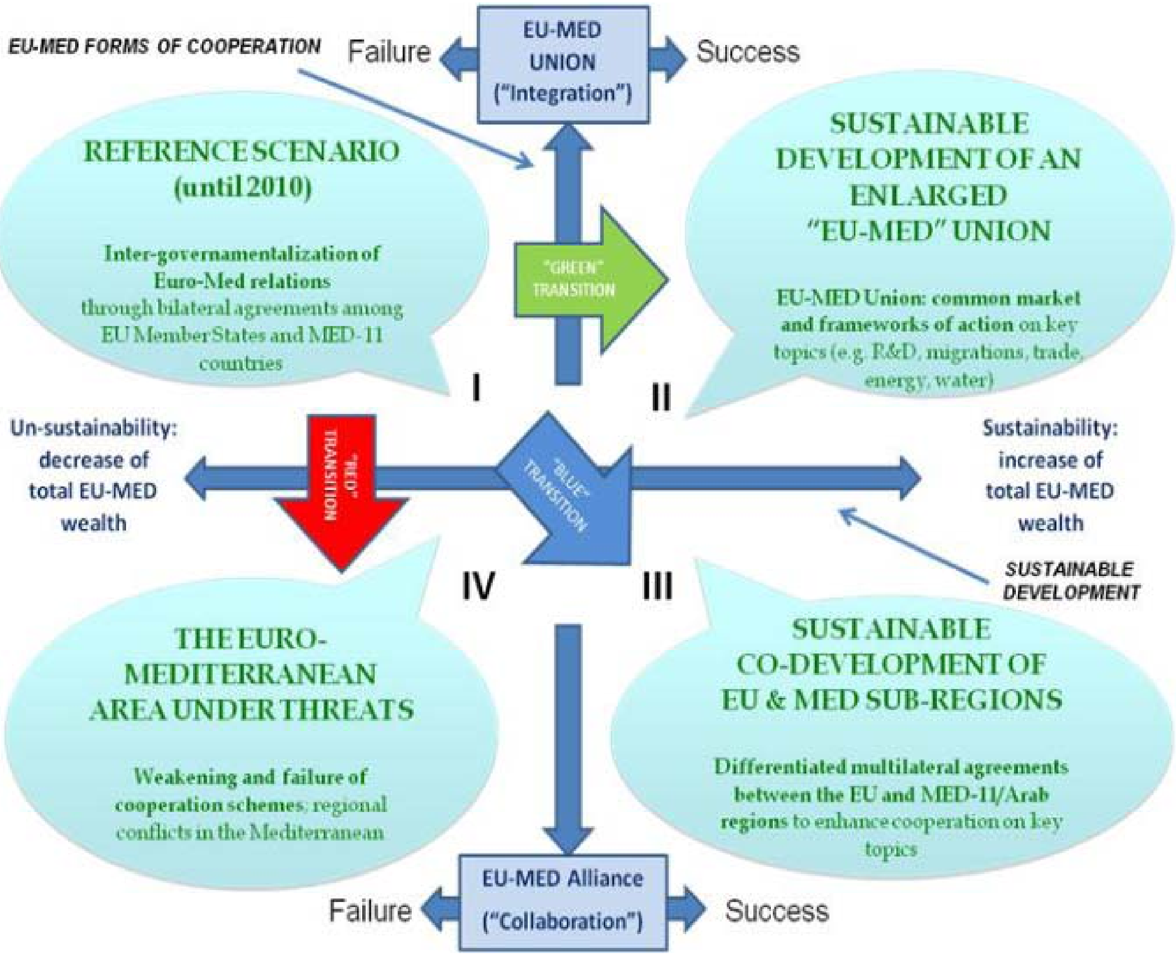
Under this scenario, strong economic growth in the entire region would provide resources for governments to spend on adaptation measures and the increase in per-capita income would strengthen households' resources for adaptation. Economic growth would drive the diffusion of innovation and stimulate the local production of advanced technologies, reducing dependency on sources from abroad. Even if equity issues over the spread of adaptation costs remain unchanged, an increase in the total wealth of the 11 SEMCs would reduce concerns about resources for adaptation.

Apart from Israel and Turkey, the SEMCs are likely to remain middle-income economies in the next decades (for a detailed analysis, see Coutinho, 2012) and their adaptation projects will depend on some type of technical, financial or organisational assistance from their northern neighbours. Foreign aid is a more volatile and hence uncertain source of funding compared with internal resources.[14] The higher the level of integration between the two regions, the higher is the level of commitment to cooperation projects. For either EU–MED projects or collaboration among the SEMCs, greater political commitment is a factor that would positively influence adaptation projects in terms of reducing uncertainty about the provision of funding and technical assistance.

[14] Plenty of studies seek to explain the effects of foreign aid volatility on the recipient economies (for some data about annual changes, see Desai and Kharas, 2010).

Under this scenario, there would be a clear and transparent assignation of governmental and private tasks that facilitates economic efficiency, fairness and ecological sustainability in adaptation. Moreover, there would be a high chance that the globally optimal mix of adaptation and mitigation investments is jointly determined and pursued because of the strong political integration with Europe, one of the major players in climate policy. This includes the location of each mitigation and adaptation project in the country where efficiency is the highest for the respective project. In this first-best world, the costs of climate change, consisting of mitigation, adaptation and residual damage costs, are minimised at the global level. Adaptation and mitigation projects are co-funded by external partners if they show positive externalities. Synergies are exploited and conflicts between adaptation and mitigation are identified and possibly reduced. The current Clean Development Mechanism (CDM) already goes in this direction (Fujiwara et al., 2012), giving the 11 SEMCs the benefits of an efficient allocation of resources and the transfer of technologies from the European area. The system is developed for mitigation purposes, but it can potentially exploit all the synergies between adaptation and mitigation through joint projects between local and foreign investors. Indeed, while EU emitters are interested in mitigation, local firms and authorities have a higher incentive to invest in adaptation.

Figure 2. Grid of four indicative scenarios defined by two dimensions: Cooperation and Sustainable Development scenarios



Source: Ayadi and Sessa (2011).

The transition to the most positive scenario for adaptation may be triggered by a global agreement on legally binding and effective mitigation targets, along with sufficient (also external) funding for adaptation projects all over the world. For the success of Euro-Mediterranean integration, it would be even more conducive if this agreement were achieved by common and joint efforts on both shores of the Mediterranean in order to encourage other world regions to join this alliance.

7.3.2 Blue Transition (Q III)

The 'Blue Transition' scenario is instead characterised by loose collaboration and spontaneous agreements between the 11 SEMCs and EU countries amid economic prosperity. Divergence in country economic, social and political patterns as well as the absence of a strong connection between the EU and the 11 SEMCs distinguish this scenario from the Green Transition one. Here, the 11 SEMCs are not necessarily worse off. The SEMCs would be characterised by different policies and being somewhat politically fragmented. Instead of full cooperation by the entire region, only some sub-regional associations would arise and some degree of internal conflict would persist. Additionally, each country would autonomously build up partnerships worldwide (e.g. with the rest of the Arab world, Far East Asia, Africa and Latin America). With no dominant role played by the EU, the US, Russia or China, regional country groups like the Maghreb would be more influential in driving the outcomes of national policies.

In this scenario, concerns about procedural justice would be more severe than those about distributive justice. Abundant economic resources may reduce poverty and increase the countries' ability to invest in adaptation, given sufficiently high tax revenues for national and regional governments, but the weak political integration may isolate some local communities and weaker countries from interregional cooperation on adaptation projects. The lack of a political alliance is likely to weaken lobbying power in diverting international funding to the region, even if good economic conditions make these countries rather influential players in the diplomatic game. Yet with respect to mitigation and adaptation policies, the UNFCCC framework would help the SEMCs to obtain assistance from developed countries and make their diplomatic influence stronger because of the good level of procedural justice in the UNFCCC's institutional design.

Even if the SEMCs cannot benefit from participation in EU institutions and the strength of regional mutual support, cooperation with other major partners may eventually guarantee a comparable level of financial and technological support in pursuing adaptation plans. Adaptation goods are highly capital- and technology-intensive, and the degree of trade and investment openness is crucial to facilitating sufficient action by the private sector (i.e. households, farmers and other firms). Currently, the 11 SEMCs are quite heterogeneous in that regard (Sekkat, 2012; Ghoneim et al., 2012) and the situation is likely to remain unchanged under this scenario unless all 11 SEMCs join international trade agreements under the framework of the World Trade Organization.

7.3.3 Red Transition (Q IV)

In a downside scenario (quadrant IV), there is no effective cooperation between the EU and the 11 SEMCs, neither concerning mitigation nor adaptation topics. Thus, as mitigation targets are more difficult to achieve and climate change goes on, adaptation may be pursued more intensively for two reasons: first, for some decision-makers it serves as a substitute for effective mitigation and gains relevance in light of the failure of mitigation negotiations. Second, adaptation may be used by some countries strategically in order to commit credibly to unambitious efforts at domestic mitigation, thereby encouraging their international partners to increase their own mitigation efforts (see section 6.2). In this atmosphere of distrust and pressure, adaptation and mitigation projects on the Mediterranean shores are unlikely to harmonise, which may lead to conflicts between them. As an example, one may think of large-scale solar energy projects conducted by the EU in North African countries, which as a side effect increase the vulnerability of those countries, e.g. by an accumulation of capital and people in exposed areas and the absence of proper protection there. Another example is the above-mentioned energy-intensive desalination plant. In the absence of clear mitigation targets and international commitments, there is little reason for a water-scarce country to care for emission reductions in their adaptation efforts.

But also the adaptation processes themselves would suffer under weak political leadership and coordination. The scenario may be described by inefficient, inadequate or missing adaptation governance (which could mean too much or insufficient or wrong intervention). Furthermore, a lack of cooperation in the formulation of adaptation policies may result in conflicts and consequently in high transaction costs for policies.

The 'Red Transition' is the worst-case scenario where, together with weak international cooperation, low long-run growth prevents the 11 SEMCs from having the economic resources necessary to carry out effective adaptation plans and the spread of poverty generates massive migrations to EU countries and other rich areas in the world. Equity problems worsen to the severest extent, for both distributive and participation concerns. As explained for the Blue Transition scenario, less procedural justice is foreseen. In relation to distributional issues, international adaptation support would have to cope with weak governments in the southern Mediterranean, asking for resources to compensate small national budgets and a high degree of vulnerability among poor households. An additional effort from developed countries would be required to balance out the lack of regional cooperation on technological and organisational issues. Under this scenario, however, EU countries would also experience low economic growth and the resources made available for foreign aid would not be enough to meet the needs of the 11 economies, even if it is in EU countries' interest to prevent waves of migration from the south.

We see the following drivers that might lead to a Red Transition scenario: i) the UNFCCC negotiations could fail to achieve an effective and legally binding agreement for greenhouse gas abatement and ii) there could be a lack of sufficient contributions to adaptation funds for projects in vulnerable countries. Both failures could lead to an environment of non-cooperation and distrust in the international climate debate. This atmosphere would be exacerbated if one of the partners has the impression that another partner is significantly contributing to the failure of a global mitigation agreement.

7.4 Directions of policy intervention

The theoretical framework in the first six sections identified some critical issues for adaptation, from equity to the interrelationship with mitigation, giving rise to several insights about the future policy measures necessary for the 11 SEMCs to face climate change under the three transitions outlined in section 7.3. As a result of the previous analysis, this section summarises the most important policy recommendations and warnings to achieve sustainable development, as in the Green and Blue Transition scenarios.

The **role of government** is essential for the achievement of good adaptation to climate change. The presence of several types of market failures, equity and geopolitical issues as discussed earlier calls for political activism. In the 11 SEMCs, climate change is expected to cause severe alteration of environmental conditions over time,[15] and constant monitoring is recommended. Problems such as coastal erosion, floods and water scarcity need prevention, and to fully minimise expected costs, adaptation measures should be implemented in advance. This basic step has only been partially implemented in the countries covered by our case studies in the appendix (A1, A2 and A3). Turkey has developed the Turkish National Sea Level Observation System to measure the sea level along Turkish coasts and the Authority for the Protection of Special Areas to keep watch on the most vulnerable areas. In Tunisia, the Coastal Protection and Planning Agency (APAL) has been active since 1995, dealing with coastal supervision. Drought monitoring is active in Turkey, Tunisia and Egypt, but there are no other types of monitoring systems operating in the region. For instance, Medany et al. (2009) point out the importance of developing early-warning systems in relation to increased occurrence of diseases and pests in agriculture. Iglesias et al. (2006) recommend monitoring water quality and scarcity. Improved data exchange may also be necessary, as the reports by the UNFCCC and Ministry for Environmental Affairs (2010) and Agrawala et al. (2004) suggest in relation to the Nile River: there should be better information sharing among Nile Basin countries and enhanced networks for precipitation monitoring in upstream countries of the Nile Basin.

[15] A general overview of climate change projections in the region is presented in IPCC (2007). For Turkey, see Ministry of Environment and Forestry (MOEF, 2009 and 2010) and Ministry of Environment and Urbanization (MOEU, 2011); for Egypt, see the Egyptian Environmental Affairs Agency (EEAA, 1999 and 2010); for Tunisia, see the Ministry of Environment and Sustainable Development & United Nations Development Program (MEDD and UNEP, 2009).

Information collection and early warning are part of the broader coordination and planning activities. In each country, the government should lead national and international coordination. Political and technical institutional bodies need to identify important areas of intervention and to exploit the project synergies and knowledge resources available across the entire country.

There are some examples of comprehensive national plans in the region. The National Water Resources Plan (Ministry of Water Resources and Irrigation, 2005) developed by the former Egyptian government aims at tackling the future shortage of available fresh water in the coming decades. It proposes interventions in both the supply and demand of water resources. This plan overlaps with another "Plan for Improving On-Farm Water Management" targeting irrigation systems in the agricultural sector with the objective of increasing efficiency by 50-75% (EEAA, 2010). Irrigation systems take up an important share of the demand for fresh water and the two plans reinforce one another.

National planning has the positive effect of showing commitment and signalling to the population the primary importance of adaptation measures. Public awareness should not be taken for granted. In a survey of Tunisian wheat farmers, Abou-Hadid (2006) shows that many individuals are not aware of the importance of farming techniques in adapting to climate change. Imperfect information is only one of the many potential limits to a proper initiative from the private sector without policy intervention. The earlier that governments make such a credible commitment, the better can private actors plan their adaptation activities according to their responsibilities.

To unleash the full potential of private investments, any possible barrier to private adaptation (in terms of incentives, legislation, knowledge gaps or customs) has to be removed. For instance, since 2003 Tunisia has implemented some measures to support private adaptation. The plan concerning water management included restructuring the farmers' bank debts, importing and subsidising drilling products and carrying out a public awareness campaign. Financial support is particularly important in countries where a large share of the agricultural sector consists of family-owned farms living in poor conditions and endowed with very limited financial and human capital.

Furthermore, the public intervention may be extended to the support of private adaptation measures with positive externalities (e.g. by financial subsidies, legislation and advocacy). Given the **potential conflicts of adaptation with mitigation**, a broader strategy is recommended, as is adoption of efficient and effective regulation of the negative externalities of adaptation measures, including CO_2 emissions. As an example related to a small, private investment, in the tourist sector building insulation should be subsidised in order to make the installation of air conditioning less attractive by comparison. For the case of a large investment, the example of water desalination plants is striking. Public authorities should favour alternative options because of the energy-voracity of this type of technology.

Coordination is crucial for making adaptation policy fully effective. International coordination is important for countries sharing river water sources or seacoasts. Since 1999, the Nile riparian states have participated in the Nile Basin Initiative, permitting the collective management of Nile issues. The cooperation has not developed smoothly, because upstream countries signed a new agreement in 2010 to use more water from the river, despite opposition by Egypt and Sudan, which were better off under the previous conditions. Even if conflicting at times, taking the diplomatic approach is necessary for reaching a good level of international resource management. A comprehensive and legally binding agreement on how to handle Mediterranean adaptation issues may also be agreed upon and ratified by states on both shores of the Mediterranean. This would include, among others, migration issues and the coordinated regulation of CO_2 emissions (as externalities of some adaptation options). Furthermore, given that climate change impacts on the Mediterranean are similar on both shores – north and south – political decision-makers may foster efforts leading to coordinated and common adaptation policies. These could materialise in common research projects, regular cooperation meetings at the department level or joint information campaigns.

Regarding the dimension of collaboration, a good exchange of knowledge between the EU and the southern Mediterranean could be supported by common research projects, meetings of researchers, practitioners and policy-makers in the climate impact community, and adaptation case studies on both shores of the Mediterranean. Decision-makers could thereby learn from experiences of long-lived adaptation measures and base their own decisions (not only, but also regarding timing) on a better knowledge base. An excellent example is the cooperation between the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and the Tunisian Ministry for Agriculture and Water Resources in developing the National Adaptation Strategy for Tunisia.

Policy development should also involve stakeholders within the country. The participation of civil society and local communities in the build-up of adaptation policies not only ensures fairness in decision-making, but also provides information inputs that would make the resulting plan more complementary with other levels of intervention. The principle of stakeholders' participation is already part of some national plans (i.e. the National Water Resource Plan for Egypt).

Alongside a definition of public adaptation goods, policy intervention has to include clear-cut limits and regulations based upon equity and security of supply. **Equity issues** may require several levels of intervention and involve different institutional parties. In the international framework, the support of developed countries to developing countries is important to ensure the implementation of effective adaptation policies, providing financial, technological and political assistance (as mentioned in relation to the German GIZ and Tunisia).

At the national level, each country should adopt specific policies to economically support the most vulnerable individuals and, in general, all possible policies for prevention and adaptation have to be implemented in a way to avoid transferring burdens onto future generations. Moreover, each country needs a deliberate strategy on how to approach the problem of horizontal equity – rules and regulations that determine which groups will be protected by public adaptation and which will not. These would have to include *a priori* devised compensation payments. The example of water pricing shows the potential conflict between resource management and equity concerns. The most effective way to reduce water waste and promote conservation is to set high water prices. This solution, however, hurts low-income individuals and farmers. It is recommended to consider more elaborate schemes that could include consumption-differentiated tariffs or water permits.

For an effective and efficient implementation of adaptation investments, **optimal timing** is a major concern and some suggestions can be given in that regard. The first one is to provide clear and meaningful knowledge to the public about the expected magnitude, location and timing of climate change impacts as well as the costs and benefits of adaptation, including the uncertainty connected with this information.

Section A8.2 in the appendix contains a collection of estimated adaptation costs available in the literature, together with some expected costs of climate change for the case studies in sections A1, A2 and A3. It provides insights about the magnitude of the potential costs of inaction. The Tunisian Ministry of Environment and the UNDP suggest an action plan for Tunisia's coast that would cost 1,460 million TD, which corresponds to 40% of the physical capital that would be lost without any adaptation measures (MEDD and UNDP, 2009). At the time of the calculation, the expected amortisation period would be eight years (including only the direct economic losses, without environmental costs). With a ten-year delay, the cost–benefit analysis may give very different results because significant coastal erosion will have already occurred during that time.

To avoid inaction by private investors, a sound institutional setting is very important. A clear assignment of responsibilities in the domain of adaptation measures – whether they are to be met by the government, by private households or by private firms, should be provided. Otherwise, waiting for action by the respective counterpart may cause delays. In addition, ensuring political stability combined with an enduring trust in property rights on the part of the private economy is crucial. The failure to do so generates distrust among individuals about the possibility to benefit from the investment in the future and aggregate private underinvestment would be the expected result.

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Appendix

A1. Case study: Climate adaptation in Turkey

A1.1. The situation in Turkey

A1.1.1. Economic profile

The Turkish Republic successfully transitioned into a market economy over the last three decades. While economic stability and predictability rose after the 2001 economic crisis, Turkey was also hit by the economic crises of 2008–09. Nevertheless, Turkish GDP grew 5.9% on average between 2002 and 2008. In the same period, GNP per capita in PPP increased from around $6,700 to $10,200. In the past, a high inflation rate (in parts 40%) was an immense problem, but the present (constant) inflation rate of around 5% no longer restrains economic growth. With respect to imports and exports, Turkey shows strong development as well: exports have quadrupled and imports quintupled in the seven years between 2002 and 2008. In 2010, the current account balance was negative at $-38.8 billion, which results from higher imports than exports, which had been the case since 2002 (International Monetary Fund, 2010).

The number of employed persons reached 22.6 million in 2010, of which 25.2% worked in the agricultural sector, 26.2% in the industrial sector and 46.8% in the service sector. Turkey's unemployment rate was 11.9% in 2010 (Turkish Statistical Institute, 2011).

In terms of development policy, Turkey is described as an anchor country for Eastern Europe and Central Asia, and after Russia it is the most important economy in this region. Furthermore, it has the second-highest population in the region, behind Russia as well.

A1.1.2. Climate change projections

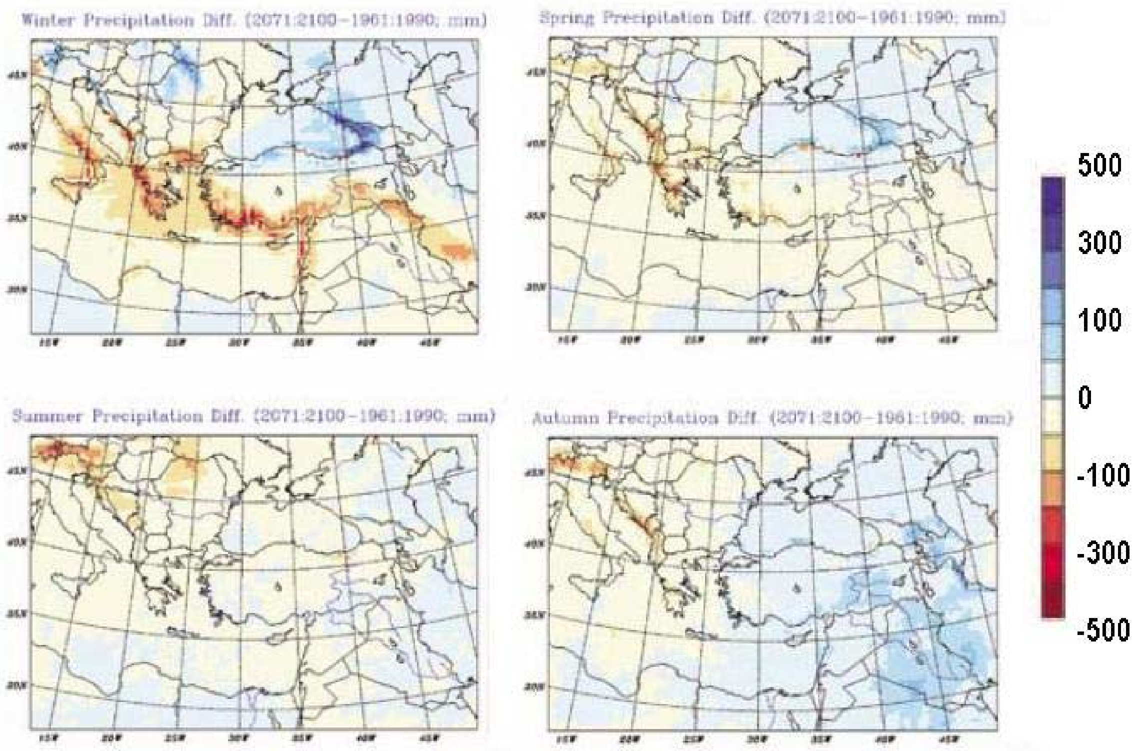
With its five basic climate regions and great variability in climatic parameters, such as temperature and precipitation, climate change is and will be distinctly diverse across the regions in Turkey.

In general, total precipitation is supposed to decrease along the Aegean and Mediterranean coasts and to increase along the Black Sea coast. In central parts of Turkey, precipitation will not change significantly. The most significant reductions will take place on the south-western coast. These changes are expected to take place in winter, when the decrease in precipitation will be up to 400 mm and in exceptional cases in spring. In summer, there will not be much change in precipitation, whereas in autumn, there will be a medium total increase in precipitation in south-eastern parts of Turkey (Figure 3). The snow water equivalent in the mountains of eastern Turkey will also be reduced as a consequence of the projected climate change. Hence, changes in the runoff regime for river basins will occur.

Temperatures will increase all over the country and in every season. In winter, the surge will be higher in eastern parts of Turkey, whereas in summer, the western and south-western coast regions will experience higher temperatures in the future (Figure 4). Especially the Aegean region will face average summer temperatures of up to 6°C higher than today. Between 2071 and 2100, the area-average, annual mean temperature is expected to increase by around 2-3°C in comparison with 1961–90 (MOEF, 2007).

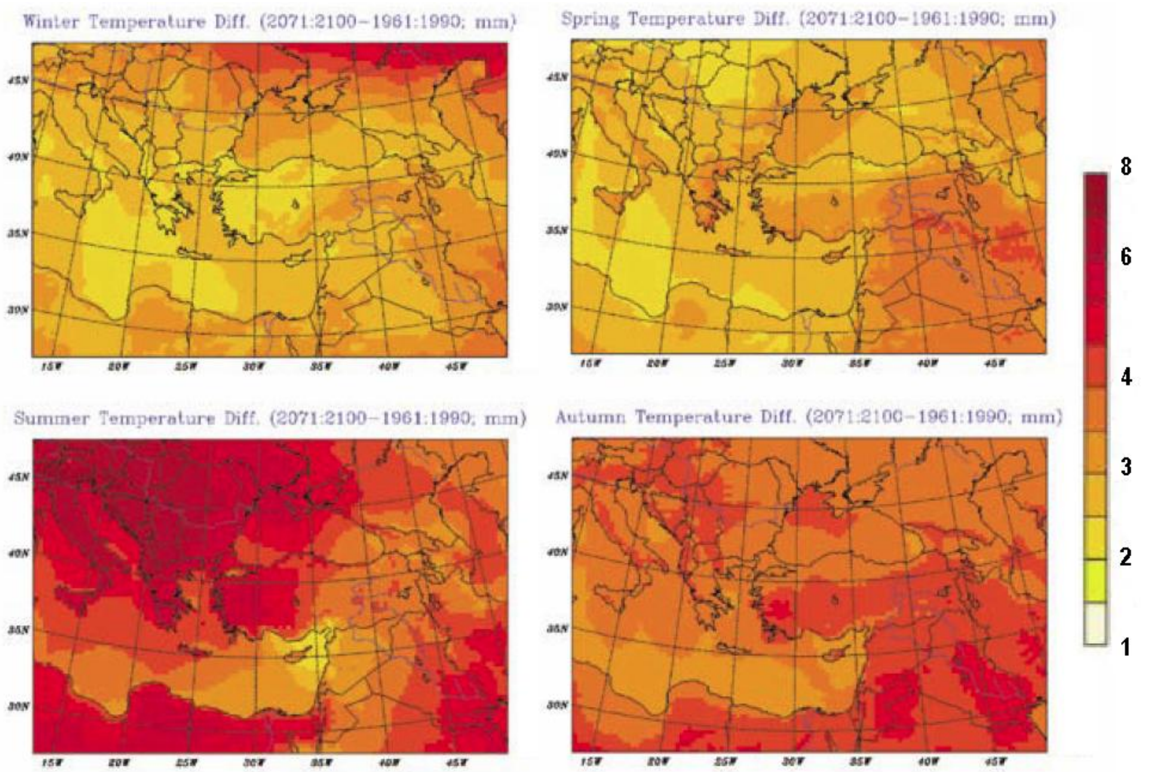
Going along with this change in climate parameters is a rising sea level, a loss in reclaimable (surface) water, more frequent and more extreme natural disasters and other negative impacts, which are described in the next subsection.

Figure 3. Precipitation change projections for Turkey: Precipitation differences between the periods 2071–2100 and 1961–90 (in mm)



Source: MOEF (2007).

Figure 4. Temperature change projections for Turkey: Temperature differences between the periods 2071–2100 and 1961–90



Source: Modified from MOEF (2007).

A1.1.3. National Climate Change Action Plan

Turkey submitted its *First National Communication on Climate Change* in 2007 under the obligations of the United Nations Framework Convention on Climate Change (UNFCCC). Additionally, Turkey ratified the Kyoto Protocol in 2009, as a part of the EU accession process, and it will contribute as an active Annex I member with special circumstances.

The Turkish government shows increasing efforts in tackling climate change at the national level. In this sense, the Turkish Ministry of Environment and Urbanization (MOEU) and the UN Development Program (UNDP) jointly prepared the strategy paper, *National Climate Change Action Plan* (MOEU, 2011). The strategy runs from 2011 to 2023 and identifies mitigation as well as important adaptation activities.

Turkey has recognised that climate change can lead to serious problems, such as water scarcity or desertification in the near future. Therefore, according to MOEU (2011), the focus of the adaptation measures is on the following five pillars:

- management of water resources – strategies with a focus on the sustainable management of water to reduce the gap between water demand and supply in the various industrial sectors in Turkey;
- the agricultural sector and food security – economic use of irrigation water and exploration of new water resources for the agricultural sector;
- ecosystem services, biodiversity and forestry – an increase in protected areas for vulnerable species and conservation support;
- natural disaster risk management – identification of risks related to climate change and implementation of an effective risk management system to tackle forecasted disasters (e.g. floods, avalanches or landslides);
- public health – different steps to reduce negative health effects on the Turkish population as a result of extreme temperatures, weather and infectious diseases; and
- crosscutting issues – the integration of adaptation at a macro level into national policies and development plans, implementation of a data information system to support decision-making and promotion of R&D.

With regard to increasing water scarcity and desertification, the Turkish government puts an emphasis on adaptation measures in the agricultural sector. These measures consist of modifications in plant species, irrigation techniques and in use of water resources, which are specified in section A1.2.

A1.2. Impacts of climate change, vulnerability and adaptation measures in critical sectors

Considering these climate projections, Turkey is seen as highly affected by and vulnerable to potential consequences of climate change (MOEF, 2009). Based on several studies by the Turkish MOEF as well as other institutions and authors, this section lists the sectors that have to deal the most with climate change effects and indicate a high degree of vulnerability. Subsequently, the socio-economic implications and possible adaptation strategies to the altered climate conditions for these sectors are presented.

A1.2.1. Coastal zones and riverine floods

A1.2.1.1. Vulnerability

The rising sea level is a problem for all of the world's countries with coastlines, especially for small island states. Based on its 7,200 km of coast, sea level rise (SLR) is naturally an issue for Turkey as well. In the last century, the rise was around 12 cm for the Mediterranean and Black Sea regions (MOEF, 2007).

The 30 million people living in Turkish coastal areas make Turkey vulnerable to this climate impact. In particular, the 2.4 million people living in the low elevation coastal zone, which covers regions lying less than 10 m above sea level, are in danger of flooding and other effects accompanying a rising sea level (World Bank, 2009).

The Turkish National Sea Level Observation System is responsible for measuring the sea level. It observed a rise of an average of 4-8 mm per year for the Mediterranean coast detected by four mareographic stations in the last 20 years (MOEF, 2007). At the Black Sea shore, the rise was actually up to 27 mm per year (World Bank, 2009). This rise is relatively high compared with other local SLR in the Mediterranean, Baltic or North Seas owing to local subsidence or land, adding to the absolute, global SLR. The World Bank (2009) nevertheless points out that the few existing studies lack consistency and leave a great deal of uncertainty.

Having a higher degree of vulnerability than the Mediterranean countries of Spain and France and less vulnerability than Egypt, which is also examined as an example in this project, Turkey is considered moderately vulnerable to sea level rise in the international comparison (Karaca and Nicholls, 2008).

The main impacts of sea level rise are erosion, flooding, inundation of coastal lowlands and saltwater intrusion. On different types of coasts, these impacts will lead to variable alterations:

- *Rocky cliff coasts*. There will not be great transformations or shifts of the coastline, but the speed of cliff recession may step up, increasing the frequency and extent of landslides and therefore potentially damaging coastal roads, buildings and other infrastructure.
- *Low and eroding soil cliffs*. Accelerated wave erosion will gradually increase the rate of cliff movement inland. As these areas are densely settled, serious damage or destruction of coastal establishments has to be considered.
- *Deltaic coasts that advance seawards, for example the Kepez Delta on the Aegean coast near Canakkale* (Akbulak et al., 2008). The increasing sea level will slow and may even undo the shoreline change, and these coasts will begin to move back. As a result of this process, there will be increased flooding across the delta plain, interrupting agricultural use.
- *Black Sea coasts*. The 23 ports along the coasts, such as Samsun and Trabzon, are vulnerable to storm surges. Potential surges could damage the very important east–west road system that runs near the shore.

Another vulnerable site is Turkey’s biggest metropolitan area, namely Istanbul. There will be a high-risk value in the event of a sea level rise by 1 m. In their study about cities with high exposure to climate change impacts, Nicholls et al. (2008) calculate that there are 70,000 people vulnerable to a 1-in-100-year coastal flooding event in Istanbul today, which ranks it 62nd among the 136 port cities examined. Today’s exposed assets are calculated to be around $2.8 billion, with Istanbul ranking 64th. The future scenario for the period 2070–80 comprises climate change impacts (SLR, increased incidence of extreme events, etc.), socio-economic developments for the 2070s and natural or human-induced uplift/subsidence. The outcomes of these forecasts involve twice as many vulnerable people (166,000) and exposed assets of around $47 billion – 17 times higher than today. The ranking positions, however, will not change significantly. As in other studies, there are limitations and simplifications leading to a great degree of uncertainty.

A key potential effect of a sea level rise is saltwater intrusion. Two large lagoons around Istanbul are vulnerable to salinisation, just as is the freshwater supply of Turkey’s biggest metropolitan area. Moreover, coastal flooding or storm surges will cause negative effects for the socio-economic well-being of the inhabitants and structures (MOEF, 2007).

Alongside the risk of a rising sea level for coastal zones, there is also the risk of flooding in river basins. On average, one river flood hits Turkey each year. According to EM-DAT (2012), Turkey experienced serious floods in 1998, 2006 and 2009. In 1998, the worst flood in many years affected over a million people. The overall estimated loss for these events amounts to approximately $2 billion.

A1.2.1.2. Adaptation measures

The above-mentioned risks of coastal erosion, flooding and inundation along Turkish coastlines are considered problems of national significance. Tourist and coastal cities are particularly under threat. In addition, many cultural sites would be damaged or destroyed by accelerated sea level rise (ASLR). ASLR is defined as an increase in the mean sea level taking place faster than in the past decades and therefore resulting in a higher mean sea level after the same amount of time. Thus, the development and implementation of adaptation strategies is of public interest (MOEF, 2007).

In contrast, Tol et al. (2008) take a more sceptical perspective of Turkish adaptation policies, with the authors examining differences between the current adaptation thinking in Turkey and that in European countries. While nearly all other affected regions and countries endeavour to develop strategies to cope with the rising sea level, Turkey generally lacks an adequate coastal monitoring programme as well as a particular adaptation programme. Although the Turkish coast is highly sensitive to SLR, the awareness seems to be very low.

Today, none of the governmental agencies is dealing with the issues and problems that will accompany SLR or general, long-term coastal management (Karaca and Nicholls, 2008). Turkey has recognised this, however, and thus the Ministry of Environment is planning to establish a Coastal Zone Department for Environmental Impact Assessment and the Authority for the Protection of Special Areas is declaring new districts as protection areas. The major challenge for the Coastal Zone Department will be to build up flood forecasting systems, which present early warnings to local authorities and to the public (MOEF, 2009).

According to the MOEF (2010), it is of importance to update the existing flood risk maps of Turkish coastal zones and river basins.

Pollner et al. (2010) mention that adaptive measures in river basins consist of flood management and catchment water-management plans, floodplain zoning, implementation of regulations and upgrading of existing flood-protection structures, for instance. Unfortunately, there was no information available on whether or to what extent these measures are indeed being pursued.

A1.2.2. Water resources, water scarcity and desertification

A1.2.2.1. Vulnerability

The river basins of Gediz and Buyuk Menderes are used as test cases for studying the consequences of climate change on water resources in Turkey. Both basins are located in western Anatolia, near the Aegean coastline. The main problem of the Gediz Basin is water scarcity, due to the competition for water among various users. A growing conflict concerns the water use for irrigation of about 110,000 ha of arable land versus the domestic requirement and fast-growing industrial demand. Current analyses affirm the problem by indicating that the overall supply of water is almost equal to the overall demand, which means there is no reserve for further water appropriation in the region.

The Buyuk Menderes Basin is known as an important wetland, supplying 1.6% of Turkey’s water potential. The basin has also changed into an extensive water-resources system, consisting of 13 dams and a large number of irrigation schemes. Moreover, it is the main cotton-producing area in Turkey and rich in terms of industry, with textiles and tourism being the major ones. In addition, 2.5 million people live in the area, which leads to a large domestic demand and hence serious competition for water.

The MOEF (2007) found that both areas are highly vulnerable to climate impacts in the near future, supported by the results of a regional, downscaling climate model.

In this specific region, the rise of annual temperatures by 2100 is estimated at between 3.2°C (scenario B2) and 4.4°C (scenario A2). Precipitation is supposed to decrease in these western Anatolian regions, generally in winter and spring. Based on these scenarios, the water budget model calculates a 10-21% reduction of surface water by the year 2030 for the Menderes Basin and a loss of 23-32% for the Gediz Basin. This decline will fall further to more than 45% in the Menderes Basin and more than 58% in the Gediz Basin by 2100 (Table 2). That will exacerbate the already existing water conflicts among the three main water users, namely agriculture, households and industry.

For continental and eastern parts of Turkey, the snow water equivalent will decrease by up to 200 mm over the high plains of eastern Anatolia and the Black Sea mountains. Hence, major losses in the stream flow for the river basins in Turkey may result. This is a significant problem for water supply, as rivers are the main sources of water. As mentioned before, water is needed for drinking water, domestic and industrial usage in addition to irrigation and power generation (MOEF, 2007).

Table 2. Runoff changes in the two Anatolian basins in 2030, 2050 and 2100

Runoff Changes under Climatic Conditions in 2030, 2050 and 2100 in the Gediz and Buyuk Menderes River Basins

	2030		2050		2100	
	B2	A2	B2	A2	B2	A2
EIE509 Gediz Basin	-%23	-%32	-%35	-%48	-%58	-%71
EIE701 B. Menderes Basin	-%10	-%21	-%20	-%38	-%45	-%71

Source: MOEF (2007).

Ceylan (2009) studies the situation in Turkey's capital, Ankara. Today, the city has more than 3 million inhabitants, 40 times more than in 1927. The urban area has even expanded around 670 times in the same period. The water demand per person is also increasing. Therefore, the severe drought conditions that hit Ankara once in every eight-year period on average are immensely relevant for the region. When dry climate conditions occur, the water resources are mostly insufficient for the demand of 3 million people. With an expected decrease in annual precipitation and river flow due to climate change, Ceylan (2009) regards the implementation of a drought management plan as fundamental. In line with the above-mentioned challenges Ankara has to face, the management plan determines four (critical) drought levels: normal, watch, warning and emergency. These categories are based on two indicators, namely precipitation and reservoir storage. The lower the precipitation level and the lower the reservoir storage, the higher is the critical drought level.

A notable aspect of rising water demand is tourism: in 2008, 26.3 million guests visited Turkey. Perry (2000) mentions that a luxury hotel consumes around 600 litres of fresh water per guest per night. With the number of visitors tripling from around 8 million in 2000 and an increase in luxury hotels, the rising demand for fresh water in Turkey, especially in the dry and tourist Mediterranean regions, has led and will continue to lead to serious water conflicts (Perry, 2000).

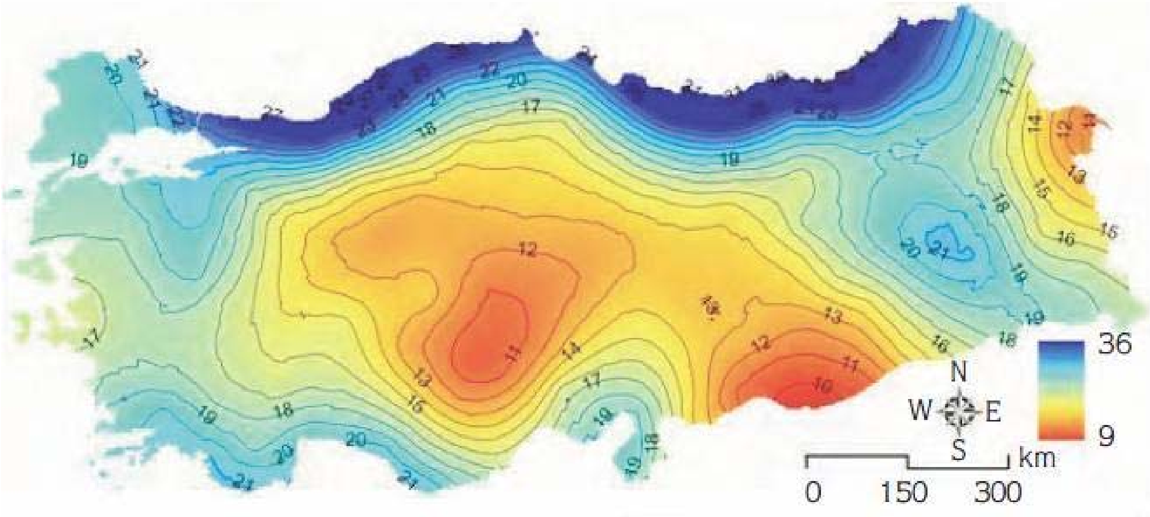
Furthermore, scientists expect some changes in the water demand of crops. The potential evapotranspiration (PET), which is the sum of plant transpiration and evaporation, will increase approximately 11% by 2030 and 26% by 2100, according to the climate change scenario B2. The A2 scenario computes an increase of 9% by 2030 and 35% by 2100. Changes in water demand will be greater than those in PET due to decreasing amounts of rainfall. Thus, while crops will demand more water than today, the climate change-induced decrease in precipitation creates a second negative impact, such that crop water demand will rise sharply. Consequently, Turkish agriculture will need to increase irrigation to meet water demand (MOEF, 2007).

Owing to its physiographic environment, incorrect land use, excessive grazing, forest fires and processes like salinisation and erosion, Turkey is highly vulnerable to climate change effects. According to the MOEF (2007), 86.5% of its total land area and 73% of its arable land is at risk of erosion, land degradation and desertification.

A convenient way to measure the vulnerability of land to the above-mentioned processes is the Aridity Index, which is defined as the ratio of precipitation to potential evapotranspiration (P/ETo). For the period 1930–93, it indicates a general tendency away from humid conditions during the 1960s towards a dry sub-humid climate at many Turkish stations today (Figure 5). The MOEF (2007) also ascertains a change from humid or semi-humid conditions in the 1960s to a sub-humid or semi-arid climate since the mid- and late 1980s in the Aegean part of the Mediterranean.

Regarding vulnerable vegetation and climatic factors, south-eastern Anatolia and the continental interiors of Turkey seem to be the semi-arid lands that are prone to desertification. In the near future, the Mediterranean and Aegean regions are likewise expected to be more vulnerable to desertification and degradation processes.

Figure 5. Aridity map of Turkey



Hyper-arid Zone	P / ETo < 0.9
Arid Zone	0.9 ≤ P / ETo < 6.0
Semi-arid Zone	6.0 ≤ P / ETo < 15.0
Sub-humid Zone	15.0 ≤ P / ETo < 22.5
Humid Zone	22.5 ≤ P / ETo

Source: Önder et al. (2008).

A1.2.2.2. Adaptation measures

Climate change will lead to big challenges in the distribution and availability of water. This subsection discusses adaptation measures to tackle these problems.

The first task is to improve water management in order to save water. The fact that only a third of the available water potential is used underpins the importance of a water-management approach. In this context, one solution could be the construction of further storage capacity in the form of dams or other water catchment basins.

Moreover, governmental programmes to advance public awareness of water conservation could help to support water-saving behaviour in private households.

Agriculture is still an important economic sector in Turkey. In 2007, agriculture accounted for 26.4% of total labour and 8.7% of Turkey's GDP (CIA, 2011). Therefore, it is of huge importance generally to extend modern irrigation techniques all over Turkey. Not only agriculture, but also every other water consumer struggles to deal with dry seasons or years. To prevent greater financial loss, Turkey has implemented an "Action plan on drought preparedness and combat [of] drought", since 2008 (MOEF, 2009). This plan includes suggestions for adapted irrigation systems, improvements in water distribution, construction of extra water storage capacity and programmes to enhance public awareness of water conservation concerns. Another adaptive measure is the implementation of river basin master and management plans for 25 important river basins within the scope of multi-purpose usage and the protection of water resources. In addition, modern rainwater capture, use and recycling approaches should be developed for all sorts of buildings, according to the MOEF (2010). Moreover, it should be a goal to encourage technological change in water transport and distribution systems (MOEF, 2007).

The drought management plan for Ankara proposes the following adaptation measures:

- normal level – a voluntary reduction in water use, with restaurants and hotels urged to save water and an increase in public education;
- watch level – like before, plus restrictions on landscape irrigation (with watering limited to three days per week);
- warning level – like before, plus watering restricted to one day per week; restrictions on outdoor use (no pool filling, no fountains, etc.); and
- emergency level – like before, plus water restricted to trees and shrubs, no parking lot or street cleaning, no drinkable water use in construction projects (Ceylan, 2009).

To take action against desertification and degradation, Turkey signed the United Nations Convention to Combat Desertification (UNCCD) in 1998. Consequently, a number of plans and programmes were prepared to mitigate and adapt to desertification and land degradation processes (MOEF, 2007).

One measure is to create thematic maps of areas that are at risk of soil degradation and desertification, aimed at monitoring the possible changes. In addition, early-warning systems could be established and highly vulnerable areas may be protected from agricultural usage (MOEF, 2006).

A1.2.3. Agriculture

A1.2.3.1. Vulnerability

The agricultural sector will require special attention, as studies show that it is one of the most vulnerable sectors (MOEF, 2009). The Turkish Agricultural Sector Model calculates a decline of 2-13% in productivity all over Turkey by 2050, which leads to a reduced amount of production and in a further step to an increase in prices for agricultural goods. At the same time, because of the sea level rise, the drainage in low lying regions will be reduced.

The raise in CO_2 concentration induced by climate change may affect the production of major crops in Turkey in a positive way, whereas increasing temperatures and water stress may reduce the production capacity of these crops. On this topic, a multi-regression analysis shows a reduction of cereal production in the Adana region and in rain-fed regions due to climate change-induced temperature rise and rainfall changes. Furthermore, water use for irrigation has been increasing and will still do so in the next decades. In addition to increasing temperatures, the reasons are diversification of cultivated crops, increased losses in delivery systems because of their age and poor maintenance, and a lack of incentives for farmers to save water (MOEF, 2007).

In Mediterranean countries including Turkey, crop yields are limited by low water availability and thereby strongly dependent on effective irrigation systems. Yano et al. (2007) examine the climate-caused changes in crop growth as well as in water demand and supply for irrigation. For this purpose they analyse the period of 2070–79 relative to the baseline period of 1994–2003. Using the SWAP model, which integrates soil–water balance and crop growth, they find that the irrigation demand by wheat will be higher due to decreasing precipitation. Moreover, a projected temperature rise of 2.2°C would lead to accelerated plant development but shorter growing periods for wheat and maize. The duration of the regular wheat-growing season, for instance, would be 24 days shorter in the future. So the changing climate conditions would affect the crop production not only in the Cukorova region considered, but also in most parts of Turkey.

A1.2.3.2. Adaptation measures

To reduce the vulnerability of the agricultural sector in Turkey, a set of adaptation measures can be implemented. In parts, these measures are related to those in water scarcity adaptation, which can be seen in the irrigation measures, for instance. The agricultural sector, being one of the main consumers, depends on water and its availability is a major key to agricultural success (i.e. yielding a large harvest).

At first, an increase in water demand could be adjusted by improving irrigation efficiency, which is even possible with the present equipment. A second measure to improve agricultural irrigation is transforming the practices from conventional, flooding-type irrigation to modern piped sprinkler or drip irrigation, which saves a lot of water (MOEF, 2009).

Developing methods for non-traditional use of water resources can be another way to adapt to the effects of climate change. Plants themselves can be adapted to the altering climate conditions. On the one hand, it is possible to develop new plant species that are more resistant to drought and salinity. On the other hand, rearing plant species that may yield quality products with low-quality water economises a lot of water preparation capacity, which saves money for farmers or drinking water for other consumers (MOEF, 2007).

Furthermore, a drought centre established by Konya Soil and Water Resources Research Institute should improve the prediction of droughts and assist farmers in managing drought situations (UN, 2008). Another important strategy is the training of farmers, with a special focus on enhancing their farming activities in the light of climate change. For instance, such soil management practices as crop rotation, terraced farming, diversifying the crops and soil mulching can be taught. Another possibility is training farmers on measures to prevent the increase in salinity levels, on working with new irrigation techniques and in breeding new types of plants (MOEF, 2010). For instance, the cultivation of spring wheat instead of winter wheat is a potential way to adjust to drier conditions (Pollner et al., 2010). Finally yet importantly, the provision of harvest insurance policies can absorb losses from dry years (MOEF, 2009).

To enhance the framework for forest policies in Turkey and in the MENA (Middle East and North Africa) region, the GIZ started a project in 2010 to advance sustainable development in forestry and to adapt to climate change impacts. No outcomes of this project are available so far, which is scheduled to last until 2014.

A1.2.4. Health

A1.2.4.1. Vulnerability

Climate affects many vector-borne diseases like malaria and infectious diseases like Leptospira. Therefore, a change in climate modifies the spread of these ailments. The driving forces of disease spread are the climate components of temperature and rainfall.

During the last 30 years, there have been two periods with significantly higher numbers of malaria cases in Turkey, namely between 1977 and 1987, as well as between 1993 and 1998 (MOEF, 2007). During the 1977–87 period, the mean temperature was significantly higher than in the period 1930–2004. This is an initial indicator of a possible parallelism between high temperatures and malaria infections.

On the other hand, there was no meaningful increase in temperature in the south-eastern provinces, even though the cases of malaria remained high. In 1993–98, the mean temperature of south-eastern Turkey was significantly higher than normal and so were the malaria cases within the region (MOEF, 2007).

Still, climate parameters are by far not the only factors that contribute to the spread of malaria. The disease is related to many other factors, such as medical care and migration. The preventive controlling measures have the most significant effects on the incidence of malaria and therefore the cases have decreased since 1998, when response measures were launched (subsection A1.2.4.2) (MOEF, 2007).

Leptospirosis is an infectious disease and affected by climate change impacts, too. The climate conditions are known as an important driving force for the transmission of the ailment. Temperature and rainfall may even have synergistic effects on this process (MOEF, 2007).

Increasing temperatures in Mediterranean countries will be injurious to health in general. The trend indicates that a greater frequency of heat waves is coming along with higher temperatures in Mediterranean regions like Turkey. Hence, health problems ranging from diminishing physical efficiency to an increase in mortality may occur. In this regard, Baccini et al. (2008) predict a 3% increase in mortality for Mediterranean cities, if the maximum apparent temperature in summer increases by 1° Kelvin. According to EM-DAT (2011), the economic loss owing to heat waves up to 2012 in Turkey has been around $1 million and the number of affected persons is 300.

A1.2.4.2. Adaptation measures

There are two main adaptation measures for health issues induced by climate change. The first one is to improve medical care and provide information about possible diseases and their health hazards. To fight malaria in Turkey for example, numerous malaria control programmes like the Roll Back Malaria campaign have been implemented since 1998. This campaign, and namely the "Enhancement of the National Capacity of Malaria Units in Turkey", was initiated in cooperation with the UNDP and the World Health Organization (WHO). In this context, the technical capacity of malaria units in the southern regions of Turkey was upgraded and 110 staff members in these units were trained to identify and treat malaria. The education included diagnosis, treatment, larvae control, pesticides and other practices (MOEF, 2007).

The second way to adapt is to make modifications to residential buildings. First, the traditional building technique and design should be retained because it protects well against heat. Rapid urbanisation often leads to poorly heat-adjusted buildings, which make people more vulnerable to heat waves and other weather extremes. In Turkish regions that already have hot summers, air conditioning could be installed in homes and workplaces.

Another approach is to protect or restore urban wind systems, which ensure an air exchange between cities and their cooler hinterland (Perry, 2005).

A1.2.5. Tourism

A1.2.5.1. Vulnerability

The final sector considered in this case study is tourism, which is very important for the economy of Turkey, supplying work for around 3 million people and contributing 7% to Turkey's GDP in 2007 (Zortuk, 2009).

Turkey's tourism industry is highly vulnerable to changes in climate conditions. Southern Mediterranean regions like Turkey will be too hot in the summer peak season. The above-mentioned future increase in the frequency and severity of heat waves indicates a loss in comfort that Turkey's tourist destinations will face. Moreover, the availability of fresh water, which is needed in vast amounts by the hotels, will be reduced due to climate change.

Coastal erosion and flooding (subsection A1.2.1) will probably impact beaches or hotels (or both), which are the fundaments of Turkish tourism.

Furthermore, some sources indicate that hot temperatures will cause an increasing likelihood of diseases like malaria or Dengue Fever in summer, making Turkey a less favoured holiday destination (Perry, 2000).

A1.2.5.2. Adaptation measures

To adapt to climate change impacts in tourism, the climate itself works in favour of a possible solution: higher air and sea temperatures will encourage a longer tourist season. If the summers are too hot, the season can be split into spring and autumn, with a short offseason in summer. Activities like art festivals, sport events or regattas can help to attract visitors in the early and late season, according to Perry (2000).

In line with the population structure, a large number of older, retired people wish to escape the cold and dark winters in northern Europe. The warm winters in Turkey should attract them to pass the time in hotels or buy a second home there. In addition, precipitation is set to decrease in favourable regions on the coastlines of the Aegean and Mediterranean Sea (section A1.1.2). Therefore, the conditions will be comfortable for northern Europeans spending their winters in south-west Turkey.

As another consequence of rising temperatures, tourists will expect air-conditioned accommodation. Installing air-conditioning systems can be a way to attract guests in summer and therefore adapt to hotter conditions (Perry, 2000).

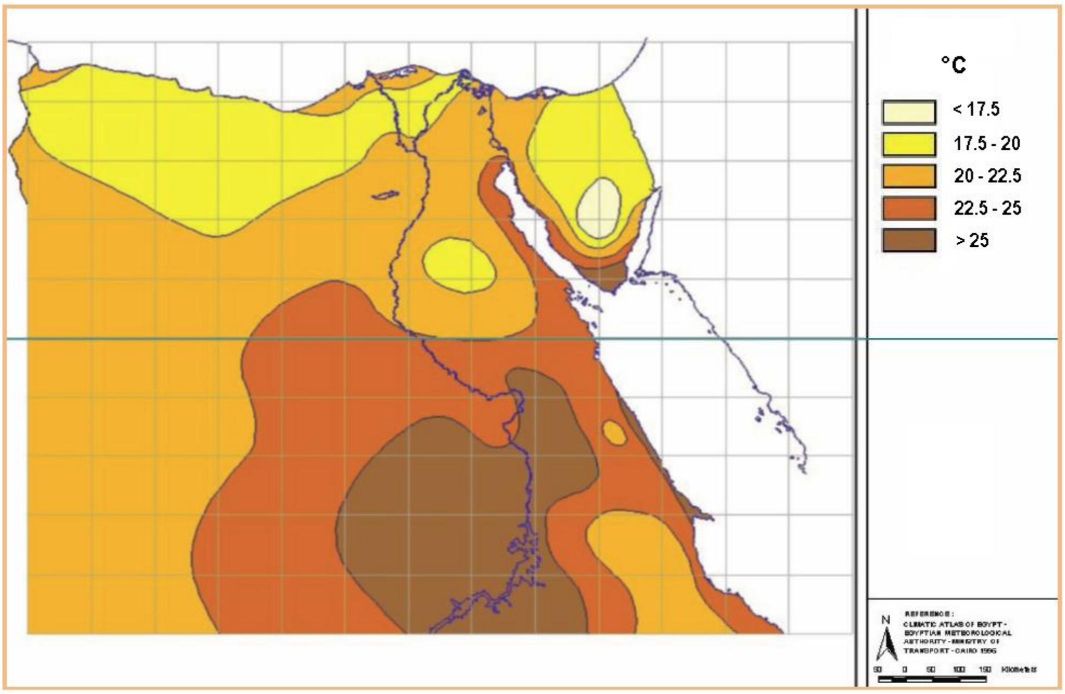
A2. Case study: Climate adaptation in Egypt

A2.1. The situation in Egypt

A2.1.1. Current climate

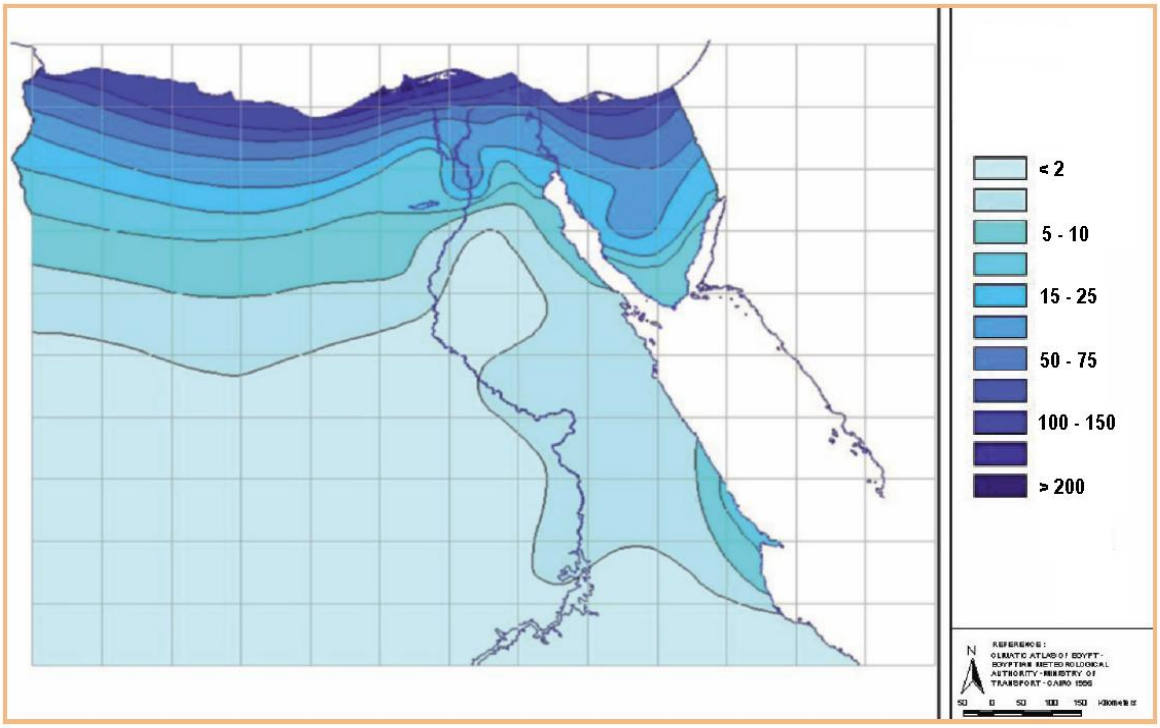
Egypt lies in an arid region and hence lacks the availability of fresh water resources. The general climate can be described as hot and dry, and the largest part of the country consists of desert (Figure 6). According to the Egyptian Environmental Affairs Agency (EEAA) (2010), the winter season is characterised by a mild climate and some precipitation mainly in coastal areas in the lower part of Egypt, while the upper part receives basically no rain, with sunny days and cool nights (Figure 7). During the summer season, the whole of Egypt has a hot and very dry climate with almost no precipitation (EEAA, 2010).

Figure 6. Average annual mean of daily temperatures in Egypt (in °C)



Source: Modified from EEAA (2010).

Figure 7. Mean annual precipitation (in mm)



Source: Modified from EEAA (2010).

A2.1.2. Climate change projections

General circulation models (GCMs) estimate an increase in country averaged mean temperatures of 1°C by 2030, 1.4°C by 2050 and 2.4°C by 2100. In doing so, temperatures rise higher in summer and less high in winter. In the catchment area of the Nile, where most people live, the increases in temperatures by 2030 and 2050 are the same as for the whole country. In 2100, the increase is expected to be 2.5°C (Agrawala et al., 2004). According to the mean calculations of eight GCMs with low error scores in prediction, Egypt’s precipitation is calculated to decrease due to climate change. The annual decrease in the country is estimated to be 5.2% in 2030, 7.6% in 2050 and 13.2% in 2100 (these are average values of the ensemble of eight climate models). The steepest decline in precipitation will be in winter. In summer, the GCMs estimate average rises of 10% (2030) and 27% (2100) in precipitation, but in annual totals, which cannot nearly compensate for the losses in winter. In the catchment area of the Nile, however, the precipitation level will slightly increase in the future. In 2030, the ensemble of circulation models calculates a 1.5% rise in the total amount of precipitation, 2.1% in 2050 and 3.7% for the average annual rise in 2100 (Agrawala et al., 2004).

A2.1.3. National adaptation strategy

Egypt was among the first Arab countries to join global efforts tackling climate change. Since the Rio de Janeiro Earth Summit in 1992, Egypt has ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1994 and signed the Kyoto Protocol in 1999.

Its *First National Communication* to the UNFCCC was published in 1999 (e.g. Agrawala et al., 2004; EEAA, 2010) and the *Second National Communication* was published in 2010, demonstrating the ongoing efforts of the Egyptian government to adapt to changing climate conditions.

According to the EEAA (2010), Egypt needs to implement the following major adaptation projects in the next four years:

- The first project is aimed at the integrated management of land resources for agricultural production. The authorities concerned are the Ministry of Agriculture and Land Reclamation, the Ministry of Water Resources and Irrigation as well as the private sector. The costs of this four-year project are calculated to be around $15 million.
- Second, a project for integrated water-resources management is to be adopted. The authorities concerned are the same as above without the private sector. For realising this project, $10 million is budgeted during the four years of execution.
- Finally, the General Authority for Coastal Protection shall implement a further project for integrated coastal-zone management.

A2.2. Impacts of climate change, vulnerability and adaptation measures in critical sectors

Egypt is expected to be among the most vulnerable countries to the risks of climate change and most affected by its possible impacts. Vulnerability is generally perceived to be high for most of the sectors concerned, while the resilience of the majority of stakeholders is low (EEAA, 2010). Based on recent analyses by the EEAA and other literature sources, the following discussion highlights the expected impacts of climate change and the specific vulnerabilities as well as potential adaptation measures for the main sectors of development in Egypt: water resources, agriculture and food security, coastal zones, tourism and health care.

A2.2.1. Water resources

A2.2.1.1. Vulnerability

The main focus of this subsection is the sensitivity of different basins of the River Nile to changes in precipitation patterns and average temperature. The natural flow of the Nile constitutes around 95% of Egypt's water resources, with 1.5% attributed to aquifers and 3.5% to rainfall, demonstrating the immense importance of the Nile for the whole country (EEAA, 2010). According to Agrawala (2005), the agricultural sector is not rain-fed but solely based on irrigation. He states that Egypt has always relied on making Nile water available for the supply of its farmland, leading also to distribution to the majority of the population, land use and economic activity along the flow of the river and its coastal delta in the north.

Hence, the potential impacts of climate change on this natural water supply system are of paramount importance for the future development of Egypt at all levels. The section of the Nile that flows through Egypt and Sudan is referred to as the Eastern Nile. The southern part of the Nile and its receiving streams is referred to as the Equatorial Nile and flows through Burundi, Ruanda, Tanzania, Uganda and southern parts of Sudan.

Future scenarios

Several studies have tried to estimate future flows of the Nile in relation to changing levels of precipitation and temperature due to climate change; however, the research is characterised by a high level of uncertainty concerning the extent of the expected climatic changes (e.g. UNFCCC and Ministry for Environmental Affairs, 2010). In their study, Strezpek et al. (1996) analysed different estimation models and concluded that besides a potentially very high degree of sensitivity of the Equatorial Nile to reduced precipitation or increased temperature, the Eastern Nile will remain the main source of Nile flows even under changing climatic conditions. These results suggest that besides the overall very high sensitivity of Nile flows to temperature and precipitation changes, the situation of the different Nile basins varies significantly, as Table 3 demonstrates. This indicates the need to develop regional assessment models in order to predict the future effects of climatic changes on the flow levels with as much accuracy as possible (EEAA, 2010).

Sayed (2004) studied the changes in water flow of the Nile in relation to changes in precipitation patterns and found large differences with respect to the geographical location studied. The study found that while the Eastern Nile was very sensitive to changes in rainfall (both increases and decreases), the flow of the Equatorial Nile only showed low sensitivity to changes in rainfall. Table 3 shows an overview of different Nile basins and the respective changes in water flow corresponding to changes in rainfall.

Table 3. Change of flow corresponding to the uniform change in rainfall for Nile sub-basins

Sub-basin	**Change in precipitation (%)**					
	-50	-25	-10	+10	+25	+50
	Corresponding change in water flow (%)					
Atbarra (Atbara)	-93	-60	-24	+34	+84	+187
Blue Nile (Diem)	-92	-62	-24	+32	+78	+165
Blue Nile (Khartoum)	-98	-77	-31	+36	+89	+149
Lake Victoria (Jinja)	-20	-11	-4	+6	+14	+33
White Nile (Malakal)	-41	-28	-11	+19	+48	+63
Main Nile (Dongla)	-85	-63	-25	+30	+74	+130

Source: EEAA (2010).

Besides the mostly large impact of changes in rainfall levels, the effect of temperature changes and hence varying evaporation levels on Nile water flows has also been investigated. The study by Strezpek et al. (1996) looked at the impact of changes in precipitation as well as changes in temperature on Nile flows and again found high sensitivity of the water flow to changes in both factors. The results are presented in Table 4, with flow changes calculated as an average of the different Nile basins. For example, a 20% reduction in precipitation together with a 2ºC warming of temperature will lead to a decrease of water flow of around 88% (Strezpek et al., 1996), indicating the high sensitivity of Egypt's vital "lifeline" (Agrawala et al., 2004) to changes in climatic conditions.

Table 4. Nile flows under sensitivity analysis

Precipitation	**-20%**	**-20%**	**-20%**	**0.0%**	**0.0%**	**+20%**	**+20%**	**+20%**
Temperature	0	2	4	2	4	0	2	4
Flow (BCM)	32	10	2	39	8	147	87	27
% of base	37	12	2	46	10	171	101	32

Source: Strezpek et al. (1996) in EEAA (2010).

There are a number of additional studies on the sensitivity of Nile water flows to temperature and rainfall changes, all indicating the potentially very high impact of climatic changes on base-level water flows of the Nile (UNEP, 2005; EEAA, 2010). As one result of this vulnerability, the Aswan High Dam was built in 1972 to cope with annual floods and variations in water flow. The construction of the dam enabled the formation of Lake Nasser, which now stores a one-year supply of water and hence constitutes a significant adaptation to climate variability, by decreasing the dependence of the country's welfare on climatic variations (Agrawala et al., 2004).

Other impacts

Besides the direct effects of reduced precipitation and increased evaporation due to higher temperatures, other factors might also pose potential threats to the balance of the Nile basin. Agrawala et al. (2004) stress the fact that while higher temperatures have a direct effect on evaporation levels, they also lead to reduced yields of important crops, such as maize or wheat, in combination with the need to use larger amounts of water for irrigation.

In addition, private households and other sectors will show a higher demand for water when the temperature rises, an effect that is further increased by growing population levels and the economic development of the country. This population growth and the concurrent urbanisation put further stresses on the distribution of fresh water as well as the disposal of wastewater, which can also negatively affect the quality of river water (EEAA, 2010).

The projected population growth will lead to an average per-capita budget of fresh water of 350 m³ per year in 2040, compared with around 700 m³ per year at present for each inhabitant of Egypt (UNFCCC and Ministry for Environmental Affairs, 2010). Yet this 50% reduction in water availability for the Egyptian population in the coming decades only holds true without consideration of any climatic changes affecting the aforementioned sensitive balance of Nile flows, which are expected to decrease the total fresh water availability.

Further on, Egypt's situation could be aggravated by eventual changes to the water allocation agreement between Egypt and Britain from 1929, then representing Kenya, Tanzania, Sudan and Uganda, and its revised form between Egypt and Sudan from 1959. This latter agreement is still in force today, according to which Egypt can utilise up to 75% of the Nile water, with Sudan accounting for the remaining 25%. The other riparian countries have challenged this agreement, however, potentially leading to a redistribution of the allocated water and hence to a reduced share of Nile water for Egypt (Agrawala, 2005). Since 1999, the riparian states have developed a new, holistic Nile Basin regime called the Nile Basin Initiative, permitting the collective management of Nile issues. Another cooperation attempt is the foundation of the Nile River Basin Commission, seeking to ratify a legal agreement called the Cooperative Framework Agreement (CFA) to replace the 1929 and 1959 agreements. In May 2010, Ethiopia, Kenya, Rwanda, Tanzania and Uganda signed the CFA. According to Martens (2011), Egypt and also Sudan expectedly will not come to terms with this agreement since it threatens the status quo of water allocation.

Conclusion

According to Egypt's *Second National Communication* (EEAA, 2010), the situation concerning the balance of the various areas of the River Nile and thereby the security of Egypt's only source of water supply can be described as follows:

- Diverse studies have shown that the flow of the River Nile is highly sensitive to changes in precipitation and temperature, at a regional level as well as collectively for the different Nile basins.
- The expected changes in temperature and precipitation levels due to climate change are characterised by a high degree of uncertainty, i.e. the future corresponding changes in the Nile flow are very difficult to project.
- Possible higher flows of Nile water may pose a threat of flooding and require a larger storage capacity and distribution network; lower flow levels, on the other hand, may lead to droughts and a reduced ability of the economy to keep up the overall development (particularly the demographic changes) in the country.
- The expected sea level rise may pose a danger to groundwater aquifers in the Nile Delta, which are considered an important part of the future water supply due to increased salinity levels. This aspect, however, is further elaborated in section A2.2.3.

The study by Agrawala (2005) stresses three factors that can increase the vulnerability of Egypt in the future: first, a potential reallocation of the amount of Nile water attributed to the country can lead to greater vulnerability. Second, the dependence of Egypt on the River Nile as the only source of water in combination with a growing overall demand for water can cause serious issues. Finally yet importantly, climate change affects water flow levels, particularly with respect to reduced flow owing to increased evaporation (i.e. higher temperatures), and reduced precipitation levels are a major threat to Egypt's water resources.

A2.2.1.2. Adaptation

While the expected impacts of climate change pose a serious threat to the further development of Egypt as well as to the immediate security of its water supply, there are a great number of additional challenges that have to be tackled by the Egyptian government. In the *Second National Communication*, the EEAA states that because of everyday challenges, such as the rocketing population growth or the need to finance low-income citizens, "climate change which appears like a long term issue is not always a top priority for the successive governments in Egypt" (EEAA, 2010; p. 75).

Nevertheless, a substantial amount of work has gone into developing future adaptation strategies. The most important strategies are highlighted in the following subsections.

Uncertainty has been identified as a major factor making projections of the effects of climate change and hence the development of suitable adaptation measures very difficult. Still, certain variations in Nile flows have already been observed over the last decades, leading for instance to the building of the Aswan dam. While such dams can store water for dryer periods, they can also serve as storage tanks for times of increased precipitation and the resulting higher water levels. Accordingly, the development of existing and new storage facilities can form an integral part of adapting to an increasingly variable water level of the River Nile. At the same time, a new major dam would lead to the known issues of very high costs, environmental damages and the relocation of people and villages, and therefore to various conflicts of interests, which makes this suggestion rather unlikely to gain support (e.g. Abu-Zeid and El-Shibini, 1997).

Even if the exact changes in water flow levels of the River Nile are uncertain, the Egyptian government expects an increasing shortage of available fresh water in the coming decades and has developed a National Water Resources Plan (Ministry of Water Resources and Irrigation, 2005). In this plan, the following measures are proposed:

- physical improvement of the irrigation system,
- more efficient and reliable water delivery,
- augmented farm productivity and an increase in farmers' income,
- empowerment and participation of stakeholders,
- quick resolution of conflicts between users,
- use of new technologies for weed control (not further specified),
- redesign of canal cross-sections to reduce evaporation losses (not further specified),
- cost recovery systems (not further specified),
- improvement of drainage, and
- change of cropping patterns and farm irrigation systems (EEAA, 2010, p. 75).

Besides improving the existing water resources and usage, the plan also suggests developing new resources in the future. The major tasks here are the potential exploitation of deep groundwater reservoirs. Moreover, the improved harvesting of rainwater can improve the water budget, while desalination is also seen as having great potential in Egypt (EEAA, 2010). Finally, improved recycling of wastewater for the industrial as well as the domestic sector and an increased reuse of land drainage water would potentially alleviate the expected stresses due to the reduced availability of fresh Nile water (UNFCCC and Ministry for Environmental Affairs, 2010).

At another level, various ‘soft’ forms of intervention are being developed with public awareness campaigns on water consumption being one of the most important ones. Also, more precise regional circulation models for predicting the expected changes with more accuracy are an integral part of this approach and are currently being developed by the Egyptian Ministry of Water Resources and Irrigation in collaboration with the UK Met Office (EEAA, 2010).

Improving data exchange among Nile Basin countries and enhancing precipitation monitoring networks in upstream countries of the Nile Basin also form important aspects of the future water security plan of Egypt (UNFCCC and Ministry for Environmental Affairs, 2010; Agrawala et al., 2004).

A2.2.2. Agriculture and food security

A2.2.2.1. Vulnerability

The agricultural sector in Egypt engages around 55% of the labour force, contributes around 14% to the country’s (2006) GDP and consumes around 80% of the available fresh water resources (EEAA, 2010). These numbers demonstrate the immense economic importance of agricultural activities in Egypt as well as the strong dependence on the availability of the fresh water supply. Consequently, adaptation of the agricultural sector forms a central part of Egypt’s adaptation measures.

The impact of climate change on agricultural productivity in Egypt has been studied by various researchers. In its latest communication to the UNFCCC, the Egyptian government has analysed a number of these studies and summarises the findings as follows: rising temperatures are expected to have a great effect on the productivity of the most important crops, leading to lower yields and poorer quality grains, while at the same time the related diminished availability of water further reduces the expected grain yields (UNFCCC and Ministry for Environmental Affairs, 2010). For example, a report by Abou-Hadid (2006) suggests a decrease in the production of wheat in a scenario of a 2ºC temperature rise by up to 15% and up to 36% for a rise in temperature of 4ºC. Other studies project a sharp decrease in soybean productivity by up to 28% for a rise in temperature of 2ºC (e.g. Eid and El-Marsafawy, 2002 in EEAA, 2010).

In addition to the direct effects of a temperature rise on crop production levels, there are some other indirect effects.

Pests and diseases, for instance, show growing severity and have negative impacts on crop productivity (Abolmaaty, 2006 in EEAA, 2010). Therefore, more pesticides are needed. But such an increase in pesticide use can have detrimental effects on crop productivity, so finding the right amount of pesticides will be a future challenge.

Egypt has one of the most unique and complicated irrigation systems in the world, covering 95% of the country’s water demand. Future climate changes will lead to a greater demand for water and will put strong pressure on this system by lowering its efficiency (EEAA, 2010). With this irrigation system, however, Egypt is less vulnerable to climate change impacts than countries that have to install these systems first.

Also the food industry will be vulnerable to climate change. Because of reduced production of fodder crops for animals, food security may be endangered. According to the UNFCCC and Ministry for Environmental Affairs (2010), rising temperatures and newly occurring animal diseases, which come along with changes in climate, will lead to negative impacts on animal productivity. To analyse the further effects of climate change on livestock productivity, more scientific research studies are needed.

More than 80% of Egypt's fishery production is generated by aquaculture projects in the northern Nile Delta. These projects are fed almost solely by drainage water and just a couple of projects are fed by groundwater. This situation makes the fisheries vulnerable to climate change. Likewise, the possibly warmer sea temperature might induce fish to shift northwards and to deeper water, which makes them more difficult to catch. Moreover, the increasing salinity in coastal lakes will reduce the existing stock of cheap freshwater fish. This will have a negative effect on Mediterranean fishermen, who rely almost absolutely on this sort of fish. According to the EEAA (2010), more studies are needed to discuss the vulnerability of and adaptation techniques for fisheries. Nevertheless, some measures to adapt to climate change in the agricultural and food sectors are presented in the next subsection.

A2.2.2.2. Adaptation

Changing the sowing dates and management are among most important adaptation measures. According to Abou-Hadid (2006, in EEAA, 2010), a ten-day delay in sowing reduces the negative effects on crop productivity by 10%. Yet, a change in sowing dates faces difficulties, such as problems with the marketing of products, for instance cash crops. In any case, changed sowing dates by farmers needs to be studied (El-Marsafawy, 2006).

For Medany et al. (2009), changing cultivars and crop patterns will be the most promising adaptation options at the national level. Furthermore, they mention that adaptation to disease-tolerant crops and close monitoring are important measures to cope with an increasing occurrence of diseases and pests.

Another approach is the implementation of irrigation systems. The existing "Plan for improving on-farm water management", which targets 5 million acres of farmland within ten years, aims at increasing the efficiency of irrigation systems by 50-75% (EEAA, 2010).

The EEAA (2010) mentions the need for a national programme that examines diseases and develops response measures. As an important objective, the results of this programme shall be communicated to farmers all over Egypt.

With regard to livestock adaptation, improving the current low level of productivity of cattle and buffalo breeds and improving the feeding programmes for increased temperatures are mentioned measures. Unfortunately, the way to implement these measures seems to be vague and the available literature provides no further information on how these goals can be reached in the Egyptian context.

For fisheries, no specific options are defined yet. Like the issue of vulnerability, more research studies are needed to develop beneficial adaptive strategies for this sector. Overall, straightforward and low-cost adaptation measures that meet local conditions and are compatible with sustainable development specifications are necessary but not yet in sight (EEAA, 2010).

A2.2.3. Coastal zones

A2.2.3.1. Vulnerability

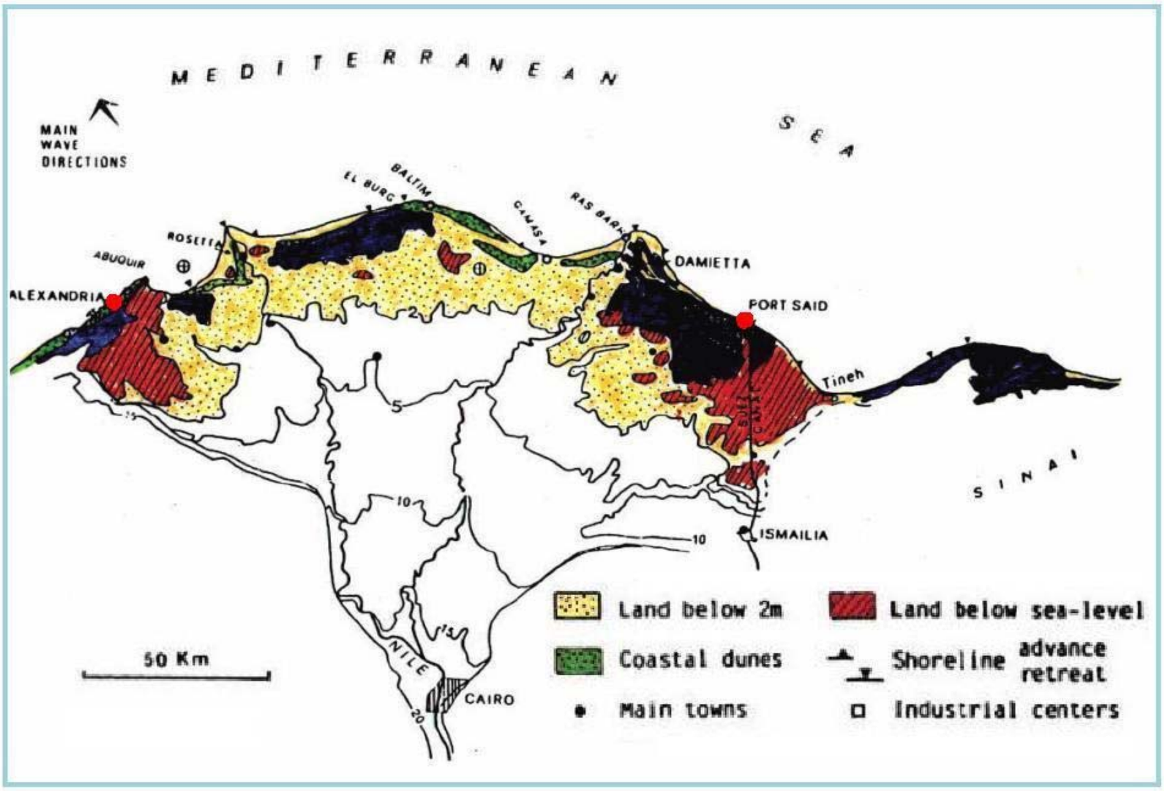
Rising sea level and corresponding threats, such as inundation, salinisation and storm surges, are major concerns for all coastal countries. With a coastline of around 3,500 km along the Mediterranean and Red Sea Coast, sea level rise is naturally an issue for Egypt (EEAA, 2010).

Egyptian coastal areas have a major share of tourism and industrial activities, and host a large part of the population and a great proportion of existing fisheries. With trading and transportation centres, the coastal zones also provide much employment.

In terms of SLR, the low-lying northern Nile Delta, which is the main agricultural, industrial and commercial area with one-third of Egypt's population, is highly vulnerable (Figure 8).

The Coastal Research Institute measured a rise in sea level for Alexandria, lying at the western end of the Nile Delta, of 1.6 mm/year between 1950 and 2000. For Port Said, lying at the eastern end of the Nile Delta, the Institute measured an increase in sea level of 2.3 mm/year (EEAA, 2010). The two measuring sites are marked with red dots in Figure 8.

Figure 8. Topography of the Nile Delta



Source: EEAA (2010).

The IPCC expects a global SLR of 18-59 cm by 2100, which makes several parts of the Nile Delta vulnerable to inundation (Table 5).

Table 5. Area of the Nile Delta affected by SLR, under an SLR of 18-59 cm by 2100

Year	2025	2050	2075	2100
Total Area Affected (km^2)	152.86	256.27	450.00	761.40
Total share from the Nile Delta Area (%)	0.61	1.03	1.8	3.01

Source: EEAA (2010).

By 2100, around 3% of the whole Nile Delta area will be affected by the rising sea level. This value is relatively low because of the Mohamed Ali Sea Wall, which protects parts of the low-lying coastal zone. Without this wall, the affected area would be up to 14.4% according to the EEAA (2010).

Dasgupta et al. (2009) assess the consequences of a continued sea level rise for 84 coastal developing countries. Their results reveal that Egypt is one of the world's most vulnerable countries affected in terms of population. Around 10% of the Egyptian population would be displaced with a 1 m SLR. Moreover, the GDP in Egypt would be affected by more than 5%, due to an immense loss in agricultural areas amounting to 13%. Considering those strong potential economic and ecological damages, the authors emphasise the need to develop national adaptation strategies now to avoid future losses.

In their study (ranking 136 port cities with high exposure to climate change impacts), Nicholls et al. (2008) list Alexandria in the top 20 for population exposure today (9th) and in the 2070s (11th). In the case of a 1-in-100-year coastal flooding event, 1.3 million inhabitants of Alexandria are vulnerable to flooding events or storm surges today. In 2070–80, the implications of climate change impacts like SLR or an increased probability of extreme events, combined with socio-economic developments and natural or human-induced uplift/subsidence, 4.4 million people could be exposed. The exposed assets are expected to escalate from today's $28.5 billion to $563 billion in the 2070s. According to Nicholls et al. (2008), Alexandria's rank in this category will therefore rise from today's 26th place to 20th in terms of exposed assets in the 2070s. As in other studies, there are limitations and simplifications leading to a high degree of uncertainty.

Another impact on low-lying areas around the Mediterranean Sea is saltwater intrusion and its possible impairment of groundwater resources. Also, water-logging problems can impair soil salinisation, which will compromise both the quality and productivity of crops. Together with a lower water quality, this will lead to health problems and probably scare tourists, who represent one of the most important sources of income in coastal regions.

In addition, unique ecosystems like the mangrove stands on the shores of the Red Sea, which offer a habitat for uncommon species and stabilise the shoreline, are at risk due to climate change impacts.

The increasing number and intensity of extreme events will also affect coastal zones in Egypt (Agrawala et al., 2004). For instance, sandstorms and heat waves, which stem from the Sahara, will damage agricultural productivity and harm public health. Likewise, heavier marine storms can possibly damage ships or harbour facilities (EEAA, 2010).

Prospective measures to adapt to these climate changes effects are presented in the next subsection.

A2.2.3.1. Adaptation

El-Raey et al. (1999) analyse the costs of adaptation measures and present the best options available for protecting most of the coastal areas in the Nile Delta. Evaluating two case studies, the cities of Alexandria and Port Said, they identified a combination of beach nourishment and hard structures as the best adaptation option, despite the associated high costs. But a lack of financial support and awareness led to the failure of concrete implementation plans.

To adapt successfully to climate change impacts, to protect the coastal regions and to improve the management of coastal resources, the Egyptian National Assembly approved new regulations to include Integrated Coastal Zone Management (ICZM) into regional development plans.

On a local scale, the EEAA (2010) mentions the following adaptation measures:

- creating wetlands in vulnerable, low-lying deltas, which can reduce the consequences of SLR;
- protecting and fixing natural sand dune systems, which form an adequate natural protection barrier;
- strengthening the Mohamed Ali Wall to protect the low lands of Abu-Qir Bay; and
- installing breakwaters (hard structures to absorb wave energy reaching the shoreline), which may be successful in terms of protecting infrastructure and agricultural land. Yet, there are possible negative side effects as well, such as those on fishing processes or changing ocean currents (Agrawala et al., 2004).

The objectives of the above-mentioned ICZM are of a more general nature: awareness raising to encourage cooperation, capacity building and the implementation of action plans. Integrating vertical and horizontal institutions in decision-making to improve the situation of natural resources is another task of the ICZM. Moreover, the ICZM should minimise the weakening of natural systems and stimulate sustainable development all over Egypt.

Nevertheless, the ICZM is a rather theoretical construct. It tends to list general institutional initiatives instead of including practical methods and measures to adapt to climate change effects (Agrawala et al., 2004). Hence, most of the measures mentioned are not even in the phase of initial planning yet.

A2.2.4. Tourism

A2.2.4.1. Vulnerability

Climate change impacts may alter the attraction of holiday destinations across Europe and neighbouring regions; hence, there is some potential need to adapt. The tourism sector in Egypt is focused on seaside and beach holidays as well as Nile cruises. Tourism is an important factor for Egypt's economy and labour force: more than 12.8 million visitors came to Egypt in 2008, providing revenues of about $11 billion. This is approximated to 6.7% of Egypt's GDP in 2008. Employees in the tourism sector account for 12% of Egypt's labour force, making the sector an important one (Dziadosz, 2009).

The expected increase in heat waves might make the climate less attractive for tourists, as already observed in the last few years (EEAA, 2010). Yet, this might also lead people to choose different seasons for visiting Egypt. For beach holidays, the seasons of spring and autumn would become more attractive than today compared with the hot summer season. Another adaptation of tourist behaviour would be more problematic for Egypt, namely avoidance of Egypt and the choice of other destinations. Another problem for tourism is the direct influence of the negative impacts of climate change on other sectors, such as food production or water resources, which are linked to tourism. Just as for the other branches of the economy, higher water demand through higher touristic consumption will lead to conflicts with agricultural, industrial and domestic users. Therefore, the vulnerability of tourism is considered to be high.

Sea level rise, as another example of linked issues, poses danger to holiday destinations in the northern Nile Delta for foreign and local tourists and leads to the losses of beaches, which reduces desirability (UNFCCC and Ministry for Environmental Affairs, 2010). The outcome of this is the potential for large socio-economic impacts if declining tourism activity is noticeable in these regions.

The main tourist attraction in the Red Sea, the coral reefs, are seen as particularly under threat, as already 15% of global coral reefs (which are among the most sensitive ecosystems) have been destroyed due to warmer sea temperatures with climate change further exacerbating this process (EEAA, 2010). The loss of this important tourist attraction (as well as fish breeding grounds) would lead to negative economic consequences.

Furthermore, Egypt's ancient monuments, which are important tourist attractions, will face potential negative effects due to higher temperatures in the summer. The most fragile elements are the coloured wall paintings in ancient tombs. Moisture that tourists generate in the chambers can make the walls unstable and therefore the number of visitors has to be limited during the hot, diaphoretic summer months (EEAA, 2010).

As tourism depends to a large extent on the environmental beauty of the coastal areas and resorts, the negative effects of climate variability on the local ecosystems would also have a negative impact on future tourism activity. For example, the ability to operate Nile cruises could be limited due to climate change effects on the Nile and other water resources (EEAA, 2010).

A2.2.4.2. Adaptation

The EEAA (2010) summarises the potential adaptation measures for the tourism sector as follows:

- expand the protected marine areas and increase regulations;
- develop coastal zones with the aid of the ICZM;
- evaluate the vulnerability and protection of archaeological and tourism sites to the impacts of climate change;
- redirect tourist hotels and associated activities to less vulnerable sites; and
- develop a solid monitoring and law enforcement system to guarantee the implementation of adaptation efforts.

Amelung et al. (2007) project that the number of months with comfortable conditions will decrease progressively from today's ten months. Thus, it could be favourable to split the 'bathing season' into the spring and autumn. During the winter season, cultural events could be organised to attract tourist attention.

With respect to higher temperatures in spring and autumn, tourists demand air conditioning systems in all accommodation, which lead to higher costs for hotel owners and to the side effect of higher energy demand as well.

In spite of these adaptation approaches, there is a lack of exploratory studies dealing with adaptation to climate change impacts on tourism. Yet given the sector's immense relevance to Egypt's economy, it is important to prepare it for the possible challenges of changing climate conditions (Tolba and Saab, 2009).

A2.2.5. Health

A2.2.5.1. Vulnerability

Climate change will contribute to diseases through direct and indirect effects. Direct effects include heat strokes and all heat-related impacts specifically on the elderly and children. Other direct effects are skin cancer, eye cataracts and in the worst case, death.

Indirect effects are mainly related to water shortages stemming from changes in rainfall patterns and higher temperatures, which often cause food insecurity. A possible consequence is an increase in malnutrition among Egypt's population.

Overall, there will be increased incidences of communicable diseases, such as bacterial or viral diseases. A concrete example of a communicable disease is malaria. Likewise, more incidences of non-communicable diseases (like cardiovascular diseases or cancer) are expected (UNFCCC and Ministry for Environmental Affairs, 2010).

A2.2.5.2. Adaptation

There are a few adaptive concepts concerning the prospective health problems in Egypt. The major ones are discussed below.

First, socio-economic vulnerability should be reduced. Information about health threats is considered an important basis from which to take responsive measures and therefore reduce vulnerability.

Another measure is the maintenance and upgrading of the national public health infrastructure. People do have access to health care, but there is a broad dissimilarity between Upper and Lower Egypt as well as between urban and rural parts of Egypt, with the least access to public health services among the rural regions of Upper Egypt. Thus, closing this gap should limit the incidence of some communicable and non-communicable ailments.

Furthermore, Egypt's population should gain access to quality health services. An improvement in the proportion of people gaining access to local health services, reaching more than 90%, would lead to significant efforts in updating the adaptive capacity to climate change-induced diseases. To fight coronary heart disease, cancer or complicated diabetes, the quality of the health care provided needs improvement. This should be achieved through reform of the health sector, which has been underway since 1998. Advancing the primary, curative and rehabilitative health care, with financial support from the European Commission and the World Bank, are the major aims of this reform (UNFCCC and Ministry for Environmental Affairs, 2010).

Additionally, the further improvement of vaccination programmes is planned. For instance, the free vaccinations for infants and schoolchildren against primary diseases have already led to a significant improvement in health indicators. Moreover, early-warning systems for certain diseases may be an effective strategy. These would possibly address malaria, tuberculosis and other water- and food-borne diseases, for instance. Finally yet importantly, weather and seasonal forecasting, disaster preparation, education and public awareness are issues to tackle. Hot weather warning systems and collaboration between the meteorological and the health care sectors are among the possible solutions in these areas. Such efforts should also include outreach and education through the media (EEAA, 2010).

A3. Case study: Climate adaptation in Tunisia

A3.1. The situation in Tunisia

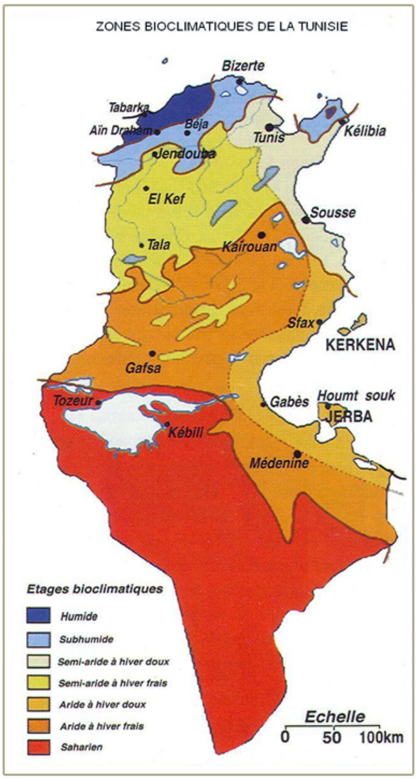
A3.1.1. Current climate

Tunisia has a Mediterranean climate that is characterised by dry and hot summers, and mild and wet winters. In general, Tunisia is affected by dryness, as 94% of the territory is directly threatened by desertification (Ministry of Environment and Land Planning, 2001).

The climate is heavily influenced by Tunisia's geographical position, i.e. in the north by the Mediterranean and in the south by the Sahara. This position between the temperate regions of the north and the intertropical regions of the south results in a highly variable climate in Tunisia, and this in turn explains the country's vulnerability to climate change. The climate in the north is Mediterranean, with regular rainfalls in the wintertime. Central Tunisia is a kind of transition zone between the Mediterranean and the Saharan domains, characterised by a high degree of variability of the climate. The south is largely under Saharan influence and thus continually arid: while the water demand amounts to 1,600-1,800 mm/year, the rainfall levels are around 100 mm.

Precipitation is very irregular and varies significantly from north to south: in the north, average annual precipitation levels can reach 400-1,000 mm, in central Tunisia they vary from 200 to 400 mm and in the south precipitation levels can be below 100 mm. Together with temperatures, especially winter temperatures, rainfall determines Tunisia's five bioclimatic zones – ranging from driest to wettest (Figure 9). In the north, average annual temperatures are around 17°C and in the south they vary from 18.5°C to 21.5°C (Ministry of Environment and Land Planning (Tunisia), 2001).

Figure 9. The five bioclimatic zones of Tunisia



Source: Ministry of Environment and Sustainable Development (2010).

A3.1.2. Economic profile

Before the revolution, Tunisia was among the fastest-growing countries in the MENA region with an impressive economic performance of average annual growth of 5% (1997 to 2007) (Ministry of Commerce, 2012). The benefits of prosperity were distributed unevenly, however, because of corruption and bad governance. Today, Tunisia is in the process of economic reform and liberalisation, and has developed a diverse and market-oriented economy with important agricultural, mining, manufacturing and tourism sectors. Key exports include textile and clothing, agro-food products, energy and lubricants, mines and phosphate, with the EU being Tunisia's largest trading partner. Notably, imports have been increasing faster than exports, which resulted in a negative trade balance of -8,610 million Tunisian dinars (TD) in 2011 (Ministry of Commerce, 2012). According to the World Bank, Tunisian GDP grew 4.5% on average between 2002 and 2010 and amounted to $44.3 billion in 2010. In the same period, the GNI per capita in PPP grew from $5,600 to $9,060. The inflation rate increased to around 4.0% in 2010 (World Bank, 2012).

In 2010, 3,277,400 people were employed in Tunisia, among whom 17.7% worked in agriculture and fishing, 33.0% in the industrial sector and 49.3% in trade and services. Unemployment remains a key concern, especially among the young and educated: while it was at 13.0% overall in 2010, for young people (aged 15-24) it was 30.7% (World Bank, 2012).

The political uncertainty after the revolution has affected both foreign direct investment and tourism, while the global financial crisis has led to a decline in exports, especially to the EU. Tunisia remains a low-wage and low value-added economy, with too few opportunities for skilled workers. Thus, the transitional government needs to address unemployment and regional development by boosting the private sector and creating jobs.

A3.1.3. Climate change projections

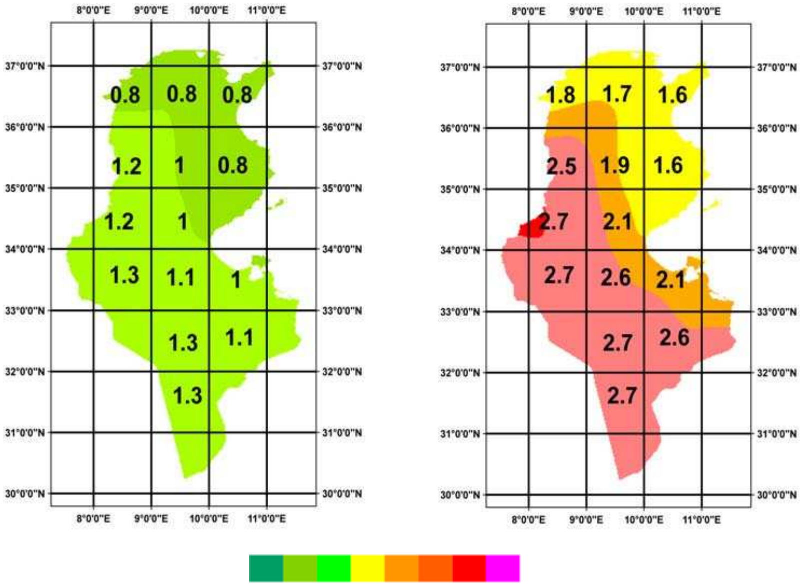
According to a study on climate change impacts in Tunisia by 2030 and 2050 conducted in the framework of the National Adaptation Strategy, Tunisia faces two main, climate change impacts: a rise in temperatures and a drop in average rainfall levels. These climate changes are based on the already high degree of variability in the regional climate, which is even expected to increase by 5 to 10% on average between 2011 and 2070. In addition, Tunisia will experience a sea level rise by 38 to 55 cm by 2100 (Ministry of Environment and Land Planning, 2001).

The whole country will experience a rise in average temperatures by 1.1°C in 2030 and by 2.1°C in 2050 in comparison with 1961–90 (Figure 10). Summer temperatures (+0.9°C to +1.6°C) will rise more than winter temperatures (+0.7°C to +1.0°C). Extremely dry years will increase in frequency and intensity by 2030. Precipitation will decrease moderately by 5% in the north and 10% in the south in 2030 and by 10% in the north-west and 30% in the south in 2050 (Figure 11).

These general projections vary according to Tunisia's three main regions (south, central Tunisia and north). In the south, the climate changes will be most severe – with the highest rise in annual temperatures, a considerable decrease in rainfall and possibly two or three succeeding years of severe droughts. Central Tunisia will experience a marked rise in temperatures but precipitation will only decline moderately, while the number of dry years will increase. In the northern part of the country, the intensity of the projected changes (such as the rise in temperatures and decrease in precipitation) will be lowest and the variability of precipitation will be stable, while the number of extremely hot or wet years will even slightly decrease.

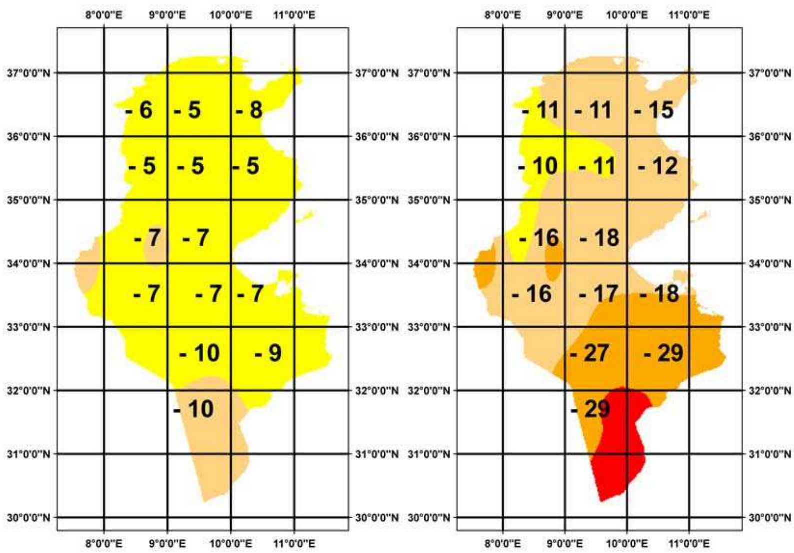
In conclusion, climate change projections in Tunisia include a rise in average annual and seasonal temperatures, a moderate decrease in precipitation and even greater variability of the climate. Especially extreme meteorological events (such as droughts, heat waves, winds and floods) will increase in frequency and intensity, notably through the succession of very dry years (MARH and GIZ, 2007).

Figure 10. Temperature change projections for Tunisia: Average annual rise in temperature in 2030 (left) and 2050 (right) in comparison with 1961–90 (in °C)



Source: MARH and GIZ (2007).

Figure 11. Precipitation change projections for Tunisia: Average annual decline in precipitation in 2030 (left) and 2050 (right) in comparison with 1961–90 (in %)



Source: MARH and GIZ (2007).

A3.1.4. National Adaptation Strategy

The National Adaptation Strategy was developed from 2005 to 2007 in the framework of Tunisian–German bilateral cooperation between the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and the Tunisian Ministry for Agriculture and Water Resources (MARH). The project aimed at identifying the impacts of climate change in Tunisia, especially with regard to its society and economy. Then it developed a national adaptation strategy and an action plan for the agricultural sector. The National Adaptation Strategy has three guiding principles:

1) developing a long-term approach with an adaptation strategy for climate-induced changes;
2) integrating the climatic volatility into agricultural and economic policies; and
3) handling, across the different economic sectors, the socio-economic consequences for the agricultural sector.

The National Adaptation Strategy consists of four key components:

1) climate – building up an early-warning system and sharing information (environment indicators) with all economic sectors;
2) water resources – enhancing the storage of water and promoting forms of agricultural production that need little water; introducing a tax on water per hectare and per year;
3) ecosystems – helping the ecosystems to preserve and to regain their natural capacity to adapt to climate change, especially forest regeneration; and
4) agriculture – restructuring farms that are affected by climate change; re-orienting non-viable agricultural production towards economic alternatives, such as biofuel; and introducing climate labels for agricultural products resilient to climate change.

An inter-ministerial committee, the National Climate Council, was created in 2007, whose mission is to implement, coordinate and adapt periodically Tunisia's National Adaptation Strategy to new knowledge and difficulties. At the international level, Tunisia envisages compensation for countries that contribute little to climate change but suffer seriously from its consequences. The findings of this project attracted interest beyond Tunisia's borders and were made available to southern Mediterranean countries.

The political upheaval and societal turmoil in Tunisia since the 2011 revolution and the consequent restructuring phase have possibly had a negative effect on the progress of the National Adaptation Strategy and have slowed down the execution of the planned measures. In addition, it is difficult to obtain information from official sources about the current state of implementation.

A3.2. Impacts of climate change, vulnerability and adaptation measures in critical sectors

Having analysed climate change projections in Tunisia, we now turn to the impacts of climate change on five crucial aspects: coastal zones, water resources, agriculture, health and tourism. This section aims at assessing vulnerability to climate change and the socio-economic consequences before evaluating current and future adaptation strategies.

A3.2.1. Coastal zones

A3.2.1.1. Vulnerability

For Tunisia, the opening to the Mediterranean on the north and east and its long coastline of around 1,148 km represents a considerable economic and ecological asset. Thus, Tunisia's coast concentrates two-thirds of the total population, more than 70% of the economic activities, 90% of the total capacity for tourist accommodation and a great part of the irrigated agriculture (Ministry of Environment and Land Planning, 2001). The most important economic sectors located on the coastline are tourism, the crafts industry and agriculture. This puts a high level of anthropic pressure on water resources and on the natural ecosystem (Ministry of Environment and Land Planning, 2001).

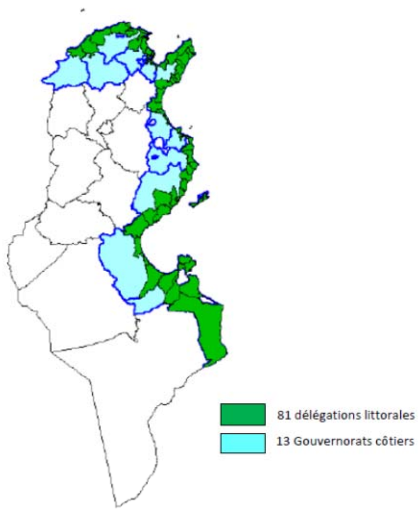
Owing to its geographical location and climate characteristics, i.e. the high variability of its climate, Tunisia is particularly vulnerable to climate change. Accelerated sea level rise (ASLR) can have serious, harmful consequences on several economic sectors, on the biological environment and on human settlements. It is estimated that the sea level will rise between 38 and 55 cm by 2100 (Ministry of Environment and Land Planning, 2001). A sea level rise of 1 m would affect 5% of the population in Tunisia (Tolba and Saab, 2008).

The potential impacts of climate change include the above-mentioned sea level rise, stronger and more frequent storms, temporary or permanent submersion of low coastal areas, accelerated erosion and increasing saltwater intrusions. These impacts will significantly affect the following resources and economic sectors:

- *Water resources*. ASLR will damage the aquifer coastal formations and other underground sweet water resources due to the intrusion of seawater. The potential loss in coastal groundwater resources caused by saltwater intrusion is estimated at 53% of the current groundwater reserves (MEDD and UNDP, 2009). For more details, see section A3.2.2.
- *Natural ecosystems*. ASLR will mostly harm humid places, such as lagoons, *sebkhas* and the lowest coastal marshes, due to submersion and salinisation. The total amount of area potentially threatened by submersion is 18,000 ha (MEDD and UNDP, 2009).
- *Coastal infrastructure*. At present, 1.4% of the coastline is protected, mainly by dykes, which are very vulnerable to ASLR. Thus, Tunisia's 22 coastal ports, 19 fishing ports, 8 commercial ports and 8 recreational ports are threatened (MEDD and UNDP, 2009).
- *Agriculture*. Agriculture (citrus fruit, irrigated cultures, etc.) is particularly vulnerable to salinisation and soil erosion. The loss of agricultural land is estimated at about 16,000 ha (MEDD, 2012a). In addition, ASLR can damage agricultural infrastructure, such as drainage and irrigation pipes. The impact on fishing is positive, with a slight production increase of 1 million TD per year. For more details, see section A3.2.3.
- *Tourism*. ASLR will affect the aesthetics and extent of beaches of the three main tourist hubs, Hammamet, the Sahel and Jerba. Currently, more than 40% of Tunisia's beaches are considered vulnerable or highly vulnerable to ASLR. This retreat of beaches results in a decline of hotel values (MEDD and UNDP, 2009). For more details, see section A3.2.5.

Tunisia's major ASLR-vulnerable zones depend on the back country geology. The most risky coastal segments include the city of Bizerte and its lakeside system, the northern and central parts of the Gulf of Tunis, the oriental coast of the Cap Bon peninsula and different segments of the Gulf of Grabes (Ministry of Environment and Land Planning, 2001). ASLR will seriously affect islands with flat topography, in particular the Kerkenna islands and Jerba (Figure 12).

Figure 12. Map of Tunisia showing the governorates and delegations that will be most affected by climate change



Source: MEDD and UNDP (2009).

A study conducted by the Tunisian Ministry of the Environment (MEDD) and the UNDP (2009) tried to assess the costs related to ASLR on the 2050 horizon. They distinguished the costs related to direct impacts from those costs due to the degradation of the environment. Direct impacts include those on the infrastructure and on the principal economic sectors on the coast (agriculture, tourism and the crafts industry). The losses in physical capital (mainly hotel infrastructure, water resources and housing zones) are calculated at more than 3.6 billion TD – which represents almost 10% of GDP – and mostly affect tourist regions, such as the Sousse Governorate and the region of Gabès/Médenine.

Annual losses in production are estimated at a total of 180 million TD (0.5% of 2006 GDP, constant prices). The loss in agricultural production amounts to 81 million TD per year (2% of the agricultural GDP) owing to the submersion of farming land and the loss of irrigation potential caused by salinisation. Yet, 56% of the production losses stem from the tourism sector, caused by the retreat of beaches, i.e. 102 million TD per year. Annual costs related to the degradation of the environment, i.e. physical effects on the littoral, water resources, soils and vegetation, are estimated at 47 million TD (0.13% of annual GDP). Together with the direct economic losses (0.5% of the annual GDP), the total costs related to ASLR are projected at 228 million TD, i.e. 0.63% of GDP, which hampers annual economic growth by 0.6% (Table 6). In terms of employment, 35,000 jobs will be lost due to ASLR, i.e. 1% of the active population. Although employment rates in fishing will increase, those in agriculture and tourism will decline (MEDD and UNDP, 2009).

Table 6. Summary of economic and environmental costs related to impacts of ASLR

Activity	Total sum in millions TD	% GDP
Economic losses	181	0.5
Agriculture and fisheries	80	0.2
Tourism	102	0.3
Environmental costs	47	0.13
Total	**228**	**0.63**

Source: Modified from MEDD and UNDP (2009).

A3.2.1.2. Adaptation measures

Having studied the vulnerability of Tunisia’s coasts to climate change and the potential economic losses, it is clear that adaptation to climate change is a crucial challenge for Tunisian political and scientific elites.

Founded in 1995, the Coastal Protection and Planning Agency (APAL) is responsible for coastal protection in general and the protection of the public maritime domain in particular. Its mission is to manage coastal areas and to ensure their compliance with rules and standards, to initiate studies and conduct research and to observe the evolution of coastal ecosystems. Its activities also include beach cleaning. The National Program for the Creation of Marine and Coastal Protected Areas aims at establishing these protected zones along the Tunisian coast. The programme currently covers five sites: the archipelago and Zembra Zembretta, the islands Kuriat, the north-eastern part of the islands of Kerkennah, the coastline from Cape Negro to Cape Serrat and Archipelago Galite (MEDD, 2012b).

The Tunisian Ministry of the Environment and the UNDP suggest in their study an action plan for Tunisia’s coast that would cost 1,460 million TD, which corresponds to 40% of the physical capital that would be lost without any adaptation measures (MEDD and UNDP, 2009). They calculate an amortisation period of eight years if considering only the direct economic losses, and of six years if taking into account the environmental costs. These findings justify the collective interest in such an action plan.

Markandya et al. (2009) compared the coastal zone management of ten Mediterranean countries (Algeria, Croatia, Egypt, France, Italy, Israel, Malta, Spain, Tunisia and Turkey) in terms of legislation and a cost–benefit analysis. Tunisia’s specific coastal-zone legislation prohibits construction within 100 m, but settlement construction is permitted within 25 m. Fines are possible and sometimes applied, but in most cases the authorities reach an agreement with the violator. The assessment of this legislation is mixed: although minor infringements are declining, major tourist development projects remain a problem and tend to violate the law. Two examples of this were given by Magnan (2009), who analysed the vulnerability of littorals to climate change. On the island of Jerba, a large tourist project comprising 15 hotels, a golf course and a marina requires the filling up of a lagoon (Lella Hadhria) in the east of the island, although the string of sand separating it from the sea is quite narrow and coastal erosion is strong. Other questionable tourist projects are currently underway in the Gulf of Hammamet (Magnan, 2009). It seems that the tourism sector does not adequately take into consideration the impacts of climate change. Moreover, a lack of quantitative studies prevents a full assessment of the effectiveness of Tunisia's regulation. Therefore, only partial conclusions are possible, but these are rather negative: tolerance of infringements is particularly high in Tunisia and a stricter regime is needed to prevent overdevelopment of coastal resources (Markandya et al., 2009).

Box 1. Urban adaptation in Greater Tunis

Johnson and Breil (2012) investigate urban adaptation to climate change. With regard to Tunis, they studied the impact of sea level rise and other climate-induced changes, conducted a vulnerability analysis and elaborated an adaptation action plan. The Tunis agglomeration covers 300,000 ha (of which 20,000 are urbanised) and it has 2.5 million inhabitants. Tunis faces climate risks that range from flash floods due to increased urbanisation (i.e. more sealed surfaces) to an increased intensity of meteorological events (such as heavy rainfalls, droughts, heat waves or coastal flooding) and coastal erosion. Adaptation measures focus on urban planning and management activities, for instance the improvement of infrastructure, adaptation of buildings and establishment of new regulation, an early-warning system for tsunamis and flash floods, limits to urban sprawl, control of water consumption and expenditure on public health systems. The annual costs of impacts from natural hazards are estimated at 140 million TD (until 2030), i.e. 49-57 TD/person/year or 0.77% of the present GDP. The total annual costs of adaptation measures (2020–50) are calculated at 612 million TD and benefits at 870 million TD, thus slightly exceeding the damages caused by climate change. Johnson and Breil (2012) suggest public funding with an estimated need for investment of 654 million TD over the entire time horizon: 339 million TD in the short term (< 5 years), 2 million TD in the very short term (< 2 years), 337 million TD within 5 years and 315 million TD in the medium term (< 10-15 years). They conclude that Tunis has not implemented any adaptation measures yet, but that the agglomeration has the capacities for doing so.

A3.2.2. Water resources and water scarcity

A3.2.2.1. Vulnerability

Water resources are of crucial importance in Tunisia, a country affected by aridity and a constant hydrous stress situation (less than 1,000 m^3/capita/year). After 2025, it is projected that all countries of the Maghreb region will be affected by water shortages (less than 500 m^3/inhabitant/year), a situation to which Tunisia is already closest (528 m^3/capita in 1995). This stems from Tunisia's geographical position, which causes a high climatic variability, with dry episodes and occasional, even disastrous, rainfalls combined with a high anthropic pressure (Ministry of Environment and Land Planning, 2001).

In Tunisia, 51% of the water resources are surface waters and 49% are underground waters. Water exploitation ranges from dams (20.5%) and groundwater resources (33.2%) to deep water resources (46.3%). In terms of usage, 81% of all water resources are used for agriculture, 14% for individual use, 4% for industry and 1% for tourism (MARH and GIZ, 2007).

Water resources are particularly vulnerable to climate change. The intensification of evaporation may lead to a rise of rainfalls, but this will not be enough to offset the decrease of sweet water resources. In addition, rains will be more frequent, but often result in torrential storms and downpours that are less absorbed by the soils (Ministry of Environment and Land Planning, 2001).

A study conducted by the Tunisian MARH and the German GIZ detected the main impacts of climate change on Tunisia's water resources: a reduction of surface water by 5%, a decrease of groundwater and coastal non-renewable aquifers by up to 28%, and increased soil water shortage because of the drop in summer precipitation and the increased evaporation rate (+9.3%/year) due to higher temperatures (Table 7). All regions will be less wet, except the north where a slight increase in precipitation is expected. As precipitation levels will diminish only slightly, streams into drainage basins are more influenced by hourly intensity than by annual levels. The direct impacts related to reduced rainfalls on the levels in dams will be rather little and can be compensated for by good management of ecosystems, but the indirect effects owing to extreme weather events will lead to an overexploitation of underground resources in order to compensate for the deficit in surface water for irrigation. Water degradation, through increased salinity, turbidity and overexploitation, will result in fierce competition among different consumers. Natural and artificial humid zones face the additional risk of eutrophication. Floods will not occur more frequently but they will be more intense, which intensifies soil erosion. Thus, it is better to take into consideration the whole ecosystem, and not only drainage basins. The south is most vulnerable, with a strong increase in water demand due to the rise in temperatures, which will lead to an overexploitation of the deep water resources. This results in a decline of piezometric levels and degradation of water quality (MARH and GIZ, 2007).

Table 7. Evolution of total water resources under the effects of climate change (in Mm^3)

Désignation	2010			2020			2030		
	Potentiel	Mobilisé	Exploitable	Potentiel	Mobilisé	Exploitable	Potentiel	Mobilisé	Exploitable
Grands barrages	2'700	2'121	1'378	2'700	2'131	1'385	2'700	1'890	1'229
Nappes phréatiques	758	758	758	781	781	591	805	805	308
Nappes profondes	1'544	1'350	1'350	1'791	1'535	1'215	2'079	1'731	1'214
Total eaux conventionnelles	**5'002**	**4'229**	**3'486**	**5'272**	**4'447**	**3'191**	**5'584**	**4'426**	**2'751**
Eaux usées traitées	253	99	99	400	156	156	512	292	292
Eaux dessalées		18	18	0	47	47	0	80	80
Total eaux non conventionnelles	**253**	**117**	**117**	**400**	**203**	**203**	**512**	**372**	**372**
Total Général	**5'255**	**4'336**	**3'603**	**5'672**	**4'650**	**3'394**	**4'798**	**4'798**	**3'123**

Source: MARH and GIZ (2007).

Coastal zones will bear the maximum risk regarding water resources. The direct effects are caused by climate warming, but the indirect effects are induced by sea level rise as the intrusion of saltwater damages the aquifer coastal formations and other underground sweet water resources (Ministry of Environment and Land Planning, 2001). These damages will be compensated for by putting additional pressure on deep water resources. All coastal water resources will be threatened by seawater intrusion, which results in a potential water loss of 53% of the current reserves (MEDD and UNDP, 2009).

In 2007, the World Bank investigated the costs related to water degradation in Tunisia. They found that the total cost amounts to 0.6% of GDP, i.e. 207.5 million TD for 2004, distributed as follows:

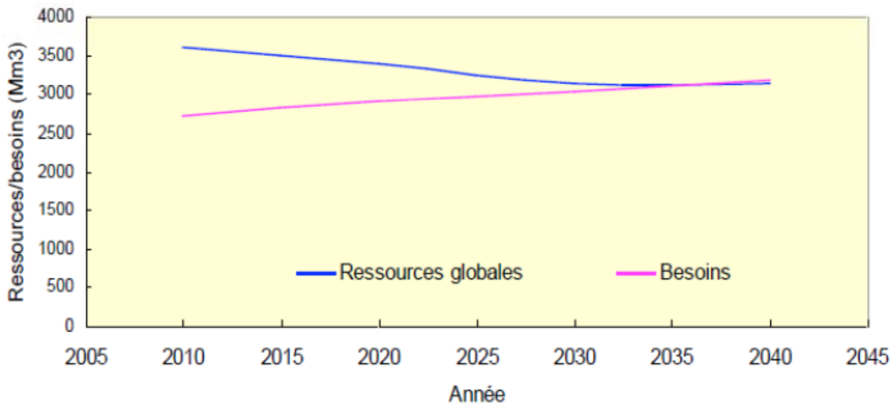
- irrigated agriculture – 67.9 million TD (0.19% of GDP),
- fishing – 16.7 million TD (0.05% of GDP),
- overexploitation of groundwater – 44.4 million TD (0.13% of GDP),
- tourism – 37.6 million TD (0.11% of GDP),
- health – 33.5 million TD (0.10% of GDP), and
- biodiversity – 7.3 million TD (0.02% of GDP).

We have to note, however, that empirical results on the impact of climate change on water resources are still not exhaustive; especially precipitation levels are difficult to measure because of their site-specific and temporal character.

A3.2.2.2. Adaptation measures

While water resources diminish, water demand rises with the population increase. In 2030, water demand is estimated at 3,743 Mm^3, while 4,201 Mm^3 are exploitable, but only if all water management programmes are successfully implemented (Figure 13). Hence, efficient adaptation strategies are needed, which has been explored by several studies.

Figure 13. Evolution of water resources and needs on the 2040 horizon



Source: MARH and GIZ (2007).

In 2003, adaptation strategies already in use included restructuring the farmers' bank debt, importing and subsidising drilling products, controlling the opening of forest land for grazing, giving priority to drinking water, restricting a certain number of summer crops and carrying out a public awareness campaign (Agoumi, 2003).

Iglesias et al. (2006) analysed Tunisia's current adaptation strategies for water scarcity and drought. In comparison with other Mediterranean countries, the relations among institutions are highly developed, but river basin authorities are only partially set up and public participation is low. A drought monitoring system has been implemented at the national level, but a drought contingency plan is still in development. Moreover, such economic instruments as water markets or water transfer mechanisms applied in Tunisia are effective during water shortages, but incentives are not adequate tools in these periods. The study recommends developing a monitoring and early-warning system for water quality and quantity and focusing on *ex ante* anticipatory measures rather than on *ex post* emergency measures (Iglesias et al., 2006).

The World Bank (2007) suggested four main adaptation strategies: controlling pollution sources, strengthening incentives to fight against pollution, developing the recycling of treated water and improving coordination among organisations.

The National Adaptation Strategy developed by the MARH and the GIZ consists of three main components:

- continuing the programme of water management, but ecosystem- and not watershed-based, while strengthening current legislation and preserving the ecosystems, e.g. by recharging aquifers;
- modifying water demand and financial costs related to water use through incentives in pricing; and
- creating capacity reserves, even virtual ones, for drought periods and especially in agriculture.

A main problem, water consumption for irrigation, remains. In 1992, the Ministry of Agriculture developed a national programme aimed at substantial water savings through the development of non-conventional water resources, including among others the reuse of treated wastewater or the direct use of brackish water, the institution of subsidies and financial incentives, the creation of hydraulic power groupings and the improvement of collective irrigation networks (MEDD, 2012a). Agricultural land equipped with water-saving technologies has increased since 1995 and is estimated at 340,000 ha, or 83% of the total area of equipped irrigated zones, in 2008. Treyer (2001) expects significant water savings in agriculture through the reuse of wastewater.

In 2030, conventional water resources will only cover 91% of needs (MARH and GIZ, 2007). To address this issue, the development of unconventional water resources is continually advanced. Unconventional water resources are the treatment and reuse of water, injection of rainwater into aquifers or desalination of seawater (Tabet-Aoul, 2008). Treated wastewater amounted to 250 Mm^3 in 2009, produced in the 106 treatment plants of the National Sanitation Office. The capacity of the pumping stations allows using 40 Mm^3 of treated wastewater in the agricultural sector. The equipped surface amounts to 7,950 ha in 25 regions. Still, the volume of wastewater effectively used only amounts to 16-28 Mm^3, which is well below the volume of available treated wastewater. Therefore, it is necessary to extend the adapted surface of agricultural land, to create storage sites and to establish further regulation (MEDD, 2012a).

Current projects include a profitability study carried out by the Tunisian Ministry of Environment and Sustainable Development (MEDD) on the transfer of treated wastewater from Greater Tunis to areas of demand. The UNDP Global Environment Facility (UNDP-GEF) conducts a project (scheduled for completion in December 2013) that facilitates investment in water reuse and assesses the advantages, impacts and operation costs of three scenarios: transport to the sea when the water is not reused in agriculture, transfer to agricultural zones, and complementary treatment and groundwater recharge. So far, the project sees the reuse of treated wastewater as a viable option because it reduces ground and surface water scarcity, recharges coastal aquifers, preserves wetlands, alleviates drought-related impacts and reduces the use of fertilizers. Nevertheless, many constraints exist, such as the risk of bacteriological contamination, MARH restrictions on irrigation with treated wastewater to industrial crops (tobacco, cotton, etc.) or a certain reluctance by famers to use this type of water. Hence, only 24% of the treated water is currently reused (UNDP-GEF, 2008).

The MEDD and UNDP (2009) propose an action plan for coastal water resources that strives to protect the aquifers from overexploitation and to recharge artificially the coastal water resources with wastewater. The costs are estimated at 100 million TD (MEDD and UNDP, 2009).

A3.2.3. Agriculture

A3.2.3.1. Vulnerability

Agriculture plays a major role in the Tunisian economy, contributing up to 12% on average to GDP, employing 16% of the active population, ensuring an even trade balance (food exports contribute up to 11% to the overall export of goods) and of course contributing to the country's food security. Agricultural lands are estimated at 10 million ha, of which arable land accounts for 5 million ha and is divided between arboriculture (2 million ha, including 1.6 million ha of olive trees), arable crops (2 million ha, including 1.6 million ha of cereals), fallow land (0.7 million ha) and other cultures (0.3 million ha). There were 516,000 farms in 2005 (10.2 ha on average per farm) (National Institute of Statistics, 2012).

The German GIZ and the Tunisian MARH identified in a joint project from 2005 to 2007 the impacts of climate change on the Tunisian agricultural sector. They considered the progressive opening of the agricultural sector until 2030 through two scenarios, one of a slow and one of a fast pace. The strategy of economic and social development for 2006–16 fixed a growth rate of 6.5% until 2016.

The main, direct negative effects of climate change on agriculture are droughts and floods because the projected extreme temperatures remain below the maximum bearable for Tunisian crops. Drought is defined as precipitation equal or inferior to 50% of the average calculated over 50 years; years with favourable precipitation levels have 1.5 times the average rainfall. The results of the study can be summarised as follows in Table 8.

Table 8. Summary of the impacts of extreme weather conditions on different agricultural sectors

	Succession of very dry years	Years with favourable precipitation levels
Olive cultivation and arboriculture	- Dry olive production will decrease by half at the time horizons of 2030 and 2050; the surface area of non-irrigated arboriculture will decline by almost 50%, i.e. approximately 800,000 ha in the centre and south. - Aquifers in the south will be heavily affected due to the decline in precipitation.	- Dry olive production will increase by 20%. - Yields of arboriculture will increase by around 20%.
Livestock	- Livestock will decrease by up to 80% in the centre and south and by around 20% in the north.	- Yields will increase up to 10%.
Cereals	- Surface areas in the centre and south will decrease by 200,000 ha on average. - Floods will reduce the production of irrigated cereals by 13% at the time horizons of 2016 and 2030.	- Rain-fed agriculture will benefit from an increase in output by over 20%.

Source: MARH and GIZ (2007).

The MARH and GIZ conclude that in the case of droughts, whatever the pace of economic opening, the declines in production will prevent the set target from being reached by 2016 (MARH and GIZ, 2007). In the case of droughts, the surface areas of cereals would decrease by 16% in 2016 and those of olive trees by 40%. For the scenario of slow economic opening, the production of cereals would decrease by 44% in 2030, that of olives by 52% in 2030 and that of meat by 33 to 66%, depending on the species. Agricultural GDP would fall from 3,191 million TD to 2,512 million TD in 2016 (-21%) and from 3,294 million TD to 2,547 million TD in 2030 (-22.5%) for the slow scenario. For the fast scenario, agricultural GDP would diminish from 3,213 million TD to 2,564 million TD in 2016 (-20%) and from 3,161 million TD to 2,567 million TD in 2030 (-19%). In the case of favourable climatic conditions, however, agricultural GDP would increase by 3.3% (2016) and 6.6% (2030) for slow opening, and by 3% (2016) and 7.4% (2030) for fast opening (MARH and GIZ, 2007).

Abou-Hadid (2006) conducted three case studies (in the Kairouan area, Sfax and Hendi Zitoun) to assess the impact of climate change on Tunisia’s olive and wheat production in the centre of the country. This region is characterised by moderate temperatures that can become hot in the summer as well as low and irregular rainfalls. In terms of vulnerability, 97% and 93% respectively of cereals and fruit trees are rain-fed and thus highly vulnerable to climate variability. This vulnerability will be exacerbated by climate change. As Abou-Hadid shows, the yields of wheat production in Kairouan will decrease by 48% if precipitation decreases by 10% and the temperature increases by 1.5°C, and by 12% if rainfall alone decreases by 10%. With a temperature rise of 1.3°C, the growing season is shortened by ten days (Abou-Hadid, 2006).

The main indirect problem caused by climate change is water scarcity, as rain-fed agriculture represents 90% of Tunisia’s agricultural area (Bachta, 2008). Vulnerability foremost concerns rain-fed crops and is concentrated on the centre and south (Requir-Desjardins, 2010). Still, as shown in subsection A3.2.2.1, the decline in water resources also poses a serious problem for irrigated crops, which cover 350,000 ha but contribute 35% to agricultural production. Requir-Desjardins (2010) critically points out that the consequences of climate change for irrigated crops remains largely ignored by the MARH and GIZ study, which does not provide any modelling of the impact on irrigated crops.

Fofana (2011) simulated the impact of climate change on farm productivity and income by replicating the production system of El Khir, a large farm 30 km away from Tunis, which mainly produces rain-fed (39% of the surface) and irrigated hard wheat (16%). The simulation results show a significant drop in land productivity and farm income: the decline in average land productivity is about 17 to 56%, and farm income drops from 4 to 69%, depending on the climate change scenario. The severity of these losses depends on the extent of changes in temperature and precipitation. Fofana (2011) also finds that irrigated crops are less affected than rain-fed crops, as the latter suffer the effects of both temperature and precipitation.

A3.2.3.1. Adaptation measures

The adaptation strategy for agriculture and ecosystems was published in 2007 and is the first Tunisian adaptation strategy. It aims at integrating climate volatility into agricultural and economic policy and it consists of institutional and economic measures as well as measures related to climatic risk management.

First, the strategy requires a rigorous implementation of an agricultural map that defines adequate crops for each type of soil, and regular updates that take into account climate-induced changes. Farms that are strongly affected by climate change impacts but economically viable may be converted to other activities, such as the biofuel market.

Second, the risk caused by climate change should be carried at the national level and transferred in parts to the adaptation fund of the Kyoto Protocol. Moreover, dual insurance should be introduced that covers both non-natural damages in the agricultural sector and natural damages.

Third, economic measures include the labelling of ‘climate’ competitive agriculture adapted to climate risks as a quality certificate. The objective is to transition to efficient ‘climate’ agriculture.

The key issue of irrigation was first addressed by a strategy for the conservation of water resources and soils from 1992 to 2002. In principal, it constructed the drainage basins and maintained or repaired existing infrastructure. The total cost of this plan was evaluated at 571.6 million TD. The subsequent plan for 2002–11, however, envisaged fewer works of this kind and was more concentrated on water mobilisation and demand rationalisation. Notably, irrigation was extended to 67,000 ha of land, and in central Tunisia 8,000 ha were equipped with water-saving techniques. For the period 2007–11, a mobilisation rate of 95% was expected to be attained and an extension of irrigated surfaces of 30,000 ha (Bachta, 2008).

Abou-Hadid (2006) suggests adaptation methods that include the selection of new cultivates as well as changes in crop variety, crop calendar, planting date, irrigation amount, nitrogen fertilisation and finally education programmes on water-saving practices and new agronomic practices. But a survey of wheat farmers from Kaiouran shows that farmers do not recognise the importance of farming techniques in adapting to climate change; thus, their investments may not be entirely efficient (Abou-Hadid, 2006).

Fofana (2011) analyses the impact of different adaptation scenarios on agricultural productivity and income. The two methods studied are the use of irrigation on rain-fed croplands and the increase of fertilisation. The study reveals that adaptation strategies in general compensate for the reduction in crop yields, in particular irrigation, but only for a 1°C temperature rise. Yet these new techniques depend on the availability of more water and the costs of mobilising it, and they do not appear to be considerably more efficient than the previous ones. Lastly, Fofana (2011) highlights the importance of the impact of climate change on prices: even if crop yields decline, farm revenue might stay the same if output prices increase more than input prices.

A3.2.4. Health

A3.2.4.1. Vulnerability

The WHO has identified five main consequences of climate change for health:

- a change of temperature and precipitation patterns will alter the geographical distribution of vectors that carry and transmit infectious diseases;
- water shortages and extreme rainfalls due to repeated torrents will increase diarrhoea;
- a temperature rise increases the amount of ozone near the ground, which exacerbates asthma attacks, and heat waves will increase morbidity and mortality rates;
- more frequent extreme weather events, such as floods and storms, will increase the number of deaths and trauma victims; and
- a temperature rise, droughts and floods can put at risk food security.

Tunisia is by nature affected by severe weather conditions with 65 to 75% of the summer days being characterised by hardly bearable climate conditions for the human body (MPH and MEDD, 2010). The projected temperature rise of 1.1°C in 2030 and 2.1°C in 2050 will exacerbate the risks related to heat, such as heat strokes, dehydration or skin burns.

There are four types of vector-borne diseases in Tunisia: malaria, cutaneous and visceral leishmaniasis, the West Nile virus (all three transmitted by insects) and urinary schistosomiasis (transmitted by a mollusc). Leishmaniasis is heavily influenced by environmental factors, such as ground vegetation, rainfall and humidity, and has been spreading across Tunisia since 1982. Malaria has disappeared since 1979 but could re-emerge due to climate change: a temperature rise and more regular rainfalls during summertime favour the introduction of a new vector coming from Sub-Saharan Africa. In the same way, climate change is a favourable context for the spreading of schistosomiasis and the West Nile virus.

Water- and food-borne diseases, such as hepatitis or brucellosis, can increase because of threatened water access and food security. Asthma and respiratory diseases will be exacerbated because of climate change impacts on air quality (e.g. an increase of pollen concentration in the air) among others.

Other risks related to climate change include the warming of the sea, the re-utilisation of wastewater in agriculture, the desalination of water and the re-emergence of new vector-borne diseases, such as the Chikungunya virus.

According to a study conducted in the framework of the National Adaptation Strategy in the domain of health, Tunisia’s health system is quite capable of adapting to climate change (MPH and MEDD, 2010). The Directorate for Environmental Health and Protection (Direction de l’Hygiène du Milieu et de la protection de l’Environnement) is responsible for environmental health, which includes prevention, the control of air and water quality, risk management, research and education.

A3.2.4.2. Adaptation measures

Despite the good foundation of the Tunisian health system in adapting to climate change, there remain some obstacles and weaknesses that need to be addressed. For that purpose, the Tunisian Ministries of Public Health and the Environment began developing a national adaptation strategy for the health system in 2006 and published their final report in 2010.

The national adaptation strategy follows a multidimensional and inter-sectoral approach, and generally aims at introducing better risk analysis based on three steps: the collection and production of valid data, risk evaluation, risk management and communication. This risk analysis requires a clearer division of labour among the agencies involved, each of them having either the function of control, assessment or intervention. Tunisia has founded several new institutions, such as the National Agency for Product Control (Agence Nationale de Contrôle des Produits) in 1999 and the National Observatory for New and Emerging Diseases (Observatoire National des Maladies Nouvelles et Emergentes) in 2008. Currently, these new structures overlap with the old ones, which produce tensions and coordination problems among the multiple actors. Moreover, the adaptation strategy calls for better preparation for floods and other extreme weather events by creating a national warning system. Strengthening epidemiology and disease surveillance is another cornerstone of the strategy, in particular by introducing an early-warning system for detecting potential epidemics and by controlling more efficiently disease vectors, such as mosquitoes. Finally, the strategy seeks to make the general population aware of the risks associated with climate change and to improve the training of health professionals.

A3.2.5. Tourism

A3.2.5.1. Vulnerability

Tunisia ranks 34th among the most visited countries in the world (Tolba and Saab, 2009). In the first five months of 2012, the Tunisian Ministry of Tourism registered 1,906,382 visits and 7,486,398 overnight stays. The revenues from tourism amounted to 924 million TD, which is a clear increase compared with the troubled year of 2011 (Ministry of Tourism, 2012).

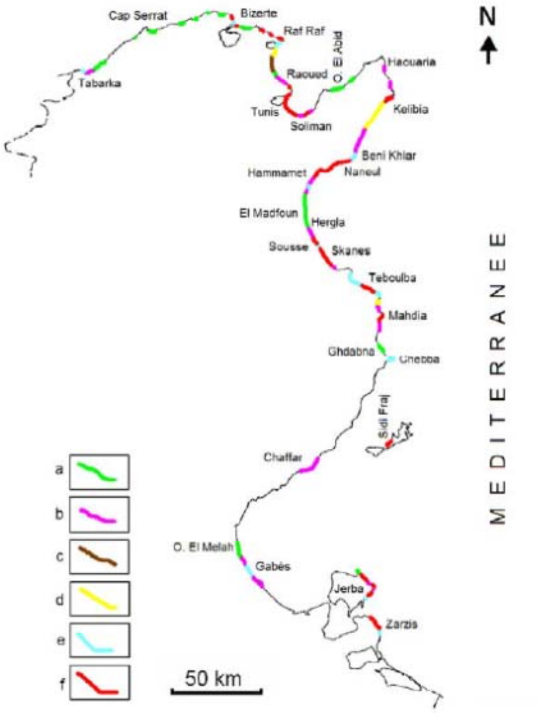
The impact of climate change on tourism goes in both directions: tourism is very vulnerable to climate change (temperatures, rainfall, air and water quality, landscape) but it can also contribute to or exacerbate it (through the emission of greenhouse gases).

In Tunisia, the three main tourist hubs are Hammamet, the Sahel and Jerba. Others are the Gulf of Tunis, the Sousse Governorate and the region of Gabès/Médenine. Being almost entirely located along the coastline, i.e. a resort hotel capacity of around 30,000 beds, Tunisia’s tourism sector is highly vulnerable to climate change, especially to ASLR and erosion. As seen in subsection A3.2.1.1, the sea level is estimated to rise by 38 to 55 cm by 2100. In addition, 8% (127 km of the total coastline) of the current beaches are affected by erosion. The coastline will retreat significantly in almost all tourist zones: 50 cm around Tunis, 20 cm in southern Hammamet and 135 cm on Jerba by 2100 (MEDD and UNDP, 2009). Sandy beaches are most vulnerable to climate change impacts; they are situated in the Gulfs of Hammamet and Tunis and on the islands of Kerkennah and Jerba (Figure 14). The retreat and degradation of beaches and tourist infrastructure (such as hotels) are the main causes of projected economic losses in this sector. Evidently, the temperature rise is another major concern, especially during the summer months. A less attractive climate may divert tourism flows from Tunisia to the north. Still, there are not yet enough studies on this topic.

The losses make up 56% of the total production losses due to ASLR and the tourism sector will lose 5% of its added value (MEDD and UNDP, 2009). An estimated 1,012 jobs will be lost in the tourism sector because of ASLR. Loss of physical capital in Sousse is calculated at 723 million TD and at 768 million TD in Gabès/Médenine. In total, production losses are estimated at 102 million TD, which corresponds to 0.3% of GDP (MEDD and UNDP, 2009).

Besides ASLR and erosion, water resources play an important role. The per-capita water consumption of Tunisians is about 60 litres per day, whereas tourism zones consume eight times that amount (Poirier, 1997). In Tunisia, where water resources are already scarce, this will create additional hydrous stress and tensions among local farmers and members of the tourism sector. Lastly, diminishing water quality owing to pollution and eutrophication will lead to reduced recreational value and an increasing risk of water-borne diseases (Tolba and Saab, 2009).

Figure 14. Vulnerability of sandy beaches to ASLR



Notes: a = no signs of erosion; b = large beaches with considerable construction; c = no construction, but a tendency to withdraw; d = beaches moving towards the continent; e = beaches with different evolutions at short distances; and f = high erosion and a necessity of protection measures.

Source: Modified from MEDD and UNDP (2009).

A3.2.5.2. Adaptation measures

The Arab Forum for Environment and Development (AFED) criticised the lack of research on the relationship between tourism and climate change (Tolba and Saab, 2009). Therefore, adaptation strategies for the Mediterranean in general will have not developed much so far.

In the case of Tunisia, a key measure was the so-called “Project Blue”, which aimed at protecting the littoral. Its objective was to achieve and maintain bathing water conditions by establishing a central laboratory for water quality assessment in Tunis, 5 regional laboratories at the major tourist sites and 32 water purification stations. It also involved the construction of 6 effluent control systems to remove contaminants from beaches (Poirier, 1997). Beyond this environmental programme, the Tunisian national adaptation strategy for the tourism sector is also currently underway.

Several authors denounce Tunisia’s lax way of driving forward tourist development. Markandya et al. (2009) indicate a 50% increase in coastal tourist density from 1970 to 2000, which puts additional anthropic pressure on coastal natural resources, and Poirier (1997) notes that the growth pace of Tunisia’s tourism does not harmonise with the environmental harms induced, such as waste or water and soil degradation. At the same time, Poirier (1997) praises Tunisia’s efforts to diversify its tourism and to divert it from the overcrowded coastline to the Saharan region in the southwest, through ecotourism for instance.

A4. Complementary approaches to public adaptation policies

In this section, we extend the discussion of governmental action beyond neoclassical economics. So far, we have concentrated on governmental action motivated by efficiency considerations. In the public and economic debate, however, equity issues often play an important role. They are discussed in the context of public policy intervention in adaptation in the next section and in a broader context in section 3 of the main report. A somewhat related issue is public intervention in private markets due to security of supply, which is discussed in section A4.2.

A4.1. Equity aspects in the provision of public adaptation goods

In the political debate on economic policy, social justice is far more often evoked than efficiency. Economists have developed different approaches to the topic, which is usually named 'equity'. There is less consensus, however, about equity as a guiding principle for public policy or more precisely about the legitimate concept of equity. With respect to adaptation, equity issues may arise within countries, among affiliated countries (e.g. member states of a multi-state organisation) and between industrialised and developing countries. As explained in the preceding section, private adaptation may be efficient in many areas, but it need not be considered alone (Mendelsohn, 2000). This argument seems especially powerful in the international context of climate change: while developed countries bear the main responsibility for the strong increase in CO_2 emissions during the last century, climate change damages are expected to be higher for developing countries where the adaptive capacity is relatively low (Parry et al., 2005; Goklany, 2007). That notwithstanding, this is essentially a topic of development economics and such a broader perspective is taken in section 3 together with other equity issues. In this section, we focus on adaptation policy in the national context.

Traditionally, economists distinguish between vertical and horizontal equity (Atkinson and Stiglitz, 1980). Vertical equity refers to the redistribution of income between high- and low-income earners and horizontal equity refers to the principle "that those who are in all relevant senses identical should be treated identically" (ibid., p. 353). As we shall see below, both vertical and horizontal equity matter for adaptation.

To measure vertical equity, economists have introduced welfare measures for unequal income distributions in a population and used them to justify progressive taxation theoretically. While welfare measures differ, as do political views on inequality, most developed countries have legislation to protect low-income households from outright poverty. This can be based on a Rawlsian view of welfare, which aims at maximising the welfare of the least favoured in a society, while taking into account the detrimental effect of redistributive taxation on economic production. In the context of adaptation, the discussion of whether low-income households may not be able to afford adaptation is important and equity concerns may thus motivate the need for governmental action. One purpose of the country case studies is to examine if and to what extent these distributive issues arise in the context of adaptation in the Mediterranean.

Yet it is the matter of horizontal equity that may raise more complicated and controversial questions in the context of adaptation. The formulation of horizontal equity by Atkinson and Stiglitz (1980) is deliberately vague: individuals who are "identical in all relevant senses" should be treated equally. This view now has consequences for our discussion of public goods. As discussed in section 2.2 of the main report, according to the Samuelson rule it may well be efficient to shelter one agglomeration from flooding while giving up another agglomeration, depending on the relative costs and benefits. Clearly, however, such a policy decision has very different impacts on real estate property rights. If taken by a central government, the unequal treatment is likely to provoke lawsuits. Certainly, individual house-owners have no general entitlement to compensation when their homes are flooded – they have to insure against this risk on a private market or to bear the losses themselves. At the same time, the government provides flood protection and provides rescue from being flooded when needed. Unequal treatment of property in the case of a flood is unlawful. To our understanding, this issue of horizontal equity in connection with climate change has not yet been sufficiently discussed in the public discourse and may cause considerable dispute in the future.

Our considerations do not falsify the Samuelson rule: there may very well be cases where the costs to protect an agglomeration against floods exceed the likely benefits too much to justify it. To ensure horizontal equity, though, future governments will have to develop rules (and limits) for compensation for households whose property is not protected. Given the huge fiscal consequence of both adaptation and compensation, this is a great, yet unavoidable task.

A4.2. Security of supply

Security of supply is one of the stated goals of energy policy in EU law (e.g. European Commission, 2009). While mostly discussed in relation to energy, arguments of security of supply are also – directly or indirectly – used in debates on food and water supply. All these sectors face considerable challenges by climate change, and thus security of supply also matters for the debate on adaptation. Besides the regulation of network externalities in these sectors (such as the natural monopoly of net industries), government intervention can also be rationalised by the presumption that the good in question is indispensable for economic production and individual welfare: indeed, a prolonged shortage of water would have devastating effects on public health and (not only the agricultural) economy. Similarly, albeit to a lesser extent, public welfare and economic production are vulnerable to blackouts of the electricity system. The policy issue arises because companies providing water or energy in a free market are not likely to insure their consumers sufficiently against an interruption of supply: given the short-term inelastic demand for the goods, markets are likely to clear at very high prices in case of a shortage – an efficient outcome, but unacceptable if we recognise that the government should provide for the most basic human needs. The private supply of drinking water is likely to be profitable during a drought period, but – given the elementary needs of the population – the government's objective would be to ensure that there are sufficient provisions for such a situation. The same reasoning applies to the energy sector, where security of supply is viewed as an important pillar of energy policy, at least in Europe (Abbott, 2001). This does not imply, though, that the provision of the good has to be organised by public authorities: in the case of liberalised electricity markets, in many countries the grid is operated by a private monopolist, which is regulated by a public agency. Then, the grid company is obliged by law to ensure the security of the network, i.e. the security of supply. The costs are incorporated into the usage fees. In other words, specific regulation can be used to enforce security of supply in otherwise free markets, carefully trading off security against efficiency.

Apart from problems to be discussed in a national context, security of supply can be a geopolitical issue: in some regions access to drinking water is seen as a right enforceable by political and – if necessary – military means. Some economists have provided insights on the impact of natural (and more general economic) resources on military conflicts (Montalvo and Reynal-Querol, 2005; Collier and Hoeffler, 2002 and 1998). Yet any welfare analysis is difficult, as property rights are usually defined and defended on a national basis. Economists may contribute to a positive analysis of these aspects of adaptation to climate change by the study of international negotiations. These may arise, for example, in the context of access to scarce water resources or agricultural land with disputed property rights. How far climate change will exacerbate these kinds of conflicts is analysed in the context of the country case studies.

As in the case of equity issues, adaptation to climate change sheds new light on old questions of security of supply: Which goods and services are elementary, such that government intervention should guarantee their security of supply? What are the costs of such a policy? What is an acceptable level of security of supply, e.g. in the case of drinking water? Public policy on adaptation will have to find answers to these questions.

A5. Real options theory and adaptation

A5.1. Examples from the literature

In their trend-setting article on uncertainty and climate change, Heal and Kriström develop two basic applications for the theory of real options in the climate debate, which – on first view – seem to contradict one another (Heal and Kriström, 2002). On the one hand, the real options theory supports the precautionary principle: as climate change is regarded as an irreversible process, the social planner should keep open the option of effective climate protection by a sufficiently early investment in climate protection measures (this aspect concerns mitigation rather than adaptation). Alternatively, the real options theory can recommend waiting for more detailed information about the concrete impacts of climate change and not investing in irreversible measures for climate protection too early (Kolstad, 1996). This point of view would be contradictory to the precautionary principle. The same issue exists in relation to evaluating different adaptation options and remains difficult to solve at the theoretical level.

Dobes (2008) points out additional examples of applying the theory of real options in the context of adaptation to climate change: in the construction of a new runway it is important to consider the possible change in climate, because in a hotter climate longer runways may be required to allow airplanes to develop sufficient speed to take off. In this case, it would not be reasonable to build a longer runway as long as there is no certainty that the climate will heat up. The more advisable alternative would be to build a normal runway first. In addition, sufficient land at the end of the runway should be purchased to enable an extension at a later stage. A monetary valuation of this option (the value of flexibility) allows a conclusion to be drawn about the level at which the higher costs of providing building land are justified.

Furthermore, it may become useful to apply the real options theory to the field of flood protection. Protective barriers should not be built at the highest level immediately. It could be more worthwhile to construct only the base of a wall or embankment, which can be upgraded to a higher level in future. The construction of a cost-intensive protective barrier may be a wasted investment if the flood risk does not change significantly.

As shown in these examples, the construction of long-lived infrastructure, such as roads, bridges, railways or complete plants, is particularly suited to the real options investment approach. Instead of the careless construction of a road in a low-lying area with an uncertain flood risk and a possible later resettlement of the route, it is very likely less cost-intensive to purchase additional land areas that can be used for future flood protection. Once again, the maintenance of flexibility can be quantified by the option value to demonstrate the benefit of purchasing additional land.

Even if Dobes describes several examples of meaningful applications, he remarks that it may not always be easy to identify appropriate “real options” for measures designed to adapt to climate change. Nevertheless, in many cases it should be worth the effort to search for them just to prevent wasteful or premature expenditures.

Woodward et al. (2010) describes one more example of how the real options theory can be applied to the issue of flood protection. He compares different scenarios to build an embankment and concludes that the application of the real options theory can be useful to save significant costs in the construction of long-term systems for flood protection. Additional examples can be found in Beare and Szakiel.

A5.2. Feasibility of real options for the climate adaptation issues

The underlying assumptions of the real options theory are decisive for the evaluation of practical feasibility in the context of adaptation. These assumptions include the irreversibility of investments as well as uncertainty, which will diminish over time.

Considering irreversibility, one can say that a lot of infrastructure investment meets this criterion. Still, current adaptation costs, like recurring training costs or irrigation costs, are not included. Obviously, ‘no-regret’ and flexible options can be ignored as well because of their certain beneficial effects even when the climate does not change; such investments should be reasonable under all scenarios.

The assumption of disappearing uncertainty is more complex. The real options theory is based on the premise that the uncertainty in terms of the occurrence of an event will dissolve at a later date. With regard to climate change, this means that from a later date the further development of climate damages will be more clear and obvious for the decision-maker. This assumption raises doubts about the practical feasibility of the real options theory for adaptation – climate change is a complex phenomenon and depends on various physical, biological and socio-economic processes. So we can never expect to gain certainty regarding the future development of temperatures or precipitation. Yet it can be argued that a certain quantity of greenhouse gas emissions will cause a certain temperature range with high probability. Thus, it can be said – with reservations – that more data on emissions development reduces uncertainty regarding climate change.

It should be noted, however, that the cost of an investment could increase over time with the effect that the delay of an investment could lead to higher total costs. But this risk should be manageable by a prudential assumption of future cash flows. Furthermore, the application of the real options theory can be criticised if the delay of an investment leads to severe irreversible damages. Take, for example, investments in coastal protection: if, during the waiting period, it turns out that an embankment was built too low, vast areas could be lost irreversibly. In terms of calculation, this case is comparable to the case of increasing adaptation costs, with the additional challenge of estimating the costs of an irreversible loss.

Finally, it is questionable whether the calculation of the value of flexibility can be operationalised, on the one hand because of problems regarding the uncertainty as indicated above, and on the other hand because in very rare cases statistical probabilities can be assigned to stochastic climate events.

Still, the concept of the real options theory is an interesting approach for critically examining expensive and irreversible investments in adaptation goods. In particular, the value of flexibility can be calculated at least in theory. Whether the approach can be used in practical investment decisions depends on many individual factors. These include the technical feasibility of real options and the chance of relatively certain climate projections at a later date.

A6. An example of decisions on adaptation timing

One of the expected impacts of climate change particularly affecting the 11 SEMCs is the increasing drought risk. Adverse consequences include productivity losses in agriculture and drinking water shortages in urban areas. The installation of desalination plants could ensure the irrigation of agricultural areas during periods of water scarcity and prevent crop losses. In this example, we do not consider the potential maladaptation character of desalination plants, which consume so much energy that their operation induces high CO_2 emissions and hence increase the risk of adverse climate impacts, although we are well aware of this issue.

In our fictive example, we have to face a decision on the installation of a desalination plant in the year 2010. The expected lifetime and the planning period of the structure are fixed at 20 years $(T = 20)$ in our example. One decisive criterion for the optimal timing is the future climate. In our case, especially the development of future precipitation regimes is important. We further assume that the installation of the desalination plant costs €500,000 today ($AC^0 = 500000$), climate damage costs (if they occur) amount to an annual value of €100,000 in the non-adapted case ($DC_i^U = 100000$) and €20,000 if adaptation has been realised ($DC_i^A = 20000$). Finally, we assume a discount rate of 5% $(\delta^i = \frac{1}{1{,}05^i})$, for $i = 1,2,3,...,T$.

A6.1. Conventional approach using net present value

To examine the conventional approach by means of net present value, we start with the case of a certain climate change. For simplicity, we assume full information about the climate; however, the concept is also basically applicable under uncertain climate change, by replacing the certain damage costs with expected damage cost estimates. We certainly know that rising temperatures and future droughts will result in additional damage costs of €100,000 in the agricultural sector caused by crop failure or land losses ($DC_i^U = 100000$). The installation of a desalination plant helps to ensure the irrigation of agricultural areas and thereby to avoid a significant share of the damage costs. Thus, in the adapted case we consider only €20,000 as residual damage costs ($DC_i^A = 20000$).

The decision-maker may install the desalination plant now (t=0) or after ten years (t=10). For this reason there is a need to calculate the present value of the costs of our investment in either case (PV^0 or PV^{10}) to find the more cost-effective alternative. Note that the investment with the lower value is more beneficial as costs are considered.

We start to calculate the present value costs of the immediate realisation in t=0 adding the investment costs to the discounted, annual residual-damage costs:

$$PV^0 = AC^0 + \sum_{i=0}^{T} DC_i^{A0} \delta^i \quad (1)$$

Applying the assumed investment costs (AC^0) and constant, reduced damage costs (DC^{A0}) yields the following result of PV^0:

$$PV^0 = 500000€ + \frac{20000€}{1{,}05^0} + \frac{20000€}{1{,}05^1} + \ldots + \frac{20000€}{1{,}05^{20}} = 769244€ \quad (2)$$

The calculation of the present value costs of later realisation in t=10 (PV^{10}) is a bit more complex. The investment costs are reduced due to the discounting effect ($AC^t \delta^t$).

$$AC^{10}\delta^{10} = 500000€ * \frac{1}{1{,}05^{10}} = 306957€ \quad (3)$$

Furthermore, we consider two different streams of annual damage costs. In the first ten years the non-reduced, annual damage costs without adaptation amount to €100,000 (DC_i^U). Through the investment in year t these costs decrease to the reduced level of €20,000 (DC_i^{At}).

$$PV^t = AC^t \delta^t + \sum_{i=0}^{t-1} DC_i^U \delta^i + \sum_{i=t}^{T} DC_i^{At} \delta^i \quad (4)$$

As a result, we can calculate the present value costs of an investment in t=10:

$$PV^{10} = 306957€ + \frac{100000€}{1{,}05^0} + \ldots + \frac{100000€}{1{,}05^{10}} + \frac{20000€}{1{,}05^{11}} + \ldots + \frac{20000€}{1{,}05^{20}} = 1224827 \quad (5)$$

The comparison of the present values shows that the early investment in t=0 is more cost-effective. The monetary benefit of later adaptation (the monetary loss of early adaptation) is obtained by subtracting PV^{10} from PV^0:

$$PV^0 - PV^{10} = -455582 \quad (6)$$

The result is negative; thus the benefit of early adaptation amounts to €455,582. Concerning the aspect of cost-effective timing of the adaptation measure, the decision-maker should prefer the early adaptation in t=0.

In our example, the assumed costs lead to lower costs in the early adaptation case. This result could change if investment costs (AC^0) increase or the gross annual damage costs (DC_i^U) decrease. Detailed knowledge about the costs is the fundamental requirement for the application of the approach.

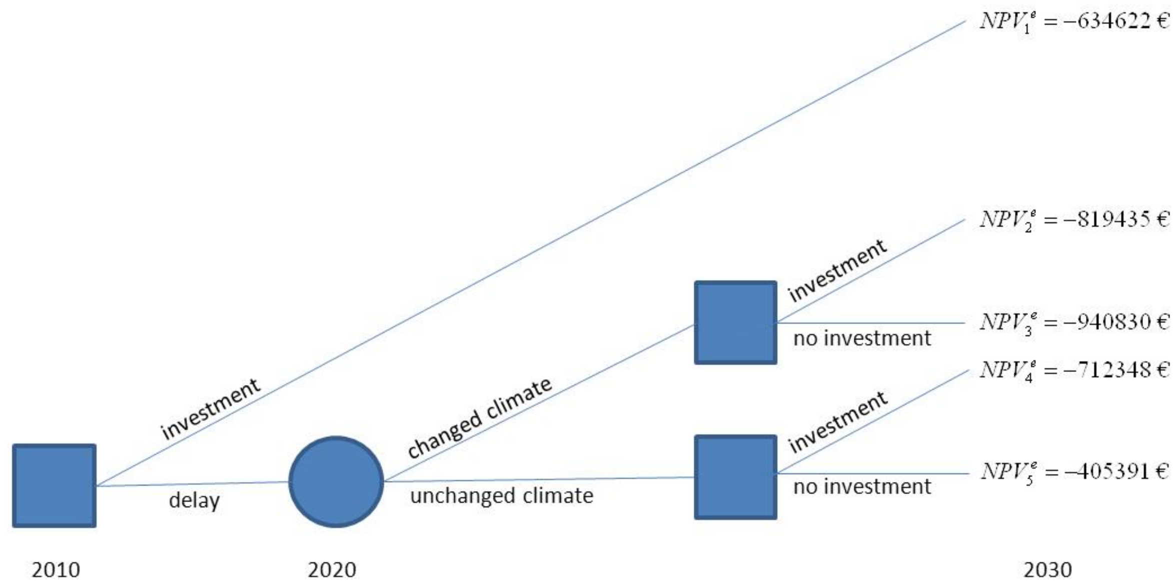
Moreover, in our example we did not consider the possibility of changes in adaptation costs or residual costs during the lifetime of the adaptation. In reality these effects should be taken into account, along with the maintenance costs of an adaptation good. This, however, will not change the basic approach presented here.

A6.2. Alternative approach using the real options theory

We now turn to the case of uncertain climate impacts and thereby approach the real situation concerning precipitation regimes in the Mediterranean. We consider two different climate scenarios for the sake of simplicity. In the first scenario, the climate will not change, so no extreme events (such as heavy droughts) will endanger the harvest ($DC_i^U = 0$). The probability of this scenario is *p*. For reasons of simplicity we set *p*=0.5. In our second scenario, the climate becomes relatively dryer. As a result, drought events lead to damages and annual crop failure costs of €100,000 in this scenario. Today, it is still unknown which scenario will be realised in the future.

Now the decision-maker has various possibilities. Either s/he decides to install the system immediately or delays this decision until s/he learns which scenario is more likely to occur. Let us assume that after ten years, in 2020, there is certainty about the climate scenario as a result of observations and measurements. If the decision-maker has decided to delay the investment in 2010, s/he may choose one of the two alternatives after ten years. Thus, there are five possible storylines.

Figure 15. Illustration of possible storylines using the real options approach.



The next step is to calculate the expected net present values (NPV) for any alternative. The discounted sum of all net cash flows is the expected NPV of an investment. We assume a discount rate of 5% and calculate different NPVs for all investment options.

If we choose option 1, we make the investment immediately in 2010; the investment costs account for €500,000. In addition, we expect annual climate-damage costs amounting to €10,000. This value stems from the following calculation:

$$\begin{aligned} & p * 0 + (1 - p)(Total\ damage\ p.a. - Avoided\ damage\ p.a.) \\ & = 0.5 * 0 + 0.5 * (100000\,€ - 80000\,€) = 10000\,€ \end{aligned} \tag{7}$$

For the purpose of calculating the NPV, all annual costs until 2030 are discounted in the year 2010.

$$NPV^e = -Costs_{t=2010} - Costs_{t=2011} - \ldots - Costs_{t=2030} \,. \tag{8}$$

We receive the NPV^e NPV^e for option 1:

$$NPV_1^e = -510000€ - \frac{10000€}{1{,}05^1} - \frac{10000€}{1{,}05^2} - \ldots - \frac{10000€}{1{,}05^{20}} = -634622€ \,. \tag{9}$$

In the case of choosing option 2, the decision-maker initially waits and sees if climate damages occur. In this option, we assume less rainfall after ten years, whereby the investment costs are incurred in 2020. In addition, the annual expected damages during the first ten years without prevention of crop failures amount to €50,000. From the date of investment, €80,000 in damage costs can be avoided annually and €20,000 remains for the expected, annual residual-damage costs over the last ten years. Considering these inputs, the NPV of the second option can be calculated as follows:

$$NPV_2^e = -50000€ - \frac{50000€}{1{,}05^1} - \ldots - \frac{50000€}{1{,}05^9} - \frac{520000€}{1{,}05^{10}} - \frac{20000€}{1{,}05^{11}} - \ldots - \frac{20000€}{1{,}05^{20}} = -819435€ \,. \tag{10}$$

In option 3, the decision-maker will not invest in adaptation measures all the time while climate damages are occurring. Although this is an irrational option, for the sake of completeness it is presented here. High annual damage costs emerge and we obtain the following NPV:

$$NPV_3^e = -50000\,€ - \frac{50000\,€}{1{,}05^1} - \ldots - \frac{50000\,€}{1{,}05^9} - \frac{100000\,€}{1{,}05^{10}} - \frac{100000\,€}{1{,}05^{11}} - \ldots - \frac{100000\,€}{1{,}05^{20}} = -940830\,€ \,. \tag{11}$$

In options 4 and 5, it becomes apparent that the climate will not change, with the result that there are no expected damage costs from the year 2020. The options differ in the investment decision. While we consider additional investment costs in option 4 (which is again an irrational choice), the expected damage costs remain only over the first ten years in option 5. The NPVs can be calculated in the usual way.

$$NPV_4^e = -50000€ - \frac{50000€}{1{,}05^1} - \ldots - \frac{50000€}{1{,}05^9} - \frac{500000€}{1{,}05^{10}} - \frac{0€}{1{,}05^{11}} - \ldots - \frac{0€}{1{,}05^{20}} = -712348€ \tag{12}$$

$$NPV_5^e = -50000€ - \frac{50000€}{1{,}05^1} - \ldots - \frac{50000€}{1{,}05^9} - \frac{0€}{1{,}05^{10}} - \ldots - \frac{0€}{1{,}05^{20}} = -405391€ \tag{13}$$

To make a decision regarding investing now or waiting for better information, we additionally calculate the ‘value of flexibility’. If we attain a positive value, it is recommended to delay the investment at first and to invest after the uncertainty with regard to climate scenarios has diminished.

To calculate the value of flexibility, the highest NPVs of the delay options are weighted according to their probability. The NPV of the direct investment option is subtracted from this sum:

$$V^{e} = (1-p)*\max(NPV_{2}^{e}, NPV_{3}^{e}) + p*\max(NPV_{4}^{e}, NPV_{5}^{e}) - NPV_{1}^{e}$$
$$V^{e} = \frac{1}{2}*(-819435€) + \frac{1}{2}*(-405391€) - (-634622€) = 22209€ \quad . \tag{14}$$

The value of flexibility is positive. From this result it can be concluded that it is more beneficial to delay the investment until 2020 independent of the climate scenario taking place. Moreover, the value of flexibility is used to identify the costs up to which a purchase of this flexibility is rational. In the example, the firm considering the installation of the plant could gain assurance that the system could be built in 2020 for the calculated price of €500,000, e.g. through conditioned contracts with suppliers and current landowners. For savings, this option has a monetary value up to €22,209.

A7. Adaptation and mitigation

A7.1. Major differences with economic implications

Adaptation and mitigation, although pursuing the same objective (a reduction of residual climate costs), exhibit major differences, which have implications for their economic evaluation.

First, the **locations** where the policies are implemented and effective vary. Whereas mitigation from an economic point of view is clearly attributed to the global level, most adaptation activities are to be taken at the local or regional level.[16] Thus, the relevant actors also differ. Cooperation is much more relevant and more difficult to achieve in mitigation than in adaptation projects.

The second major difference lies in the aspect of **timing**. It is commonly acknowledged that mitigation tackles the long-term causes of climate change and becomes effective mainly in the future, whereas adaptation is also able to reduce the short-term damages. In the domain of adaptation, even reactive action is possible – i.e. adjustment to the climate effects experienced. This concept of reactive action is hardly possible in the domain of mitigation. These differences have implications for the economic evaluation of both strategies:

1) The discounting assumptions of future damages and benefits are crucial for the optimal mix of adaptation and mitigation (Antweiler, 2011). High discount rates imply a relatively low value of future policy benefits and would speak in favour of adaptation, as it has more benefits in the short term than mitigation. Lower discount rates would work in the opposite direction.

2) The differences in timing suggest a certain sequence of policies: mitigation should be pursued immediately; adaptation may follow later (Bosello et al., 2010; Wang and McCarl, 2011). There are two reasons for this sequence: mitigation effects come with a large time lag because of slow changes in the carbon-climate cycle. Second, mitigation involves innovation and decarbonisation of the energy sector, which is only achievable after some time.[17]

Third, both mitigation and adaptation are affected by **different kinds and sources of uncertainty**. If global mitigation is compared with local preventive adaptation, it is argued that the uncertainty of policy benefits should be greater for the adaptation alternative (Lecocq and Shalizi, 2007). Whereas in

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[16] The only example where adaptation requires action at the global level is the enhancement of adaptation capacity, e.g. the raising of funds for adaptation projects in poor countries or large-scale education programmes (Tol, 2005).

[17] The suggestion of a sequence of policies has implications for the question regarding the complementary character of adaptation and mitigation (which is treated in depth in the next section). If adaptation follows mitigation in terms of timing, this is a case in which the strategies are complements rather than substitutes (Bosello et al., 2011).

the case of mitigation, the uncertainty over the shape of global damage functions as the only uncertainty that matters, in the case of adaptation the identification of exact locations and affected groups (households, sectors and countries) is also relevant. This argument, however, is weakened by the fact that mitigation benefits appear rather in the longer term, which aggravates the uncertainty problem again relative to adaptation.

A7.2. Complements or substitutes?

In the literature, there is an ongoing debate on the question of whether mitigation and adaptation are complements or substitutes. Although the authors use slightly different definitions of complementarity, it generally means some kind of positive effect of one policy on the net benefits of another. Economically speaking, substitutability implies (*ceteris paribus*) an increasing demand for adaptation if the costs of mitigation increase – and vice versa. In other words, a crowding-out of policies can be observed. In contrast, the two policies are complements in an economic sense if (*ceteris paribus*) a decrease of mitigation costs induces greater mitigation efforts and thereby raises the efficacy of adaptation, hence causing a higher demand for adaptation. This section sheds light on this discussion and presents major contributions with their views on the topic.

One strand of literature argues for the standpoint of adaptation and mitigation as substitutes. Tol (2005) highlights the substitutability of climate policies and states that for this reason the two policies have to be analysed together. In this vein, he proposes the "double trade-off" of mitigation and adaptation. The first trade-off stems from the restriction of resources, which makes a decision on the preferred policy necessary – resources spent on mitigation are lost for adaptation and vice versa. The second trade-off stems from the efficiency of policies: if mitigation is pursued, climate change damages are expected to be reduced, thus marginal adaptation benefits will decrease and adaptation becomes less efficient – and vice versa. A similar argument is supported by Ingham et al. (2005), who illustrate the case of economic complementarity as a very unlikely combination of presumptions. Also, in one of the first contributions to the adaptation–mitigation nexus, Kane and Shogren (2000) acknowledge the possibility that the two policies can be clear substitutes, especially in the case of some technical adaptation options that have adverse effects on mitigation efforts, namely in the agricultural sector.

On the other side, Bosello et al. (2010 and 2011) argue that both strategies are complements in the sense that only together do they achieve full effectiveness; however, Bosello et al. (2010) also admit that both strategies have to be weighed up because of the double trade-off described by Tol (2005), as mentioned above.

A further contribution is worth noting: Bosello and Chen (2010) examine how the introduction of uncertainty influences the optimal mix of adaptation and mitigation. With regard to the crowding-out of policies, they state that both policies are still substitutes to some extent, but the crowding-out effect becomes weaker under uncertainty. This stems from the fact that in their theoretical model, mitigation (in contrast to adaptation) is able to reduce the risk of catastrophic climate damage and is more robust in terms of spatial uncertainty (i.e. where damage occurs).

A7.3. Determinants of the optimal policy mix and the role of uncertainty

This section summarises the literature on the economically optimal mix of policies and residual damages. As both adaptation and mitigation in essence work in the same direction of reducing climate damages but exhibit major differences in cost and benefit structures and their sensitivity to uncertainty, their optimal (i.e. most cost-efficient) mix is not a trivial issue. In most cases, a complete reduction of climate damages by aggressive mitigation or adaptation (or both) will not be efficient, so the question of the optimal policy mix must always tackle the question of the optimal residual damage level. In a first step, we summarise some suggestions of how determinants work in the different directions in terms of mitigation vs. adaptation in the optimal mix. Second, we focus on the topic of how the introduction of uncertainty (and which kind of uncertainty) changes the optimal policy mix. Again, the literature examined is almost entirely characterised by theoretical optimisation models, which are currently difficult to operationalise due to scarce empirical findings on the costs and benefits of climate policies. Thus, most authors restrict themselves on showing tendencies, e.g. stating the direction in which the optimal policy mix shifts owing to a relative increase of a certain factor.

Regarding the main determinants of the optimal policy mix, Antweiler (2011) mentions two main factors: the mitigation/adaptation cost ratio (which is intuitive) and the climate change damage elasticity, whereby the latter is dependent on the non-linearity of climate change. More rapid and sudden damage from climate change implies an increase in both adaptation and mitigation, but the increase in mitigation should be greater, and thus the mitigation/adaptation ratio also rises. Moreover, the author finds that the introduction of multiple heterogeneous countries – in comparison with the single country case – enhances the attractiveness of adaptation.

The results of Settle et al. (2007) go somewhat in the same direction. They state that according to their model, adaptation is rather more attractive (relative to mitigation) if nations are unlikely to cooperate. But, regarding the nature of damages, their model suggests that if damages are catastrophic instead of continuous, adaptation should again be preferred to mitigation. Still, the time preferences play a role: short planning horizons imply a higher preference for mitigation whereas long planning horizons speak in favour of adaptation.

An opposite view is proposed by Wang and McCarl (2011). As mitigation is designed to tackle the long-run cause of climate change, the time dimension speaks for mitigation if climate damages predominantly long-lived capital. Also, Bosello et al. (2010) conclude from their model that mitigation is relatively preferable when the discount rate of decision-makers is low.

Another approach is chosen by Brechet et al. (2010), who analyse the impact of economic development on the optimal mix a country should follow. They find that the optimal ratio of adaptation/mitigation depends on the economic efficiency (or state of development) of the respective country and this dependence is characterised by an inverted U-shape. In other words, the middle-income countries should pursue more adaptation than the low- and high-income countries – always in relation to their mitigation efforts. One important drawback of this study is the assumption of the closed economy. The model in its current form works for the world as one or for closed economies, but ignores international effects (e.g. externalities and the reactions of external partners).

These results (which are sometimes clearly contradictory to one another) give a hint of the complexity of this issue. More importantly, they show the high dependency on the underlying assumptions in the theoretical models. It is quite relevant whether adaptation is seen as a stock or as a flow variable, what lifetime is assumed for adaptation and mitigation investments, how efficient the measures are expected to be with regard to climate effects and how exactly the climate damage is modelled (continuous vs. catastrophic, early vs. late, etc.). At the moment, the uncertainties of these and other parameters do not allow a definite answer on which models best capture the complex interdependencies of adaptation and mitigation. Furthermore, the optimal policy mix is also affected by climate uncertainty per se. This is summarised in the following discussion.

The introduction of uncertainty shifts the optimal policy mix in the direction of mitigation. This at least is the common finding of Lecocq and Shalizi (2007) and Bosello and Chen (2010). Both articles consider the spatial uncertainty of damages. If the location of damages is unknown, the expected benefits of proactive adaptation (which in most cases has to be targeted at a specific location) are reduced. Bosello and Chen (2010) deliberately distinguish between spatial and catastrophic uncertainty and conclude that both kinds of uncertainty shift the optimal policy mix towards mitigation, the first by raising the robustness of mitigation and the second by raising the relative importance of mitigation. Nevertheless, at least the second conclusion (that catastrophic uncertainty raises the relative importance of mitigation) is driven by the assumption that adaptation cannot reduce the costs of catastrophic climate change. Finally, Bosello et al. (2010) mention that if the probability of catastrophic events is small, adaptation is relatively more attractive in comparison with mitigation than when the probability is higher.

A8. Literature review and adaptation costs

A8.1. Tables presenting the literature review

Table 9. Literature review of climate change impacts and adaptation studies for the 11 SEMCs (by reference number to the literature sources in Table 10)

Literature base on adaptation in the 11 SEMCs	**Sectors**																			
Countries	**Water supply**		**Energy**		**Health**		**Agriculture**		**Ecosystems/ biodiversity**		**Tourism**		**Fishery**		**Migration and conflicts**		**Coastal protection**		**Various**	
	No.	**Adapt. incl.**	**No.**	**Adapt. incl.**	**No.**	**Adapt. incl.**	**No.**	**Adapt. incl.**	**No.**	**Adapt. incl.**	**No.**	**Adapt. incl.**	**No.**	**Adapt. incl.**	**No.**	**Adapt. incl.**	**No.**	**Adapt. incl.**	**No.**	**Adapt. incl.**
Algeria			4				56	X									25		1	X
							83	X												
Egypt	10	X	5		7	X	10	X			7	X	6		6		25			
	7	X			6		6				63						10	X		
	9						17	X			64						8	X		
	6						7	X			48	X					7	X		
	16	X					16	X			90	X					9			
	40	X					57	X									16	X		
	46	X					65	X									17	X		
	61						66	X									6			
	62						84										61			
	67						88	X									89	X		
	68																91			
																	95	X		

Table 9. Cont'd

Literature base on adaptation in the 11 SEMCs	**Sectors**																			
Countries	**Water supply**		**Energy**		**Health**		**Agriculture**		**Ecosystems/ biodiversity**		**Tourism**		**Fishery**		**Migration and conflicts**		**Coastal protection**		**Various**	
	No.	**Adapt. incl.**	**No.**	**Adapt. incl.**	**No.**	**Adapt. incl.**	**No.**	**Adapt. incl.**	**No.**	**Adapt. incl.**	**No.**	**Adapt. incl.**	**No.**	**Adapt. incl.**	**No.**	**Adapt. incl.**	**No.**	**Adapt. incl.**	**No.**	**Adapt. incl.**
Israel	36	X	36	X	36	X	36	X									25			
	37	X	37	X	37	X	37	X									36	X	31	X
	43						32	X									37	X		
	52	X					33													
							34													
							78													
							85	X												
							94	X												
Jordan	11	X	12	X	11	X	11	X											86	X
	12	X			13	X	12	X												
	13	X					13	X												
	43						60													
	52	X																		
	60																			
Lebanon	14		18				14		14								14		18	
	43						56	X												
	45	X																		
	52	X																		
	87	X																		
Libya	3																			

Table 9. Cont'd

Literature base on adaptation in the 11 SEMCs	**Sectors**																			
Countries	**Water supply**		**Energy**		**Health**		**Agriculture**		**Ecosystems/ biodiversity**		**Tourism**		**Fishery**		**Migration and conflicts**		**Coastal protection**		**Various**	
	No.	**Adapt. incl.**	**No.**	**Adapt. incl.**	**No.**	**Adapt. incl.**	**No.**	**Adapt. incl.**	**No.**	**Adapt. incl.**	**No.**	**Adapt. incl.**	**No.**	**Adapt. incl.**	**No.**	**Adapt. incl.**	**No.**	**Adapt. incl.**	**No.**	**Adapt. incl.**
Morocco	15						15				90	X					15		53	X
	19						19													
							56	X												
							83	X												
Syria	43						56	X											80	X
Tunisia	3				54	X	21	X	20								25			
	20						55	X									20			
	55	X					56	X									58	X		
							57	X												
							81	X												
Turkey	23		27	X	35	X	23		35	X	74	X	38	X			25			
	27	X	35	X	38	X	27	X	38	X							23			
	38	X	38	X			35	X									35	X		
	42	X	39				38	X									38	X		
	71						39										41	X		
	76	X					56	X									69			
							75	X									73			
							3										76	X		

Table 9. Cont'd

Literature base on adaptation in the 11 SEMCs	**Sectors**																			
Countries	**Water supply**		**Energy**		**Health**		**Agriculture**		**Ecosystems/ biodiversity**		**Tourism**		**Fishery**		**Migration and conflicts**		**Coastal protection**		**Various**	
	No.	**Adapt. incl.**	**No.**	**Adapt. incl.**	**No.**	**Adapt. incl.**	**No.**	**Adapt. incl.**	**No.**	**Adapt. incl.**	**No.**	**Adapt. incl.**	**No.**	**Adapt. incl.**	**No.**	**Adapt. incl.**	**No.**	**Adapt. incl.**	**No.**	**Adapt. incl.**
Mediterranean (non-specific)	28	X	28	X			22	X	48	X	26				28	X	28	X	47	X
	43	X	77				28	X			28	X					48	X	50	X
	44						44	X			29									
	48	X					48	X			51	X								
	59	X					49	X												
	77						56	X												
							77													

Source: Authors' compilation.

Table 10. Literature sources in Table 9

No.	Reference
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Source: Authors' compilation.

A8.2. Adaptation costs

For the purpose of getting an overview of the available literature on adaptation costs in the 11 SEMCs, we examined all available reports, articles, papers and country studies that concern adaptation costs in this area. In this context, we investigated the texts on considered measures, quantitative adaptation costs and the methods applied. The result of our review is Table 11, which contains 12 sources with concrete information about quantitative adaptation costs, yet only 3 of them are single country studies. This shows the sparse availability of adaptation cost studies particularly referring to the 11 SEMCs. Moreover, 6 of the 12 entries refer to a single report. In addition to the adaptation cost studies that were found in the published literature, in the context of the MEDPRO project a note by Bosello (2012) on adaptation costs was prepared (Table 11). This note gives rough estimates of the costs for protecting the biodiversity and protected areas of the 11 SEMCs for neutralising the adverse effects of climate change.

The comprehensive study on the *Economics of Adaptation to Climate Change* (EACC) assesses the risks posed by climate change and models adaptation activities (see World Bank, 2010a-f in Table 11). The reports of the study include estimated quantitative adaptation costs for the entire world in seven various sectors. Estimations for the MENA region have been carried out for five of seven sectors considering two different climate change scenarios. A systematic evaluation shows total net costs for annual adaptation of between $2.3 and $2.4 billion in 2010–50, the majority of them in the infrastructure sector. An interesting point is that adaptation in the water supply sector will lead to net benefits in the drier climate scenario. Another aspect worth mentioning concerns the relatively low adaptation costs in the agricultural sector. These stem from the applied methodology in this sector, which is based on the occurrence and reduction of malnutrition. Even if climate change is expected to have a severe negative impact on the agricultural yields in the 11 SEMCs, this does not translate into high adaptation costs given that malnutrition is not so dominant in this region, even under climate change conditions. More information on the methodologies of adaptation cost estimations is given in the subsequent sections, split by the affected sectors.

All absolute cost numbers should be treated with caution, because of significant uncertainties and the structure of the MENA region, which includes the Arabian Peninsula but excludes Turkey.

In addition to the World Bank's EACC study, which can give a rough impression of adaptation costs, we found two associated reports that use the integrated assessment model AD-WITCH. This method links the different effects of adaptation, mitigation and climate change damages and calculates the optimal cost-effective combination of adaptation and mitigation measures, while it differentiates between "reactive adaptation", "anticipatory adaptation" and investments in "adaptation capacity". For the MENA region the model suggests total, annual adaptation expenditure amounting to $941 billion until the year 2100.

Table 11. Literature review on adaptation costs in the 11 SEMCs

Source	Region	Smallest spatial unit	Timeframe	Sector	Climate change scenarios	Considered measures	Quantitative adaptation costs	Methods	Other remarks
World Bank (2010a), *The Economics of Adaptation to Extreme Weather Events in Developing Countries*, World Bank, Washington, D.C.	World	Middle East and North Africa	2010–50	Adaptation to extreme weather events	Two global climate models: “wet” (NCAR) and “dry” (CSIRO)	The additional education of young women is considered. The literature has suggested that higher education levels imply fewer disasters.	Costs are considered in relation to how many additional young women would have to be educated to neutralise the increased vulnerability caused by increasing climate change and the risk of extreme weather events, with these results: • NCAR in 2050 (in thousands), 244 new primary and 372 new secondary students; • CSIRO in 2050 (in thousands), 219 new primary and 323 new secondary students; • Total costs in 2050, NCAR, $958 million CSIRO, $892 million.	The fixed-effect estimations of risk equations link losses from floods and droughts during the period 1960–2003 to three basic determinants: the risk of death from a flood, the risk of being affected by a flood, and the risk of being affected by a drought. These estimated risks in combination with socio-economic factors and climate scenarios are used to calculate specific costs for different regions.	A strong upward bias in cost estimations is expected, because adaptation is modelled as the restoration of the no-climate-change state.
World Bank (2010b), *The Costs of Adapting to Climate Change for Infrastructure*, World Bank, Washington, D.C.	World	Middle East and North Africa	2010–50	Infrastructure	Two global climate models: “wet” (NCAR) and “dry” (CSIRO)	No concrete measures are considered.	The additional infrastructure cost of adapting to climate change in 2050 (total costs for all infrastructure sectors) is $1 billion (both scenarios).	Estimation is made of the infrastructure costs of a baseline scenario without climate effects. Estimation is also made of the additional costs due to climate change according to different assumptions and literature sources.	A strong upward bias in cost estimations is expected, because adaptation is modelled as the restoration of the no-climate-change state.

Table 11. Cont'd

Source	**Region**	**Smallest spatial unit**	**Timeframe**	**Sector**	**Climate change scenarios**	**Considered measures**	**Quantitative adaptation costs**	**Methods**	**Other remarks**
World Bank (2010c), *The Costs of Agricultural Adaptation to Climate Change*, World Bank, Washington, D.C.	World	Middle East and North Africa	2010–50	Agriculture	Two global climate models: "wet" (NCAR) and "dry" (CSIRO)	Investments to increase agricultural productivity are considered, i.e. agricultural research, improvements in irrigation efficiency, the expansion of irrigated area and rural road construction	The additional annual investment expenditure needed to counteract the effects of climate change on nutrition (in million US $ at 2000 prices) are as follows: • NCAR, $206 million; and • CSIRO, $230 million. There are slightly higher costs if only developing countries invest.	The effects of climate change are estimated by using the IMPACT model. Different effects are calculated: effects on yields and crop production, and climate change impacts on agriculture and human well-being. Adaptation is modelled as the reduction of the number of malnourished children up to the number under no-climate-change conditions.	A strong upward bias in cost estimations is expected, because adaptation is modelled as the restoration of the no-climate-change state.
World Bank (2010d), *Cost of Adapting Fisheries to Climate Change*, World Bank, Washington, D.C.	World	Middle East and North Africa	2010–50	Fisheries	Two global climate models: "wet" (NCAR) and "dry" (CSIRO)	This study considers any action taken to reduce the risk posed by the impact of climate change developments on the gross revenues obtained from fisheries.	The estimated, annual actual adaptation costs (in billion US $ at 2005 prices) are as follows: • mild scenario, $0.12-0.28 billion; and • severe scenario, $0.24-0.40 billion.	Four steps are involved: 1) determination of the potential loss/gain in landed values or gross revenues; 2) calculation of estimated household incomes from global fisheries under different climate change scenarios; 3) determination of the amount of endowment needed to replace lost gross revenues at the global and regional levels; and 4) estimation of direct (actual) adaptation costs under climate change using historical cost data.	This is the first attempt to estimate adaptation costs in the fishing sector. So the numbers presented are uncertain and may be a conservative estimate of the potential costs.

Table 11. Cont'd

Source	Region	Smallest spatial unit	Timeframe	Sector	Climate change scenarios	Considered measures	Quantitative adaptation costs	Methods	Other remarks
World Bank (2010e), *Costs of Adaptation Related to Industrial and Municipal Water Supply and Riverine Flood Protection*, World Bank, Washington, D.C.	World	Middle East and North Africa	2010–50	Water supply and riverine flood protection	Two global climate models: "wet" (NCAR) and "dry" (CSIRO)	In the water supply sector, adaptation measures can be divided into supply-side and demand-side measures. In terms of flood protection, adaptation options can either reduce the probability or magnitude of flood events or can reduce the impacts of floods.	The average annual net costs of adaptation in the industrial and municipal water supply sector (in billion US $) are as follows: • CSIRO, -0.39 billion (benefit); and • NCAR, 0 (neutral effect). The average annual net costs of adaptation in terms of riverine flood protection (in billion US $) are as follows: • CSIRO, $0.46 billion; and • NCAR, -$0.29 billion (benefit).	Estimation is made of climate change adaptation costs in the industrial and municipal water supply sectors and the costs for riverine flood protection in consideration of geographical, socio-economic and climate change effects.	The absolute cost numbers should be treated with caution because of significant uncertainties.
World Bank (2010f), *The Economics of Adaptation to Climate Change*, Synthesis report, final consultation draft, World Bank, Washington, D.C.	World	Middle East and North Africa	2010–50	All analysed sectors	Two global climate models: "wet" (NCAR) and "dry" (CSIRO)	All measures in all sectors	The total annual net costs of adaptation for all sectors (in billion US $ at 2005 prices) are as follows: • CSIRO, $2.4 billion; and • NCAR, $2.3 billion.	This study gives a summation of the estimated costs of all the different World Bank papers.	Compared with the UNFCCC (2007) study, the estimated costs are high.
Fankhauser, S. (1998), *The Costs of Adapting to Climate Change*, GEF Working Paper No. 16, GEF, Washington, D.C.	World	Egypt	Unknown	Coastal protection	Unknown	Measures to reduce the coastal flooding risk	The cost of adaptation measures are as follows: • Egypt, 0.45% GNP/year; and • South Mediterranean, 0.07% GNP/year.	Unknown	Adaptation measures increase the number of people at risk in Egypt, because they allow people to remain in risk areas that would otherwise be abandoned.

Table 11. Cont'd

Source	**Region**	**Smallest spatial unit**	**Timeframe**	**Sector**	**Climate change scenarios**	**Considered measures**	**Quantitative adaptation costs**	**Methods**	**Other remarks**
Agrawala, S., et al. (2004), *Development and climate change in Egypt: Focus on coastal resources and the Nile*, Working party on global and structural policies, OECD, Paris.	Egypt	Egypt	Unknown	Coastal protection	No scenarios	Beach nourishment techniques, breakwaters, change in land use and legal development regulations are considered.	No quantitative costs are considered. The costs for beach nourishment measures are low compared with installing breakwaters or changes in land use.		
Bosello, F., et al. (2010), *Climate Policy and the Optimal Balance between Mitigation, Adaptation and Unavoided Damage*, Nota di lavoro 32.2010, FEEM, Milan.	World	MENA	2010–2100	All sectors	Doubling of CO_2 concentration and temperature increase of about 2.5°C above preindustrial levels	All measures in all sectors	The estimated calibrated adaptation cost in AD-WITCH is 1.01% of GDP.	The integrated assessment-modelling framework AD-WITCH is used, which links adaptation, mitigation and climate damage.	
Bosello, F., et al. (2011), *Adaptation Can Help Mitigation: An Integrated Approach to Post-2012 Climate Policy*, Nota di lavoro 69.2011, FEEM, Milan.	World	MENA	2005–2100	All sectors	Doubling of CO_2 concentration and temperature increase of about 2.5°C above preindustrial levels	All measures in all sectors	The adaptation costs from 2005 to 2100 in net present values (3% discounting, in billion US $ at 2005) are as follows: • expenditure on reactive adaptation is $278 billion; • investment in anticipatory adaptation is $414 billion; • investment in adaptive capacity is $249 billion; and • total adaptation expenditures are $941 billion.	The integrated assessment-modelling framework AD-WITCH is used, which links adaptation, mitigation and climate damage.	

Table 11. Cont'd

Source	Region	Smallest spatial unit	Timeframe	Sector	Climate change scenarios	Considered measures	Quantitative adaptation costs	Methods	Other remarks
UNFCCC (2010), *National Environment and Economic Development Study for Climate Change, Jordan National Report*, Submitted to the UNFCCC, Bonn.	Jordan	Jordan	2010–50	Agricultural and water sectors	Expected reduction of water availability from surface and groundwater sources (40%) and a temperature increase (2-4°C)	This study considers 8 proposed adaptation measures for the agricultural sector and 17 for the water sector (overviews given in Tables 5 & 6).	The additional cost of the proposed adaptation projects for the agricultural sector up to 2020 is $154.3 million. The additional cost of the proposed adaptation projects for the water sector up to 2020 is $1.47 billion. (The costs of specific projects are listed in Tables 5 & 6.)	Estimation is made of the cost of future projects and programmes due to climate change in consideration of vulnerability to climate change, different climate change scenarios and the costs of potential projects.	
Bosello, F. (2012), "Assessment of Economic and Climate Change Pressures on Biodiversity in MED-11 Coastal Areas and Possible Management Strategies: The cost of adaptation in the tourism sector", note in the context of the MEDPRO project.	11 SEMCs	Countries	2003–50	Environmental protection and biodiversity	Quantifying the four MEDPRO scenarios, using a temperature increase of +1.9°C and differences in the importance of the tourism industry in 2050	To recover 100% of the protection costs, the study uses unit costs times country hectares of terrestrial and marine areas (Lopez et al., 2006).	The adaptation costs of biodiversity losses in the 11 SEMCs (% of total GDP) are as follows: 1) with no increase in protection (BAU scenario), 0.013; 2) Decline and Conflict scenario, 0.003; 3) Enhanced Cooperation scenario, min. 0.104 and max. 0.34; and 4) Fragmented Cooperation scenario, min. 0.05 and max. 0.17.	To estimate the total "current" expenditure for protected areas, the study uses average expenditure per ha of protected area and the flow of biodiversity-related foreign aid. These data are assumed for the BAU scenario. For three alternative scenarios, parameters are roughly estimated.	The cost estimation regards conservation/ management of protected areas at present and the costs of biodiversity protection under climate change conditions.

Source: Authors' compilation.

As already mentioned, the majority of adaptation cost estimates stems from the study by the World Bank (2010a-f in Table 11). Thus, we see the need to analyse the costing methodology of this study a bit more thoroughly. In the following discussion, all World Bank estimates from it are reassessed in terms of methodology and consequent limitations.

Infrastructure

To calculate the additional infrastructure costs of adapting to climate change, the investment costs of a baseline scenario without climate change were compared with changed investment costs due to different climate change scenarios. The exact estimation required various steps: initially, baseline projections of infrastructure were constructed, including an efficient stock of infrastructure assets for periods from 2010 to 2050. These projections take into account standard assumptions about income and population growth, population structure and urbanisation. The unit costs used to calculate the value of new investments were compiled from a large variety of World Bank and other sources. In a second step, projections of climate variables were added from two climate scenarios (the NCAR and CSIRO scenarios). These variables were used to determine changed infrastructure quantities under the alternative climate scenarios. On the basis of a complex dose-response relationship function, the altered unit costs of infrastructure caused by climate change were calculated. To estimate the total, additional infrastructure costs of adapting to climate change in the MENA region, the costs owing to the changed infrastructure quantities as well as the altered unit costs of infrastructure were considered and added to the total adaptation costs of $1 billion for the MENA region in both scenarios.

The main problem with this procedure is a two-sided uncertainty with regard to the projections of asset quantities and prices. The first is caused by the expected assumptions about income and population growth, which cannot be predicted with a high degree of certainty. The other uncertainty results from the generalisation of the dose-response relationship function. The use of this approach does not allow a sophisticated distinction among individual adaptation measures and only very general differentiation among infrastructure types.

Extreme weather events

In the calculation of adaptation costs to extreme weather events, the scarcity of available data hindered an estimation of direct cost measures in the form of cost functions that could be used for projections. Instead, an indirect approach was used, considering the question of how many additional young women would have to be educated to neutralise the increased vulnerability caused by an increasing risk of extreme weather events. The fact that improvements in female education are powerfully associated with reductions in disaster risks was used to determine the costs of educating as many primary and secondary students as required for "climate change neutralisation". Considering an anticipated change in precipitation, the increase in additional educated women that would be just sufficient to restore the risk level prior to the precipitation change was calculated, with the result that the MENA region would have to educate between 219,000 and 244,000 new primary as well as between 323,000 and 372,000 new secondary students in 2050. The resulting regional adaptation costs to extreme weather events, depending on the climate change scenario, range from $892 million to $958 million.

The data limitations on this topic lead to the described indirect approach with restricted validity of the results. Aside from the education of young women, other important adaptation measures, such as building measures, cannot be taken into account. Considering only one possible adaptation measure would expectedly lead to an overestimation of the real adaptation costs.

Water supply and riverine flood protection

The costs of adaptation in terms of water supply were defined as the costs of providing enough raw water to meet future industrial and municipal water demand. Therefore, the costs were estimated for three different scenarios. In the baseline scenario, socio-economic data were used to estimate the future water demand. The second scenario considered both socio-economic and climatic changes. The third scenario yielded the difference between the previous two scenarios and hence considered only climatic changes. Along with future demand, the additional requirement for reservoir storage capacity was calculated by using storage-yield curves that show the storage capacity needed to provide a given firm yield and reliability of water supply over the course of a year. Based on that data, the cost of reservoir storage construction in the MENA region was estimated to be between 0 (neutral effect) and $-0.39 billion (benefit), depending on the specific scenario.

In a similar manner, the adaptation costs in terms of riverine flood protection – defined as the cost of providing flood protection – against the 50-year monthly flood in urban areas and the 10-year monthly flood in agricultural areas were estimated for the three scenarios again. The magnitude of the 10-year and 50-year monthly floods was estimated by using a specific rainfall-runoff model and the costs of providing these standards of flood protection were assumed to be $50,000 per km² for urban areas, and $8,000 per km² for agricultural areas (the assumptions were derived from the review of different reports). In the MENA region, costs of between $-0.29 billion (benefit) and $0.46 billion were estimated. The significant uncertainty of data used for the estimation limits the validity of the results. Thus, the absolute cost numbers should be treated with caution.

Agriculture

For estimating the adaptation costs in the agricultural sector, an indirect approach similar to the one for extreme weather events was used. Three investment types (public spending) were measured to restore child malnutrition as its baseline (i.e. for the neutralisation of the effects of climate change on child malnutrition): agricultural research, rural roads and irrigation. Hence, to calculate the investment costs of adapting to climate change, the investment costs of a baseline scenario (a world without climate change) were compared with the changed investment costs due to different climate change scenarios. The target was to calculate the required agricultural productivity growth to fulfil a neutralisation of effects on malnutrition and to estimate the investment costs to generate that growth.

The estimation required different steps: at the beginning, a scenario of no climate change was constructed and the number of malnourished children under age 5 for the year 2050 was estimated. Data to estimate the cross-country regression, the percentage of malnourished children, were derived from the World Development Indicators, FAOSTAT and the UNESCOSTAT. The assumption for this regression was that life expectancy, maternal education and access to clean water were held constant over time. The next step was to run a scenario with climate change and to estimate the number of malnourished children in 2050 again. Finally, the last step was to find a composition of increases in agricultural productivity growth rates, through which a scenario with climate change is produced that results in the same number of malnourished children as in the no-climate-change scenario. With these results the required investment costs were calculated.

The agricultural research investments were estimated on the basis of historical rates of expenditure growth (for example published research and other R&D expenditures). The time lag between the investment and the effects on productivity were also considered in the estimation. To estimate the investment cost in rural roads, area expansion and yield growth were considered. Any growth in cropped area led to a one-to-one growth of rural roads (e.g. to deliver goods) and a higher density of rural roads implies decreased transaction costs and so forth. Irrigation investments were estimated by an expansion of the irrigated area and the improvement of water use efficiency.

Considering these estimations, the total results for the MENA region showed nearly similar findings between the NCAR and CSIRO scenarios. The resulting costs of agricultural adaptation ranged between $206 million and $230 million.

General shortcomings of the regarded estimation are that several categories of climate change impacts exist (not only the effect on malnourished children), but due to a lack of data it is not possible to model them. The integration of these categories would surely lead to more considerable negative effects of climate change (for example on livestock, weeds or the sea level rise on coastal agricultural areas). Furthermore, the individual adjustment costs of farmers or traders and the changed production potential in 2050 are not considered. Finally, the changeability of climate change and extreme events are not included either.

Fisheries

To estimate the changes in production and the possible loss/gain in fishery catches due to a redistribution of biomass, different climate change scenarios were used. The marine adaptation cost was estimated in various steps. Initially, data about adaptation measures to counteract declining biomass (buybacks,[18] fishing quotas, livelihood diversification measures, etc.) were collected. The next step, after splitting the world into developed and developing countries, was to calculate the average costs with the available country-specific data. The gross fisheries revenue for the baseline projections (a world without climate change) was estimated by an NPV calculation for 2010 to 2050.

To capture the adaptation expenditures four variables were estimated: the potential loss/gain in gross revenues or ex-vessel landed values, household income from the marine sector under various climate change scenarios, the required endowment to substitute lost revenues, and finally (with the use of historical data), predicted adaptation expenditures under a climate change scenario. The predicted annual costs of adaptation under various climate change scenarios for the MENA region differ significantly between the two scenarios. For example, an over-exploitation of biomass in a severe scenario would lead to $240 million in adaptation costs, twice as much as in a mild scenario.

The main problems in the calculation of adaptation expenditures are that extreme events are not considered. Furthermore, technological improvements in the marine sector that would probably reduce the adaptation expenditure are not included. Also, the scenario lacks hard adaptation measures, such as the development of fisheries infrastructure or equipment.

Finally, a serious shortcoming is the integration of a baseline discount rate of 5%. A sensitivity analysis shows that a lower discount rate would lead to higher adaptation costs, because future costs are weighed higher.

[18] "Buyback programs reduce fishing capacity through direct purchase. Successful buyback programs achieve multiple goals. They improve resource conservation by reducing fishing pressure on fish stocks, they provide financial assistance to participants who choose to exit the fishery, and they increase the profitability of participants who remain in the fishery by reducing competition for the resource." See the National Fisheries Conservation Center website, "Buyback Programs" (http://www.nfcc-fisheries.org/ir_io_bp.html).

About MEDPRO

MEDPRO – Mediterranean Prospects – is a consortium of 17 highly reputed institutions from throughout the Mediterranean funded under the EU's 7th Framework Programme and coordinated by the Centre for European Policy Studies based in Brussels. At its core, MEDPRO explores the key challenges facing the countries in the Southern Mediterranean region in the coming decades. Towards this end, MEDPRO will undertake a prospective analysis, building on scenarios for regional integration and cooperation with the EU up to 2030 and on various impact assessments. A multi-disciplinary approach is taken to the research, which is organised into seven fields of study: geopolitics and governance; demography, health and ageing; management of environment and natural resources; energy and climate change mitigation; economic integration, trade, investment and sectoral analyses; financial services and capital markets; human capital, social protection, inequality and migration. By carrying out this work, MEDPRO aims to deliver a sound scientific underpinning for future policy decisions at both domestic and EU levels.

Title	MEDPRO – Prospective Analysis for the Mediterranean Region
Description	MEDPRO explores the challenges facing the countries in the South Mediterranean region in the coming decades. The project will undertake a comprehensive foresight analysis to provide a sound scientific underpinning for future policy decisions at both domestic and EU levels.
Mediterranean countries covered	Algeria, Egypt, Israel, Jordan, Lebanon, Libya, Morocco, Palestine, Syria, Tunisia and Turkey
Coordinator	Dr. Rym Ayadi, Centre for European Policy Studies (CEPS), rym.ayadi@ceps.eu
Consortium	Centre for European Policy Studies, **CEPS**, Belgium; Center for Social and Economic Research, **CASE**, Poland; Cyprus Center for European and International Affairs, **CCEIA**, Cyprus; Fondazione Eni Enrico Mattei, **FEEM**, Italy; Forum Euro-Méditerranéen des Instituts de Sciences Economiques, **FEMISE**, France; Faculty of Economics and Political Sciences, **FEPS**, Egypt; Istituto Affari Internazionali, **IAI**, Italy; Institute of Communication and Computer Systems, **ICCS/NTUA**, Greece; Institut Europeu de la Mediterrania, **IEMed**, Spain; Institut Marocain des Relations Internationales, **IMRI**, Morocco; Istituto di Studi per l'Integrazione dei Sistemi, **ISIS**, Italy; Institut Tunisien de la Compétitivité et des Etudes Quantitatives, **ITCEQ**, Tunisia; Mediterranean Agronomic Institute of Bari, **MAIB**, Italy; Palestine Economic Policy Research Institute, **MAS**, Palestine; Netherlands Interdisciplinary Demographic Institute, **NIDI**, Netherlands; Universidad Politecnica de Madrid, **UPM**, Spain; Centre for European Economic Research, **ZEW**, Germany
Budget and Funding	Total budget: €3,088,573 EC-DG RESEARCH contribution: €2,647,330
Duration	1 April 2010 – 31March 2013 (36 months)
EC Scientific Officer	Dr. Domenico Rossetti Di Valdalbero, DG RESEARCH
Website	www.medpro-foresight.eu
Contact e-mail	medpro@ceps.eu