The Future of the Mediterranean

From Impacts of Climate Change to Adaptation Issues

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1. Introduction

The conclusions of the IPCC[1] are unequivocal: climate change is underway and its effects within the coming half-century are at least partially inevitable (IPCC, 2007a). In less than two decades, the question of climate change and its consequences has indeed become the focus of international concern. In particular, the topic has been addressed within the scope of the United Nations Framework Convention on Climate Change (UNFCCC), and is the subject of regular dedicated international conferences (for example the *Conference of the Parties* or COP), which deal with the two approaches to tackle climate change – namely the reduction of greenhouse gas emissions (or mitigation) and adaptation. While most of the attention remains focused on the mitigation aspect, adaptation becomes increasingly important as we become aware of the difficulties of defining and obtaining mitigation objectives that are at the same time mutual, realistic and sufficiently ambitious. It is the awareness of a certain irreversibility regarding the ongoing climate changes that encourages increased attention on the needs and issues of adaptation.

It was during the COP13 (Bali December 2007) that the issue of adaptation was put firmly into the spotlight, a position that was reaffirmed during the COP14 (Poznan December 2008) and will be again in Copenhagen in December 2009 (COP15). While the COP's main theme in terms of adaptation concerns questions of finance (Who pays? How much? To whom? According to which mechanism?), scientists are more concerned with the implementation and analysis of vulnerability and of society's capacity to adapt to climate change. From these questions arise new ones, notably those that concern the connection between adaptation strategies and/or measures with other public policies at different scales. Indeed, the fight against climate change (mitigation *and* adaptation) should not be separated from other policies, such as sectorial, development, planning and environmental protection. These other policies are of equal importance for the future of any society, as are the consequences of climate evolution: it is at the crossroads of climatic, socioeconomic and environmental issues that the fight against climate change must be considered for the short, medium and long term.

This is particularly true in the Mediterranean. The region's rapid growth in recent decades, while delivering significant positive impacts for the living conditions of the population, has however largely occurred at the expense of the environmental balance, which is essential for human wellbeing, and has often contributed to an increase in social and economical disparity, which are characteristic of the Mediterranean basin today. Major pressures and threats already place a heavy demand on the resources and activities of the Mediterranean. Climate change will accentuate these pressures, but will not change their nature. The aim therefore is to act upstream of these pressures and threats to reduce their effect and to avoid the occurrence of new ones. As the Mediterranean offers a diverse range of cultural, political, economical and environmental circumstances, it is expected that the impacts of climate change will take contrasting forms, as should the possible solutions. The Mediterranean therefore appears to be a priority for adaptation, and also serves as a laboratory for testing measures that could be implemented elsewhere in the world.

This report aims to provide a general framework for the implementation of adaptation in the Mediterranean context, based on a number of important clarifications and accompanied by operational recommendations. In the first part (section 2) the scientific basis of the study will be set, notably from the works of the IPCC. We will assess the major climatic evolutions predicted for the Mediterranean over the coming century, concentrating on temperatures, rainfall regimes and variation of sea level. This will lead us to present (section 3) the induced physical impacts and to study the consequences on natural resources and human activities. We will then explore the central topic of adaptation in more detail, by first proposing some essential framing elements (section 4). We aim to ensure that the debate remains firmly fixed within the context of all the important developments, and not just climate change, that are already at stake in the Mediterranean (economical, demographical…), in order to highlight the links that exist between adaptation and mitigation, which issues are linked to the distinction between climatic variability and climate change, to identify the stakeholders and populations that are the targets of adaptation, and to

[1] Intergovernmental Panel on Climate Change

examine the terms under which migration movements are considered. A more pragmatic approach will then be developed (section 5) which will present a few examples of existing strategies and projects in the Mediterranean, and then will propose recommendations in the form of key principles for the implementation of adaptation.

2. What climate science tells us… and what it doesn't

The first part of this report provides an overview of the scientific basis for the determination of which climatic developments will be important in the Mediterranean basin in the coming century. The aim is to take stock of the information provided by climate modelling studies, particularly in terms of the major trends at the Mediterranean scale.

Through climate modelling, that was initially conducted on a global scale but has become progressively focused on the regional level, climate science informs us that the future of the Mediterranean will be the scene of important changes in climate conditions. To clearly understand the basis for the climate projections and derived uncertainties, it is necessary to briefly describe the scientific foundations (models and scenarios) that have established these perspectives.

2.1. Models and scenarios

Future climate change will depend on two factors: greenhouse gas emissions (which are directly linked to development patterns) and the response of the climatic system to these emissions. To determine climate projections, scientists work out future emission scenarios and design climatic models. The former are mainly derived from economic, social and technological sciences, and the latter from physics and biology.

2.1.1. Emission scenarios

The intensity of future climate change depends not only on our historical and current greenhouse gas (GHG) emissions, but also on our future emissions. Indeed, the longer it takes for emissions to diminish, the more significant and prolonged the climate change will be. Therefore, to get an idea of what the climate will be like in the next 50 to 100 years, it is necessary to know what these future emissions will be. However, these emissions will depend on complex economical, technological and social factors, as well as political choices that are at present undecided. It is therefore impossible to establish with any precision the emission levels that will be reached in 2100, 2050 or even 2020. Instead, to make it possible for climatologists to conduct their research, it is necessary to use emission scenarios that pose the question: "how will the climate change if emissions follow a particular trend?"; rather than "what will future greenhouse gas emissions be?". Emissions scenarios must therefore by no means be considered as forecasts that are more or less likely to occur.

Scientists use emissions scenarios as the basis for climatic simulations: from these climatic models scenarios for the future evolution of the greenhouse gas effect can be deduced at the global scale, and then used to predict climate scenarios. To simplify the comparison of results from different climate models, the IPCC uses "standard" scenarios that were defined in 2000 (Nakicenovic and Swart, 2000) which are known as the "SRES scenarios" (*Special Report on Emissions Scenarios*). There are six standardized emissions scenarios (Inset 1), which reflect different directions of economic and demographic growth, globalization, technological progress and its diffusion[2]. Climatic simulations are conducted on the basis of these different scenarios and for each provide an image of climate evolution within the coming century. When considering climate change projections, the importance of making reference to the particular scenario(s) used can therefore be fully appreciated.

[2] Note that these scenarios do not therefore take into account the current and future policies for the reduction of greenhouse gases (even if the technological dimension, for example, can be one of its consequences).

Figure 1 shows the evolution of emissions and the increase of global temperatures according to the different SRES scenarios. This underlines the important role played by the chosen emissions scenario. Furthermore, it is important to note that between 2000 (the date of publication of the SRES scenarios) and today, the growth of greenhouse gas has been slightly greater than the most pessimistic emissions scenarios.

Six scenarios are used for the IPCC simulations. They cover a large panorama of future key characteristics, such as demographic changes, economic development and technological change. No scenario is considered to be more probable than the others.

Scenarios **A1**. Three scenarios are grouped into this family. They all describe a very rapid economic growth, a global population that platforms in 2050 and the rapid introduction of more efficient technologies; the major regions of the world converge economically and strongly interact. The three scenarios differ by the technological intensity of their energy sector; very intensive in fossil resources (**A1FI**), rapid and exclusive use of non-fossil sources (**A1T**) or a balanced energetic mix (**A1B**).

Scenario **A2**. The world is very heterogeneous (the globalization movement weakens), the global population increases continuously and the economic growth and technological changes are fragmented and slow.

Scenario **B1**. The regions of the world rapidly converge, the global population levels out in 2050 and the economic structure rapidly becomes a service and information economy (less intensive in material and more efficient energetically) and a global sustainable development.

Scenario **B2**. Global population increases continuously, economic development and technological change are at intermediate levels, and sustainable development research is carried out at a more local level.

Inset 1. The six SRES emissions scenarios

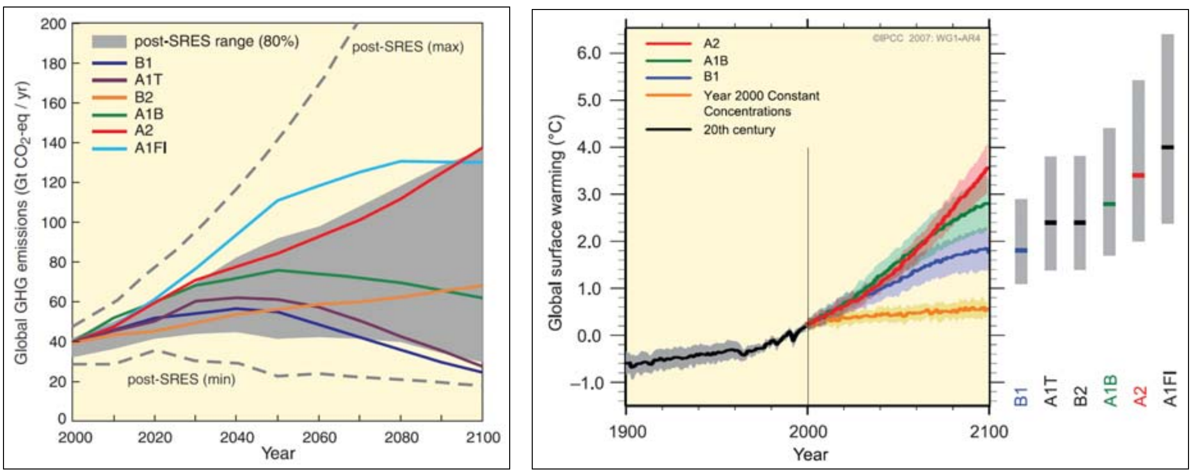


Figure 1. GHG emissions and temperature increase at the global scale according to the different SRES scenarios (Source: IPCC, 2007a).

The emissions scenarios are often mistakenly confused with climatic scenarios under the common name of "IPCC scenarios". Climatic scenarios are plausible although sometimes simplified representations of a coherent future climate, built upon the different climatic projections that scientists produce. They are often used as foundational elements for impact analysis of climate change. Emissions scenarios and climatic scenarios do not therefore intervene at the same time in the scientific chain of analysis of climate change.

2.1.2. Climatic models

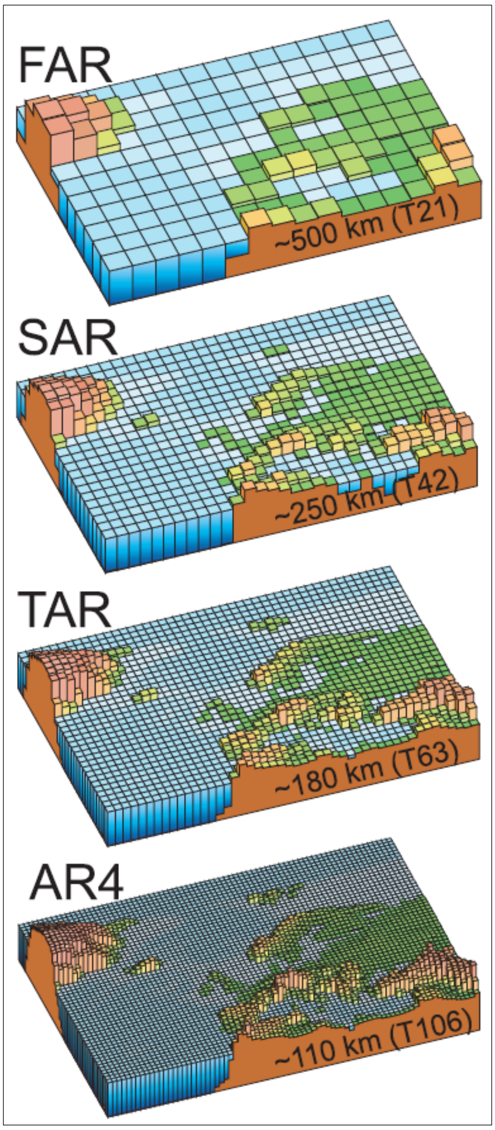
The climatic models remain poorly understood outside the scientific circles that use them. We generally use the term "climatic models" to refer to the digital models that provide information on the evolution of climate, rather than the physical models that consist of a set of physical laws that theoretically govern the climatic system. These digital models are currently the only available tool to obtain a plausible representation of future climates. Based on the physical processes that govern circulations and interactions of the different components of the climatic system, they are a simplified representation of the real world. Their functioning is limited on one hand by the calculation and data storage capacities of the supercomputers at our disposal today, and on the other hand by our understanding of the physiochemical phenomena. Therefore a certain amount of simplification must be made. The gradual increase of supercomputing power and a better understanding of the relevant phenomena, have however allowed the models to become progressively complex. Currently the most complex models are the Atmosphere Ocean General Circulation Models (AOGCM).

Within the last 30 years, the scientific community has worked on making these models more and more "realistic" (by increasing the number of physical processes that are taken into account, the duration of simulations and their spatial resolution) and to validate them. The first digital models of climate that were developed in the 1970s were limited to the contributions of carbon dioxide (CO_2) and water vapour (H_2O). They were then improved by the incorporation of a relief map of the terrestrial surface, and in a more limited way, the role of clouds and the cryosphere (ice caps, glaciers, ice floes, snow…).

Successive publications of IPCC reports were then produced with important advances progressively taken into account, for instance: a "flat" ocean and its interaction with the atmosphere was included in the first report (*IPCC First Assessment Report* (FAR), 1990); volcanic activity, some aerosols and a three dimensional ocean with certain internal circulations were incorporated into the second report (*IPCC Second Assessment Report* (SAR), 1995); the carbon cycle, water cycle, all the aerosols and a more complex ocean circulation were integrated into the third report (*IPCC Third Assessment Report* (TAR), 2001); and finally, a partial modelling of vegetation and its interactions with the climate and atmospheric chemistry were incorporated into the fourth and latest report (*IPCC Fourth Assessment Report* (AR4), 2007).

These innovations were introduced together with a gradual increase in complexity of the modelling of the processes already taken into account. In parallel, the resolution of models has increased progressively. For purely technical reasons of calculation capacity, the models cannot be used to develop calculations for every point of the globe or the atmosphere; we must therefore be satisfied with a limited number of points. All these points linked together form a three dimensional net for which the mesh size is variable from one model to another. Currently, global models use meshes with a width of about 100 km. Figure 2 illustrates the effect of using different meshes on the representation of the European Mediterranean relief map, as used in the successive IPCC reports.

Figure 2. The downscaling principle in the IPCC reports.



Models do not therefore offer a continuous representation of the globe's surface or the atmosphere, but a discrete one (point by point); and so we must extrapolate the calculated values between two points of a mesh. This approximate calculation, although it is constantly refined, remains a problem for the assessment of the impacts of climate change at a local level. Therefore, regional models are built that differ from global models in that they are concentrated on a specific region of globe and allow the use of a reduced mesh size. However, these regional models cannot operate autonomously, independent from an understanding of global climatic processes.

Three systems – so called downscaling – allow global processes to be taken into account in regional models. The first is a system of variable mesh, which allows adjustment of a model's mesh size according to its global position: a small size at the level of the studied region, and a much larger one at the opposite side of the globe. The second system is the nesting of a regional model to a global model: the global model forces the regional system into a certain number of points and therefore allows the regional simulations to take into account global phenomena. A third method called empirical or statistical downscaling, involves the use of relationships that link global atmospheric variables with local or regional climatic variables. Local climatic data are then derived from the atmospheric variables given by global models.

Climatic models therefore show limitations in terms of climate forecast because they are an incomplete representation of our understanding – which is also unfinished – of the ongoing physical mechanisms; and also because difficult to predict societal evolutions must be taken into account. Thus climate models cannot be credited with prediction capabilities that they do not have. Such models still have substantial potential for improvement, through the advancement of current computational power and the further extension of scientific knowledge. In particular, the representation of clouds, certain tropical variables and regional details can still be improved. However, as the considered scale decreases, there are some physical phenomena that are fundamentally unpredictable and chaotic: they represent limits to the precision of models that cannot a priori be overcome. Moreover, in some cases a better understanding of these phenomena can induce an increased amount of uncertainty.

Despite this, four elements allow the models to be given certain credence (Randall *et al.*, 2007). The first element is that these digital models are based on established physical laws (such as the conservation of mass and energy) and on a profusion of observations. The second element is the excellent capacity of models to simulate important aspects of the current climate. The third element lies in the capacity of these models to simulate the historic climate and climate changes. Finally, the gradual refinement of models does not contradict the results obtained with simpler models. Over several decades of development, the models have systematically and without ambiguity shown that an increase in greenhouse gas emissions is accompanied by a significant warming at a global scale.

To produce its reports and accompanying climatic scenarios, the IPCC uses 23 AOGCM models (the most complex), which are generated by different research centres. These models[3] are distinguished by their parameterisation[4], and the differences result mainly from the documented choices made by the scientific teams that conceived them. Utilisation of the 23 models allows the IPCC to produce more robust results because they are less dependent on the parameterisation choices: far from increasing the uncertainty, this methodology allows it to be reduced and its margins defined.

2.1.3. Uncertainties related to climate science

We can distinguish four main sources of uncertainty related to the data obtained by climate modelling (Terray and Braconnot, 2008). These sources concern both global models (AOGCM) and regional ones, the downscaling tending to reinforce the degree of uncertainty by adding a level of complexity in the feedback components taken into account.

The first source is linked to greenhouse gas emissions, which are themselves determined by socioeconomic evolutions, i.e. indirectly through the societal behaviour and advancement in terms of innovation in several areas (energetic efficiency, transport…). Generally this source of uncertainty results in a necessarily approximate assessment of the trajectory of GHG emissions in the future (half-century and century to come).

The second source is strictly linked to the functioning of models and is considered as "structural" uncertainty. They are firstly inherent to the model's structure (the type of equations) which, as we have seen before, cannot take into account the entirety of the operating climate processes. A second cause of structural uncertainty lies in the differences between parameterisation from one model to another, i.e. to the variation of the data set and its weighting within the model.

A third source relies on the long-term unpredictability of natural climate variability. Other than droughts, floods or storms, this concerns phenomena such as ENSO (*El Nino Southern Oscillation*) and NAO (*North Atlantic Oscillation*): linked to the perturbation of atmospheric circulation, which are mainly expressed by the modification of precipitation zones and the inversion of marine currents, which also has an influence on the atmospheric balance at different scales. However, while we are now able to predict these phenomena in the relatively short term (usually one year in advance), it remains impossible to make accurate predictions over several decades, to say, for example, whether a year will be an ENSO year or not. Moreover, there is nothing to indicate that an improved knowledge of climate changes will reduce these difficulties.

Finally, a last source of uncertainty must be noted here, concerning downscaling, which is based on methodologies aiming at the identification of local climate evolutions from elements taken from global models. The main difficulty is then to integrate local climate variability phenomena, themselves inherently derived from the characteristics of large scale areas and their interactions (salinity of marine waters, type of terrestrial vegetation, nature of hydrographic network, pedology…).

[3] Note that two of these are from France (through Météo-France and the Pierre Simon Laplace Institute), two from Germany (Max Planck Institute for Meteorology, and Meteorological Institute of the University of Bonn, in partnership with the Meteorological Research Institute of the Korea Meteorological Administration), and two from the United Kingdom (both from the Hadley Centre for Climate Prediction and Research).

[4] Approximation of the physical laws in operation, mathematical discretization methods, spatial resolution, representation of processes that are insufficiently documented.

2.2. Foreseeable climate evolutions

On these scientific bases, three main components of the ocean/atmosphere system are vulnerable to major future climate evolutions: the changes will concern temperatures (of air and sea), the precipitation regimes and sea level.

2.2.1. Evolution of surface temperatures

The general tendency will be for climate warming: concerning the increase of air temperature at the global scale, the range of possibilities for the six SRES scenarios[5] and the 23 models currently used in the framework of the IPCC, an increase between + 1.1°C and + 6.4°C is predicted before the end of this century. If such an increase can a priori seem insignificant, we must be conscious of the fact that "only 5°C separate us from the last ice age" (Van Grunderbeeck and Tourre, 2008, p. 1-13). This increase of a few degrees must be understood in terms of its implications for atmospheric, ocean and terrestrial surface components, and their interactions[6].

At the scale of the Mediterranean basin, it is probable that the growth of the average annual temperature will be slightly higher than that of the world level (Hallegatte *et al.*, 2007; Van Grunderbeeck and Tourre, 2008). When considering all the SRES scenarios, this average increase is estimated to be between about 2°C and 6.5°C by the end of the century. Regarding seasonal variation, this will remain significant, even if temperature increases are more marked in winter than summer. Finally, infra-regional variations must also be considered: in autumn for example, the western Mediterranean basin is likely to be characterised by a temperature elevation that is slightly higher than for the rest of the basin, whereas over the summer this trend is likely to be inversed, effecting southern and eastern countries.

The increase of average temperature will have repercussions partly on the evolution of the sea's surface temperature, with implications on the dynamics of the lower atmosphere (interaction of depressions and anticyclones) and indirectly on precipitations and natural habitats. Although the warming of the sea's surface is also affected by the circulation of water masses and will be lower than the warming of air temperature (the thermal inertia of sea is larger than that of air), the expected average increase will still be around +2°C to +4°C by the last quarter of the 21st century (Hertig and Jacobeit, 2007; Somot *et al.*, 2007, based on the A2 scenario) (Figure 3). This universal warming will influence the general volume of Mediterranean sea masses, then indirectly the coastal and marine habitats and associated ecosystems. However, there are also some differences to be considered, notably the increase in average temperatures will be greater for the Adriatic and Aegean Seas, and lower at the level of the Levantine basin (Table 1).

Finally, the coupled growth of average temperatures of air and sea will influence, and simultaneously be influenced by, the regional and local precipitation regimes. This highlights the importance of the level of interaction between the components of the ocean/atmosphere system, and therefore demonstrates the necessity to take both into account in order to identify the effects caused by climate change on ecosystems, societies and Mediterranean territories.

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[5] Which are far from representative of all the possible GHG emission trajectories.

[6] It is worth remembering that a temperature increase of 1°C, for example, would probably translate into a migration of the ecological zones of about 100 km northwards and a 150 m rise in altitude.

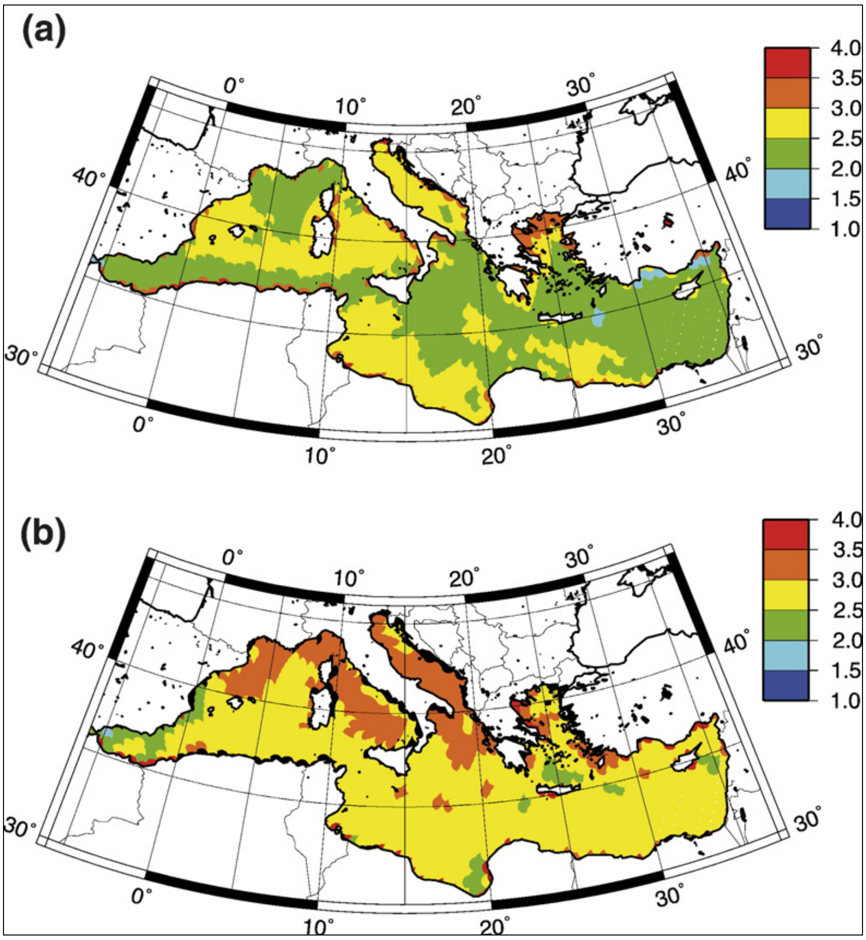


Figure 3. Foreseeable changes in sea surface temperature in winter (a) and summer (b) from 2070 to 2099 compared to 1961 to 1990 (Source: Somot *et al.*, 2007)

	T	Increase T (est. – obs.)	S
Mediterranean Sea			
Observed (obs.)	19.7	+ 2°C	38.16
Estimated (est.)	21.7		38.61
Gulf of Lion			
Observed (obs.)	17.7	+ 2.1°C	37.90
Estimated (est.)	19.8		38.34
Levantine Bassin			
Observed (obs.)	21.4	+ 1.9°C	39.06
Estimated (est.)	23.3		39.47
Adriatic Sea			
Observed (obs.)	17.7	+ 2.5°C	37.76
Estimated (est.)	20.2		39.19
Aegean Sea			
Observed (obs.)	17.9	+ 2.2°C	38.32
Estimated (est.)	21.1		39.31

Source: MEDAR/MEDATLAS, 2002

Table 1. Sea surface temperature (T, in °C) and salinity of the sea surface (S, in psu, *practical salinity unit*) estimated for the end of the 21st century (from Van Grunderbeeck and Tourre, 2008).

2.2.2. Evolution of precipitation regimes

Projections of the precipitation regimes for the coming centuries, according to the different SRES scenarios, are even more difficult to ascertain, mainly because they depend – to an even greater degree than temperature – on the specific conditions in the Mediterranean basin.

Globally, making a comparison between what is likely to happen in the two last decades of the 21st century, and events in the two last decades of the 20th century, models suggest that there will be a reduction of the regional average precipitation, within the range of -4 % on the northern coasts, to -27 % on the southern coasts (scenarios A1B) (Christensen *et al.*, 2007). However, we do not expect this generalised decrease to be homogenous throughout the whole year (Figure 4), with the summer period likely to be more affected than the winter: from June to August, between almost -5 % in the southeast and more than -30 % at the far west and in the northwest; over the months from December to February, of more than -20 % in the southeast of the basin and a slight increase of the averages in the northwest. As a result, the risk of summer drought is heightened for the whole of the basin: indeed we estimate that by 2080 to 2099, almost one year out of two could be considered as dry.

In parallel, figure 4 shows that major spatial variations will operate at infra-regional scales. For instance, while the reduction of precipitation will affect all the countries of the Mediterranean basin in summer, a north/south gradation occurs in winter, with the north of the basin being less affected. At an even more precise scale, these variations will probably be accentuated or attenuated due to the influence of topography and microclimatic phenomena, however we do not yet know enough about the effect of these influences.

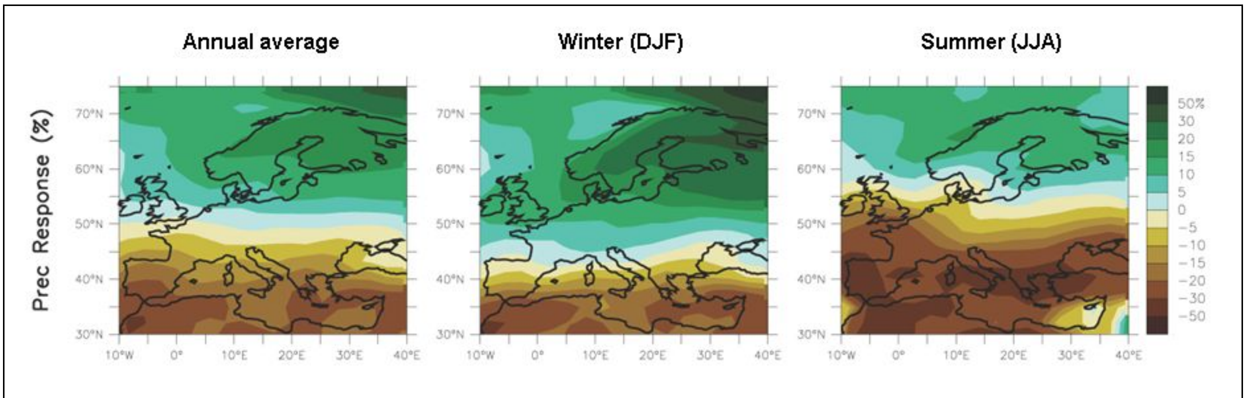


Figure 4. Evolution of precipitation in the Mediterranean and in Europe for 2080 to 2099, compared to the period of 1980 to 1999, according to the emissions scenario A1B (Source: IPCC, 2007b)

2.2.3. Evolution of sea level

Projections for the elevation of sea level are probably the most uncertain, although it is one of consequences of climate change that receives the most media attention, especially in the Mediterranean where the coasts play a crucial role in the development of the surrounding countries (demographic growth, urbanisation, littoralisation, tourism…). Besides this, it must be remembered that the general rise in sea level is a consequence of both an increase in the quantity of seawater, due to the progressive melting of glaciers and the ice caps; and also because of an expansion of oceanic water mass because of its increased temperature.

While the Earth has experienced multiple episodes of sea level variations during its history, the changes expected in the coming decades are atypical in that they will take place extremely rapidly. The global models used in the framework of the IPCC concur on an elevation range at the global scale, for all SRES scenarios, between 18 cm and 59 cm by 2100, while during the entire 20th century the Mediterranean has only experienced elevations between 11 cm and 13 cm. However, the margins of uncertainty remain extremely high, particularly concerning the rate of ice melt

(Figure 5). Indeed, some hypotheses also mention, on the basis of sound scientific reasoning, a sea level elevation at the global scale of more than one metre during the current century, and up to tens of metres over longer time scales (Hansen, 2007; Rahmstorf *et al.*, 2007). Today, it would therefore appear wise to consider that "no solid estimation can be given for the Mediterranean Sea" (Hallegatte *et al.*, 2007). Thus, here we will only take into account the figures provided by the IPCC.

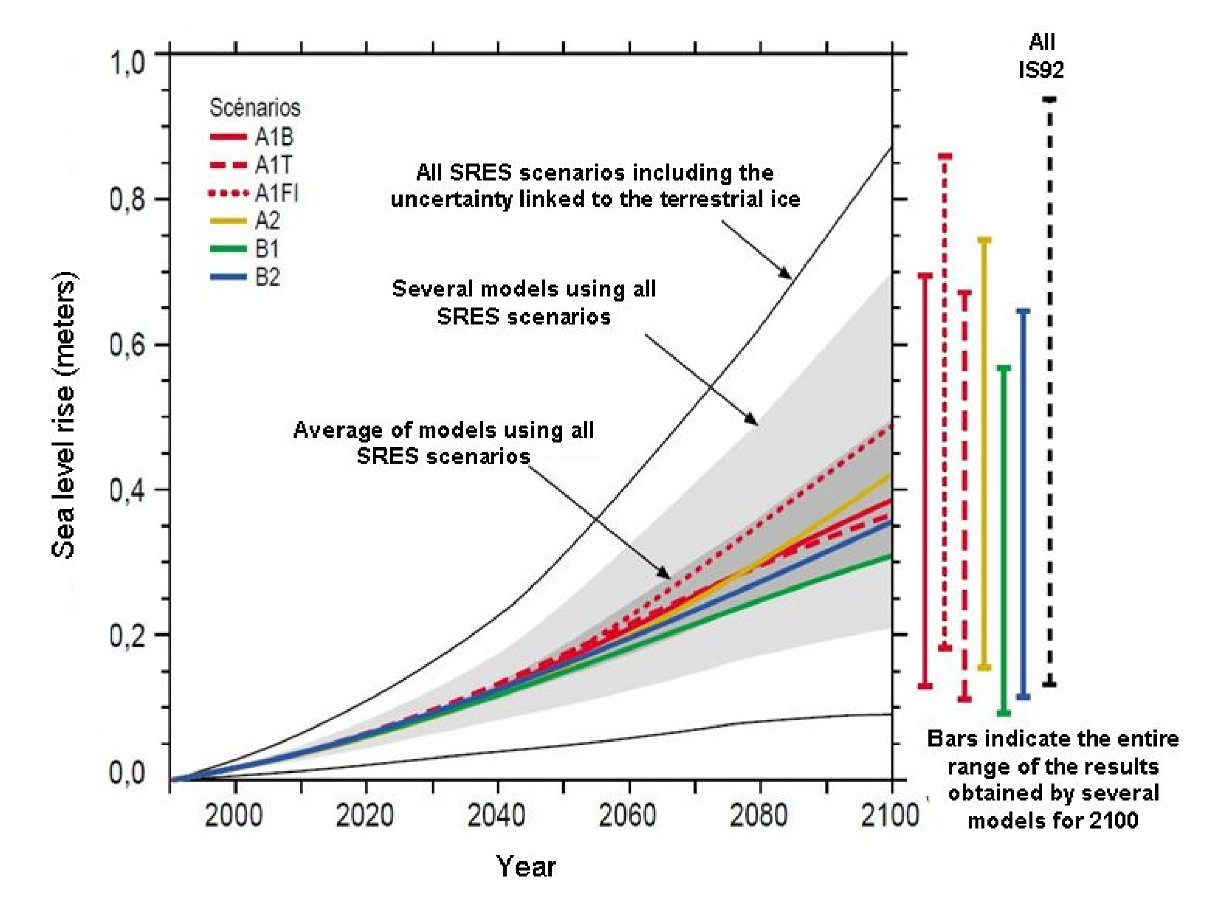


Figure 5. Uncertainties regarding the expected elevation of sea level during the 21st Century (IPCC, 2001)

Regarding the Mediterranean basin, the main point is not so much the actual numerical value of the regional average, but rather the infra-regional differences that are important, for two main reasons. The first reason is that differences in the marine level exist already (Figure 6), with an elevation rate in the short term that is more significant in the eastern part of the basin (between +5 and +15 mm per year, compared to less than +5 mm per year in the western region, for example). The second reason lies in a set of characteristics that are specific to the Mediterranean Sea, which will also be affected by climate evolution, leading to a modification of the general conditions and therefore to changes in volume. Factors of particular importance include: salinity, the action of atmospheric pressure, water balance (evapotranspiration, water input from rivers, exchanges with the Atlantic) or the influence of dominant currents (Hallegatte *et al.*, 2007).

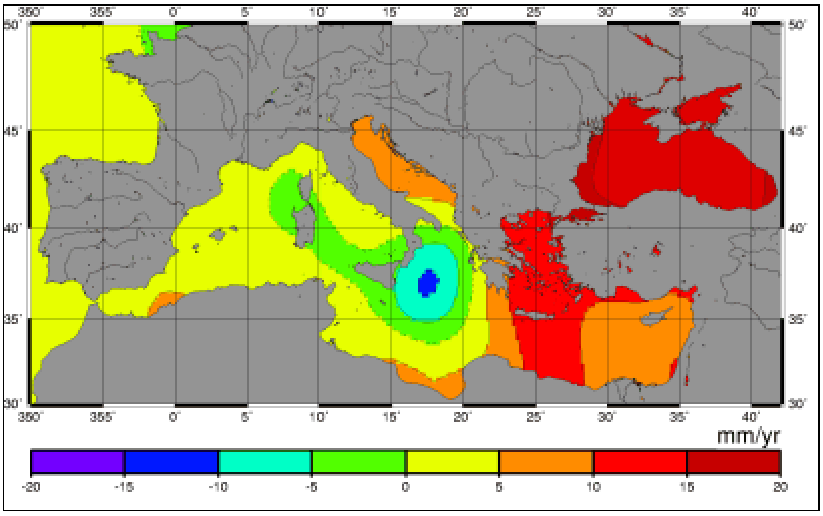


Figure 6. Sea level variations observed between 1992 and 1998 by the TOPEX/Poseidon programme (Source : LEGOS-GRGS-CNES)

3. Overview of the expected impacts of climate change in the Mediterranean

While the issue of climatic tendencies is delicate, as we have just seen, due to the multitude of factors that must be taken into account, then the complexity is even greater when the reading scale is refined to include the question of the impacts of climate change. Indeed, these impacts are the result of confrontation between the major trends of temperature, precipitation and sea level, and the specific conditions of the affected area, in other words the natural and manmade characteristics of the Mediterranean zone. The aim is therefore to put forward here a general overview of the impact types that can be foreseen, then to discuss their pertinence according to the zones in question. Beforehand it is however crucial to remind ourselves that the Mediterranean is already characterised by natural environments that are put under a high pressure by the societies that are developing there. However, these pressures will only reinforce the problems inherent to climate change, and vice versa.

3.1. Current natural conditions and human pressures

The current conditions result from both the natural characteristics of the Mediterranean basin and the human activities that developed there over several millennia, which have been particularly non-sustainable during the past five decades (Benoit and Comeau, 2005).

The Mediterranean basin is characterised by diverse climatic and environmental specificities that include a structurally weak availability of water resources. This situation results mainly from a climatic context where confrontation of three major air masses of very different characteristics occurs during the year: a dry tropical air from Saharan Africa, dynamic air mass over continental Europe, and a humid air mass coming from the Atlantic (Villevieille *et al.*, 1997). This configuration stimulates a rainfall regime that is irregular in both space and time. For instance, southern countries only receive 10 to 13 % of the annual average precipitation of the basin. Similarly to countries of the east coast, they are characterised by a marked aridity, notably in Libya and Egypt. The northern coasts offer more temperate conditions and the contrasts between the littoral zones and inland areas are more obvious than in the countries in the south for example. Beyond this regional view, it is important to note that *"the Mediterranean climate has a whole range of nuances due to the magnitude of the latitude and longitude of the basin, its chaotic relief configuration, the interweaving of land and sea, the presence of numerous islands and the softening effect of relatively warm sea"* (Lanquar *et al.*, 1995, p. 38). Indeed contrasts can be particularly marked between places such as Djerba in Tunisia (rainfall of about 100 mm per year) and a town such as Genova in Italy (1200 mm per year). The temporal irregularity translates into relatively abundant rainfalls between autumn and spring, and much less frequent during the summer.

This global situation, although very schematically described here, leads to the existence of natural hazards of climatic and hydrometric origin that are important at the scale of the basin, particularly droughts and floods. It is necessary at this stage, prior to addressing the question of the impacts of climate change, to clarify that the natural constraints are real problems only because of their confrontation with the results of development – direct pressure on resources and increasing the exposure of societies to hazards. It results in a constant increase of natural risks in the Mediterranean. For example, demographic pressure[7], agricultural intensification, industrialisation and an urbanisation that is both intense and badly managed[8], currently apply a considerable pressure on ecosystems and water resources (Benoît and Comeau, 2005). Blue Plan estimates show that water demand has doubled in the second half of the twentieth century, bringing regional consumption to 290 km^3/year and increasing the threat of scarcity.

Furthermore, without going into the full detail, Mediterranean soils tend to be quite volatile in nature and have suffered deforestation in the last few decades, which has greatly exacerbated the problems of erosion (Maurer, 1985; De Franchis, 2003). Similarly, the availability of freshwater, originally quite low, is under considerable pressure because of increasing consumption demand within the basin (agriculture, domestic consumption, industry…) (Troin, 1985; Margat and Treyer, 2004)

Finally, it must be remembered that the Mediterranean is also exposed to non-climatic hazards, most notably earthquakes and tsunamis resulting from intense tectonic activity. These are risk factors that are equally as important to take into account in development strategies as those of climate processes (Villevieille *et al.*, 1997). Especially since the effects of the tsunami hazard, for example, will be accentuated due to the elevation of average sea level.

3.2. Impacts of climate change

The changes in temperature, precipitation and sea level over the decades and centuries to come will result in various physical impacts (hazards), of gradual occurrence for some, or as extreme events for others. These disturbances are not necessarily new, many Mediterranean areas are already plagued by some of these hazards. The "novelty" of climate change lies mainly in the intensification of these disturbances and their occurrence, which is estimated to be "very likely" by the global climate models. This perspective is particularly problematic because of its consequences, so that beyond the description of the expected impacts of climate change is the existence of "chains of impacts" that should be emphasized, i.e. sequences of repercussions from climate impacts to human activities, through natural resources (Figure 7).

The view proposed here is not exhaustive as the complexity of the chains of impact is considerable, and sometimes still poorly understood. The aim is only to give an overview of this complexity by showing how climate change will affect indirectly a few key sectors of the Mediterranean economy, highlighting the issue of socioeconomic inequalities in the basin, and also in each of its countries.

[7] Between 1970 and 2000, the number of inhabitants increased by 50 %, reaching a total of 428 million people in 2000.
[8] 64 % of Mediterranean inhabitants were living in a town in 2000; this will be 72 % in 2025

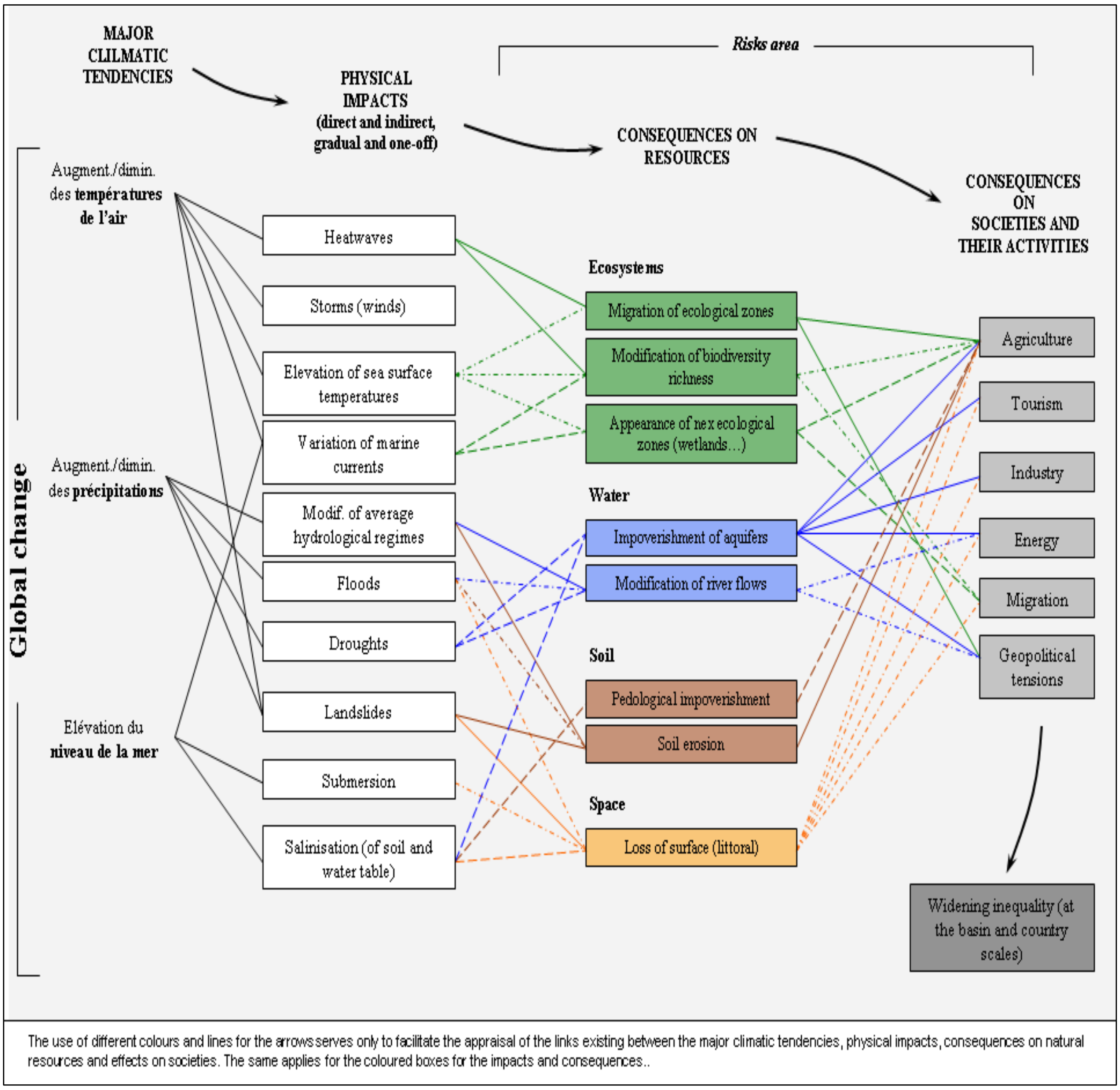


Figure 7. Some examples of "chains of impacts" that explain the effects of major climatic changes on future human activities.

3.2.1. Physical impacts

We can distinguish ten major physical impacts that are directly or indirectly caused by climatic changes.

Clearly, warmer air temperatures will lead to an increase in average temperatures of the sea surface, and indirectly a change in the movement of water masses. The movement of air masses from the lower atmosphere will also be subject to change (Tsimplis *et al.*, 2007) and this is likely to translate into an intensification of the winds. However, it is not currently known whether the present direction of the prevailing winds will change. Finally, more locally, episodes of extreme heat will increase and – while this is currently purely hypothetical - it may be expected that by influencing vegetation cover and soil stability, these episodes together with precipitation will cause landslides. Evapotranspiration (total quantity of water transferred from the soil to the atmosphere by evaporation from the soil and transpiration by plants) will also be increased.

The evolution of precipitation will disrupt average hydrological regimes, mainly through a change in water volume received by the Mediterranean, which will in turn affect the flow of rivers and also the areas of water retention (lakes, for example). When rain falls at a steep gradient and in an irregular manner (torrential rain), another effect will be the accentuation of flooding and soil erosion. Regions such as the south of France, for example, are regularly subjected to such extreme events. Similarly, when precipitation becomes scarcer, drought will increase, raising concerns over the future of areas that are already subject to water stress and thus to recurrent water shortages (mainly the southern and eastern shores of the basin). However, it is also possible that areas that currently never or rarely experience flooding and/or droughts will not be immune, forcing them to become progressively ready for certain “unknown” events, which is where the weight of uncertainty in long-term climate forecasting at the local scale becomes problematic. Finally, in less fortunate areas, alternating floods and droughts may be observed, which will promote erosion and landslides. It should be noted that any given particular impact is often the result of different types of climatic changes (temperature, precipitation…).

The expected rise in sea level will generate submersion of low coastal areas (sandy and rocky, wetlands…) but also the intrusion of marine water into aquifers will cause problems of groundwater salinization. While it remains difficult to predict changes of coastal currents - which would influence sedimentary dynamics and thus the erosion/development of beaches - we can however specify that the consequences of such changes will be particularly pronounced in coasts that currently experience subsidence, i.e. a progressive deepening due to a lack of accumulation of sediments carried by major rivers or, more locally, by overly dense urbanization (weight effect plus consequence of pumping groundwater). While the case of the great delta of Bangladesh is very well known, the Mediterranean also offers similar examples such as the Nile Delta in Egypt. The main difference is that in the Mediterranean, the input of terrigenous sediment to the sea has been significantly disrupted in recent decades through the construction of many large dams (such as the Aswan dam). While this may seem good news in terms of energy supply or irrigation, the downside is that by blocking the majority of sediment upstream (-90 % in fifty years), these infrastructures have considerably aggravated the problem of sediment scarcity and indirectly exacerbated coastal erosion. Furthermore, growing littoralisation of activities and settlements has led to the proliferation of coastal developments, most of which continue to have catastrophic effects in terms of coastal erosion.

Here we see that effects of various origins, both natural and anthropic, have combined to strengthen the threats associated with anticipated climate change. This observation introduces the idea that beyond the major trends, local factors (topography, pedology, plant density, patterns of human occupation…) will play an important role in explaining the occurrence or not of impacts and the magnitude of their consequences. Meanwhile, we can be sure that all the impacts presented here will not affect all the regions of the Mediterranean, and not in the same way or with the same intensity. Tectonic phenomena, for example, may work to raise certain coasts (e.g. in Algeria, Italy, Greece or Turkey), which in turn will tend to mitigate the consequences of sea level rise, therefore we must address the issue of climate change impacts in the Mediterranean with caution and be aware of the limits of over generalisation.

However, some natural processes exist that make it possible to understand how the indirect impacts of climate change will affect the natural resources of the basin. We can therefore review some "chains of impacts".

3.2.2. Effects on natural resources…

As it is not possible to be exhaustive, we will only refer to four major types of resources that are important for human activities: ecosystems, water, soil and space. The aim is not to describe each link shown in Figure 7, but to focus crudely on some of the chains of impact, as the main purpose of this chapter is to show that combinations of effects primarily explain the impacts of climate change on natural resources.

A first example is the reduction of space that threatens certain coastal sections. It results either directly from submersion phenomena; or more indirectly from soil salinization and/or repeated flooding. These phenomena can make a place become "uninhabitable", or at least lead to planning constraints, such that in the absence of sufficient economic resources to massively curtail the problem, a progressive abandonment of the area becomes the only option in the long term. Clearly, this loss of space also impacts on biodiversity (species, landscapes…).

A second example is the profound changes that may occur at the level of ecosystems and their richness in terms of biodiversity. The gradual increase of terrestrial and marine temperatures will cause the modification of natural habitats, which in the Mediterranean are already subject to intense pressures (pollution, over fishing, habitat degradation, invasive species). Equilibrium conditions of ecosystems will be disrupted and there are many uncertainties about the way in which different species will be able to adapt or otherwise to these changes – their pace of evolution being indeed slower than that of the expected climate changes. A massive loss of biodiversity, in addition to that already projected as a result of direct human pressures, is possible during the 21st century, with a drastic reduction in associated ecosystem services (supply of fresh water, productive soil conservation, resistance to invasive pests, pollination of plants, reproduction of fish resources, moderation of coastal erosion, climate regulation…).

3.2.3. … then on human activities

The links with human activities are therefore often indirect but potentially strong. Figure 7 illustrates this by focusing on a few major sectors of the Mediterranean economy: agriculture, tourism, industry and energy production. It encompasses questions relating to population migration and geopolitical relations, which are two points that arise in part from economic developments and concentrate many issues.

It is not necessary to explain the logic behind the economic impacts of climate change on natural resources. However, it is essential to remember that these indirect effects of climate change will affect the evolution of regional and national socioeconomic inequalities. In turn, these inequalities will make it more difficult to implement collective strategies in the fight against climate change, both in terms of reducing greenhouse gas emissions and adaptation. Following the logic of chains of impacts, this will have a negative effect on the physical consequences of climate change and its adverse effects on resources and human activities.

3.3. Uncertainties related to the functioning of socio-ecosystems

As we have seen in the first part of this report, the uncertainties of climate models translate into uncertainties on regional and sub-regional trends, affecting predictions of the tangible impacts of climate change on the environment and societies. Furthermore, the complex workings of natural and/or human systems add an additional level of uncertainty as their reaction to the impacts are themselves difficult to predict – especially as they will be potentially highly variable from one place to another. There is therefore a real difficulty in developing prospective climate and socioeconomic works that, at regional or local scales, provide the necessary scientific knowledge to make informed decisions for the future.

The response of ecosystems or societies to climate stress, including extreme events and gradual changes, must also be integrated as a source of uncertainty. Elements have already been considered in this report, but it should be remembered that the greatest source of concern remains the adaptation pace of ecosystems and societies in the face of the relative rapidity of the climate and environmental changes to come. The adaptation capacities of ecosystems and societies encompass the uncertainties and risks of biodiversity loss and the threat to the future of human communities. The richness of the Mediterranean basin, in terms of biological, socio-cultural and political diversity, provides a further degree of complexity: species and societies will not react the same way.

With specific regard to human societies, their capacity to respond to the climatic threat raises the question: will they be able to reduce their GHG emissions in the necessary proportions and within the required time scale? And what anticipation/adaptation capacity do they have to respond to the aspect of climate change that is already inevitable? The remainder of this report will focus on this second point.

4. Adaptation to climate change: framework elements

The IPCC's definition of adaptation to climate change is the most commonly accepted, and it describes adaptation as an "*adjustment of natural or (...) human systems facing a new environment or a changing environment.*" The concept of adjustment refers to the concept of flexibility, which allows the system in question to change its structures and modes of operation and its development strategies according to perturbations that occur. Whether these disturbances are extreme or more gradual events, there must be various forms of adaptation that include anticipation strategies (prior to the disturbance) or reactive (following the event). The adaptation thus appears as much as a picture of the system at a given time (is it suitable or not?) as the continuous and dynamic process by which the system adapts. A form of adaptation at a given moment and in a specific context is therefore likely to change over time.

Furthermore, we often associate the words adaptation and vulnerability. According to the IPCC, vulnerability is "*the degree by which a system may suffer or be negatively affected by the adverse effects of climate change, including climate variability and extreme phenomena. The vulnerability depends on the nature, extent and pace of climate change to which a system is exposed to, as well as its sensitivity and ability to adapt*." Adaptation and vulnerability present therefore *a priori* an inverse correlation: the less vulnerable an area is, the more it could be considered as "adapted"; conversely, a high degree of vulnerability would translate as a low adaptation capacity. While this inverse relationship should be interpreted with caution, as it is not always true, the fact is that one relevant way of understanding the situation of Mediterranean countries facing climate change lies in an assessment of vulnerability levels. An evaluation that must be understood not in terms of a normative judgement but as a tool for the assessment of the balance between the strengths and weaknesses of the territory facing the climatic threats/opportunities.

But for now, the centre of the debate lies ahead of these aspects, and it involves understanding the process of adaptation and its logical implementation. Indeed, major questions must be clarified: at what spatial scales (territorial levels) should adaptation strategies be defined and implemented? At what pace? And in what ways can this be achieved on the field? To provide a first few framing elements, four main points are considered as underlying the identification of adaptation strategies in the Mediterranean. Before that, let us remember that in the Mediterranean in particular, the diversity of cultures, societies, political systems, environmental contexts… induces different ways of approaching the question of adaptation and links it to broader issues of development and sustainable development. It is necessary to keep this fact in mind when reading more general elements on adaptation in order to understand the complexity of identifying contextualized and realistic adaptation strategies.

4.1. Non-climatic drivers of change

As we have seen, it is important not to regard climate change as the only driver of change in the Mediterranean, or even the principal one in many cases. Rapid and profound socioeconomic changes, independent of climate issues, have indeed been important in recent decades and should still be observable in the 21st century. Any long-term strategy, with regard to adaptation in particular, must take this into account: it is important to always considered the impacts of future climate on the future society, and not on today's society, even if this adds to the complexity. These major trends can be quickly presented through significant economic changes, which reflect, as much as they influence the demographic and urban dynamics. Associated with environmental pressures described above, these elements characterize the conditions on which will be based the adaptation capacity of territories and the context in which adaptation strategies must and will be deployed.

4.1.1. Economic trends

One can approach the analysis of the structure of the Mediterranean economy[9] by studying the development of major activity sectors (primary, secondary, tertiary), and show that despite strong growth, large disparities between countries remain. A possible regional strategy for adaptation should take this into account, because all countries are not at the same stage of development and do not present the same issues, nor the same ways to address the challenges.

While agriculture still represents between 10 % (Tunisia, Algeria) and more than 20 % (Albania, Syria) of the GDP in many Mediterranean countries, it contributes a minority share (less than 5 %) in countries such as France, Spain, Italy, Malta or Israel. Such differences have implications for jobs. Those relating to agriculture characterize just under half of the Albanian labour force, between a third and a quarter of those from Morocco, Tunisia, Egypt and Syria, and less than 4 % for France. The fisheries sector also shows some worrying signs as, while the fishing effort has intensified throughout the Mediterranean (+20 % of vessels between 1980 and 1992) and catches have increased (+ 16% during the same period, + 15% between 1980 and 2000), we recognize today that stocks are heavily affected in their capacity for regeneration. The share of primary sector in the economic activity of all the Mediterranean countries therefore decreases.

The secondary sector also tends to remain relatively present in the Mediterranean economies. It accounts for nearly 1/5 to 1/3 of national GDP, except in Egypt and Algeria, where its contribution is higher (respectively 40 % and 60 % of GDP) and Albania where the opposite is true (less than 20%). Again, the situation in the region is not uniform, which is also true in terms of development because for example, four countries are characterized by a decline in the importance of the secondary sector in their economies (France, Spain, Italy and Greece). Despite these contrasts, Mediterranean configurations show that today, except in the case of Albania, the secondary sector largely dominates the primary sector. However it remains behind the service sector in terms of its economic weight.

The tertiary sector has really boomed in the last half century. The service sector (trade, tourism, transport, finance, administration...) contributes more than half the GDP of a vast majority of bordering countries, or even over 60 % in Spain, Italy, Turkey and Tunisia, and more than 70 % in France, Greece, Malta, Cyprus and Israel. Only Bosnia-Herzegovina and Algeria show contributions of less than 50 % of GDP. Within the tertiary sector, tourism distinguishes itself (Bethemont *et al.*, 1998) as much by its direct effects as its induced ones. By itself the hotels and restaurants sector, for example, represents almost 24 %, 34 % and 39 % of the tertiary sector's contribution to GDP of Libya, Tunisia and Lebanon respectively. More generally, the dynamism of this activity places the Mediterranean at the forefront of the world’s tourist regions, as much in terms of tourist flow as of income linked to tourism. The impacts of climate change on this sector will be particularly crucial for the Mediterranean economy.

4.1.2. Demographic trends and urbanisation

The population of Mediterranean countries is estimated at nearly 450 million, against nearly 285 million about forty years ago. Clearly, this reflects an important demographic dynamism, even if differences between the bordering countries exist. This population is distributed as follows: 45 % in the countries on the northern shore (from Spain to Albania), 33 % in the south (from Egypt to Morocco) and 22 % in eastern countries (from Turkey to Palestine). However, in these last two groups, the expected population growth rate for the period of 2000 to 2025 are respectively 14 and 13 times higher than the average of the northern countries.

On a more precise scale, there is a particularly strong and increasing occupancy of the coastlines. This is evident in countries with a high proportion of coastal land, such as Greece, Israel or Lebanon, where more than 80 % of people are concentrated close to the sea. But it is also true in a more continental context: in Tunisia, for example, this proportion varies between 60 and 70 %.

[9] The figures go back mainly to the year 2000 and are derived from the works of Blue Plan (Benoit and Comeau, 2005). We notice that because of the scattering of data and of their non-uniformity between one country and another, between one region and another, it is extremely difficult to obtain more recent data at the scale of the whole Mediterranean basin.

Finally, in other countries, the proportion of the population referred to as Mediterranean is not dominant, as in Spain, Egypt or Albania (around 40 %), and even more so in France, Morocco and Slovenia (less than 20 %). In total, the Blue Plan estimates that a third of the inhabitants in countries bordering the Mediterranean are actually concentrated in coastal regions, where average population densities amount to 128 inhabitants/km², a concentration of population close to 2.6 times higher than national averages. In addition to this endogenous demographic pressure must be added the national and international tourists that travel within the Mediterranean basin, numbering almost 218 and 145 million respectively. While these tourists are not necessarily focused on the coast (the major European cities capture a significant share), those who stay there, foreign and domestic combined, represent about 35 million people at the time of peak attendance in August. In summer, the sum total of residents (permanent and secondary) and tourists bring the coastal densities to about 160 inhabitants/km². This increase of human pressure over a limited period raises the issue of what is the most appropriate capacity for the infrastructure and equipment in place.

More broadly, the concentration of population is correlated to the phenomenon of urbanization that, not including the large non-coastal capitals such as Paris, Madrid and Ankara, is particularly relevant in coastal areas. The number of coastal cities of at least 10,000 inhabitants has almost doubled during the second half of the twentieth century. Thus, 30 % of people in bordering countries live on the coast, which represents slightly more than 140 million people. Furthermore, while the share of urbanites living on the coast is predominant in the countries of the northern shores (40 %) compared to other sub-regions (28 % in eastern countries and 38 % in the south), the work of Blue Plan has satisfactorily demonstrated that the demographic dynamism of countries in the south and east was more pronounced (3.3 % growth between 1970 and 2000 against 0.8 % for the countries of the northern shore).

Moreover, the trend of littoralisation and urbanization is correlated with the negative development of the rural population, which generally follows the declining curve of farming populations. This population, which is mainly situated inland, was indeed reduced by 25 % between 1960 and 2000 (from 114,700 to 84,000). This means that only a few countries still have important agricultural populations (Turkey, Syria, Egypt, Albania, Morocco).

Finally, the general trend towards urbanization is linked to the development of infrastructure such as roads, airports (112 along the Mediterranean coast where more than half have an annual traffic of more than 500,000 passengers) or the commercial ports and marinas (over 1,000 in total, 70 % of which are recreational). On the coast there are other infrastructural facilities, for example, those used for energy production, desalination of seawater and wastewater treatment. In total, it is estimated from the nightime light radiation survey[10] that nearly 42 % of the Mediterranean coasts are built up.

4.2. Links between adaptation and mitigation

Attenuation (or mitigation) and adaptation are the two options identified to minimize the impacts of climate change and their consequences. Mitigation consists of limiting the process of climate change in two ways: the first is to reduce GHG emissions at the source (from the various economic sectors in particular), the second is to develop "sinks" that can capture and hold these gases separately from the atmosphere. The purpose of these two methods is to reduce the quantities of greenhouse gases in the atmosphere, in order to reduce the greenhouse effect. Adaptation, however, is a mechanism for management and prevention of the impacts of climate change.

Too often these two strategies were considered as alternative options in the fight against the effects of climate change. Ideally, in a situation where the risks of climate change had been demonstrated prior to any disturbance of the climate system, a single mitigation strategy would have sufficed. We could have stopped the emission of greenhouse gases before climate changes took effect. In reality, it took time to become aware of the climatic changes caused by greenhouse gas emissions, a net increase of which began in the industrial revolution. However, given that

[10] National Oceanic and Atmospheric Administration (NOAA), www.noaa.gov.

greenhouse gases have a long lifetime in the atmosphere[11], and that a certain level of inertia characterizes the climate system, the effect in time of emissions is extended, and subsequent emissions add to previous ones. Even if we stop GHG emissions immediately, those that have already been issued will still lead to climate changes. The path of adaptation is therefore inevitable, in the same way that we cannot do without mitigation, in an ideal case where climate change would be sufficiently limited so that the planet in general and humanity in particular could adapt relatively easily and at a low cost, then it would probably be unnecessary to address mitigation. In reality, however, if nothing is done to reduce emissions of greenhouse gases, climate change will not be constrained and so adaptation will rapidly become too expensive or even impossible. While mitigation is used to avoid the unmanageable, adaptation aims to manage the inevitable (SEG, 2007), and there is no need to regard these two strategies as alternative options.

In practice, however, adaptation and mitigation are dealt with by different communities (international negotiations, scientists, NGOs…) and often in different locations. Without seeking to question a situation that arises from undeniable practical considerations (different approaches, spatial and temporal scales, stakeholders, scientific areas…), this distinction should not obscure a number of interrelations between mitigation and adaptation. These interrelationships can be grouped under two main categories: adaptation actions that have consequences on attenuation, and the mitigation actions that affect adaptation (Klein *et al.* 2007).

4.2.1. Adaptation actions that have consequences on mitigation

Adaptation actions can have positive and negative consequences on mitigation. Indeed many possible adaptation strategies involve increasing energy consumption: air conditioning to cope with rising temperatures, the technical solutions to counter the loss of water (desalination, increased pumping, re-treatment…), for example. Yet energy production often involves the emission of greenhouse gases. However, the relationship between adaptation and mitigation can also be positive, especially if it is well planned. Indeed, new standards for the construction industry must be established in response to climate change. These standards may have a positive impact, intended or otherwise, on mitigation, for example improved building insulation will reduce the discomfort of temperature rise, and at the same time reduce energy needs.

4.2.2. Mitigation actions that have consequences on adaptation

Again, there are positive and negative interactions. For example, conflicts may occur between mitigation actions and adaptation measures at the level of water management: a classic strategy to reduce emissions is to switch to energy sources that emit less greenhouse gas, such as hydraulic power; however dams contribute to the reduction of sediment input into the Mediterranean[12], aggravating coastal erosion which may be caused by climate change and the rising water levels, making adaptation more complicated. An example of a positive relationship is the protection of biodiversity: deforestation is a major source of greenhouse gas emissions, and protection of forests can at the same time reduce these emissions. It also helps to preserve global biodiversity, which has proved to be of importance for adaptation.

The identification of these two major categories of interrelations shows that it is productive to explore possible synergies and potential trade-offs between adaptation and mitigation. Taken independently, these two strategies can lead to counterproductive and ineffective actions, although they serve the same purpose. An integrated strategy taking into account the issues of mitigation and adaptation, as well as the short and long-term issues, would prevent many conflicts and allow the better management of climate change constraints.

Ultimately we realize that the questions being raised do not only concern adaptation or mitigation, or synergies and compromises between the two, but more broadly encompass issues of sustainable development: how can adaptation and mitigation strategies be part of sustainable

[11] Twelve years for methane (CH_4), around a century for carbon dioxide (CO_2) and more than 50,000 years for tetraflurомethane (CF_4)

[12] The sediment input by rivers has been reduced by 90 % in the second half of the 20th century due to the construction of dams and major extraction of aggregates.

development, taking into account the constraints linked to all of the issues, rather than just the specific constraints of the strategies themselves? To think along these lines is not straightforward, and translating these thoughts into action is even less so. However, there is a way of avoiding future conflicts between components of a strategy to achieve a common goal.

4.3. Climate variability and climate change

Climate change is not easy to comprehend, with climate intrinsically variable. Climate is defined as the current weather situation taken as a whole, and more specifically as a statistical description of the averages and variation of elements (such as temperature, humidity, wind, pressure) over a period of a few months to several million years. The period used to calculate the average is 30 years, as recommended by the World Meteorological Organization. The climate is changing naturally, under the influence of internal factors (such as ocean circulation and the Earth's rotation), which is known as climate variability. This variability includes the difference between day and night, between seasons, and climate extremes (storms, floods, droughts).

Climate change is outside of this framework and is defined mainly by the fact that its origin is not internal to the climate system, but external, and that this change is long-lasting. We can distinguish two types of external sources: natural external origins (such as the influence of the sun and its cycles, or volcanism) and external sources due to human activity. To simplify the distinction between climate variability and climate change, we often limit the term climate change to refer to external human origins, grouping all the natural origins of climate variation under the generic term "variability". In particular, this is how the United Nations Framework Convention on Climate Change (UNFCCC), distinguishes climate change from climate variability, variability being natural and change considered anthropogenic: "*climate change is a change of climate attributed directly or indirectly to human activity that alters the composition of the global atmosphere in addition to natural climate variability observed over comparable time periods*" (Article 1 of the UNFCCC). This distinction shall be applied here.

As it is based on the cause of the phenomenon, the distinction between climate variability and climate change is clear enough in theory, however, it is much less evident in practice. Manifestations of climate variability and climate change are similar, have the same temporal and spatial characteristics, are cumulative, interchangeable and often (still) impossible to distinguish. At the moment it remains, for example, difficult to say precisely whether a particular drought is the result of climate change or not. In the decades to come it will be impossible to distinguish with certainty the tangible effects of natural climate variability from the impacts on climate change of human origin. Climate change is said to be still within the "noise" of climate variability.

How can we deal with adaptation to climate change in this context? Human societies, from the poorest to the richest, are still insufficiently adapted to climate variability. Is it reasonable then to focus only on additional efforts related to climate change? Clearly not, for three main reasons: first, it is difficult to distinguish between variability and change, and thus to "select" the subject of adaptation; secondly, it would be irrational to choose not to adapt to the climate variability that we endure today and prefer to adapt to climate change whose impacts will be felt mainly in the future; and thirdly, adaptation to climate variability often takes the same form as adaptation to climate change, and it would not therefore be feasible to only consider the latter. Adapting to natural climate variability (with its storms, droughts, floods, hurricanes...) is therefore considered by many as an excellent strategy for adapting to climate change.

However, the debate is not so simple and the issue's main stumbling block is the funding for adaptation. Such funding is being established at international level on the tacit "polluter pays" principle: countries that have contributed most to climate change (those who are now developed and in doing so have produced large amounts of greenhouse gas emissions into the atmosphere) are willing to help poorer countries adapt to the impacts of climate change, to which they have contributed little. This funding framework therefore returns to the cause of the phenomenon by making the distinction between natural and human origin, and thus raises again the question of what should be subject to adaptation. If funding is based on the polluter pays principle, it is limited to climate change adaptation, while adaptation to natural climate variability lies outside of its scope.

Besides funding issues, the challenge lies in the definition of adaptation strategies (what do we adapt to?). In practice, however, we note that adaptation projects already implemented are mostly adaptations to climate variability: for example, projects of irrigation and water management, or mechanisms for disaster management (information, early warnings, insurance…). For reasons of image, or to highlight the fact that adaptation to climate variability reduces vulnerability to climate change, these projects are often labelled as projects for adaptation to climate change. However, careful analysis shows that, in reality, these projects consider the impacts of climate change in a very limited or nonexistent way, which may in some cases create the risk of poor adaptation (known as "mal-adaptation"). While we should not limit the scope of adaptation to the area of climate change, we should neither do the opposite and limit the scope of adaptation to climate variability. Adaptation projects for climate variability may well increase vulnerability to climate change, mainly because they would only take into account the variations around an average, not the evolution of this average.

4.4. Adaptation, by whom and for whom?

4.4.1. Stakeholders

- *Individuals*

In all likelihood, people will adjust their ways as has always been the case, according to the changing climate among other things. They will seek to minimize the probability that their activities and security will be adversely affected by climatic conditions and the linked environmental circumstances. The possible adaptation options are infinite, for example changes of activity, changes in practices, technologies, or migration (see 4.5)… and they can be both reactive (post-perturbation) and proactive (before the perturbation occurs). Psychological studies[13] suggest that individuals will particularly take into account the extreme events (storms, flash floods, heatwaves…), despite their low probability of occurrence and how difficult they are to predict. A better understanding of how decisions are made at the level of the individual or small group will be crucial to anticipate and thus prepare individuals for adaptation. In this context, we start from a firm basis: thirty years of research on public perceptions of risk are available for some societies, for example in the areas of nuclear power and genetic manipulation it has been amply demonstrated that efforts to convince people that a strategy is in their interest may fail, leading to a divorce between public opinion and expertise.

Concerning consumer trends (food, energy, water, leisure…), individuals will adapt to climate change, and also to the potential emissions reduction policies that may be implemented. Regarding climate change, the example of tourism is enlightening (Hamilton, 2003; Billé *et al.*, 2008): the choices of tourists are strongly linked to climatic conditions (both at the place of origin and destination), and will therefore evolve. However, tourist choices are not entirely determined by climate conditions, for example culture, fashion, accommodation and transport costs play critical roles. Age is also an important factor: Mediterranean tourists – of which the majority of the international flow comes from Europe – are older because of ageing population demographics; will they develop an increased sensitivity to the environment? to health? to security (environmental, but not only) or to culture? Will the aging tourist population, together with global warming lead to a relative decline in the summer resort segment, to the benefit of other forms of tourism such as extended stays in winter, as it is already the case on the Costa del Sol and Malta? Concerning policies for the reduction of greenhouse gas emissions, consumers will probably adapt to price signals related to the "carbon content" of the available products: fruits and vegetables, meat, touristic destination, mode of transportation, types of accommodation and activities…

- *The private sector*

The adaptation of the private sector should be considered by taking into account the different sectors, and within each sector the different companies, that have various interests and approaches, ranging from small/medium enterprises (often predominate) to multinationals; and from sectors

[13] See for example the work of Agnes Allansdottir (University of Siena, Italy).

highly dependent on climate (agriculture, tourism…) to the more independent (banking, IT…). In addition to the size of the company, its financial and technical resources, access to capital for investment, its type of clientele… we can distinguish between companies whose activity is strongly committed to a certain place and those that are much more mobile. Their ability to adapt to climate change is inevitably diverse. For example, in the tourism sector, we quickly realise that we cannot consider all hotels relating to a major brand to be on the same level. Depending on the type of relationship (subsidiary, "managed", franchise), challenges and opportunities for adaptation differ widely (Billé *et al.*, 2008). In the same way, the response capacities of small independent hotel managers will not be the same as multinational groups.

Climate change can have four major types of impact on the private sector. The first concerns the design of production facilities or services: are the statistics used in the design of facilities/infrastructure robust enough to cope with possible changes in intensity, persistence and frequency of climate data? The second type relates to the demand of goods or services: what are the opportunities for changes of factors that control the demand of goods and services? The third concerns supply: what are the likely environmental changes ahead that will affect the management of production? The final impact is related to extreme events: in future what will be the consequences of industrial incidents that are caused by climate change?

At the level of production sites for goods or services, the most obvious adaptation possibility is the displacement of the activity. Whether this location change is spontaneous or forced, in theory it provides a solution, but of course in practice there are numerous obstacles. One option that is often more realistic and effective, is anticipation of the future impacts of climate change in the current investment strategy. However, it requires a strong awareness and availability of climate information, vulnerability maps… Finally, less drastic possibilities lie in the environmental management of facilities (such as water and energy saving, devices for rainwater harvesting, wastewater recycling, design and architecture of adapted buildings). These adaptation measures are particularly well received when they result in savings for entrepreneurs.

Finally, technological innovation can overcome to some extent the constraints of climate change. For the hotel industry, some examples are air conditioning, temperature controlled swimming pools, imported food rather than local, the maintenance of a substantial vegetation cover (which contrasts with adjacent areas), the desalination of sea water, artificial regeneration of eroded beaches… To some extent, climatic changes are "compensated" by technological developments. However, all companies do not have the necessary financial capacity, while technical solutions will not solve all the problems. We note in particular that many of these "solutions" tend to increase greenhouse gas emissions and thus the problem. A short-term or local perspective can therefore be harmful in the longer term or at a different scale.

- *The national and local public authorities*

In general, individuals and the private sector will adapt specifically in response to certain changes in given regions, and through adaptation measures taken at the local level. However, public policies have a key role to play at two main levels:

– First, by the development of adaptation strategies for activities under the jurisdiction of public policies (infrastructure, sectorial policies…), integrating the concerns related to climate change into national development strategies, planning and urban development documents, plans of risk prevention, instruments for coastal planning… Today, the general level of integration or *mainstreaming* remains low, probably partly because of the "novelty" (relative) of the climate problem, but mainly because that on the Mediterranean coast, for example, the management of coastal areas remain poorly adapted to the current climate; it is not integrated and does not help to put Mediterranean companies on the path towards sustainable development (Billé, 2008).

– Second, by supporting stakeholders and their adaptation efforts, through the creation or strengthening of legal frameworks and economic and financial instruments that are necessary to make possible or even encourage the implementation of adaptation strategies. In this sense, public policies that promote a more rational management of resources (e.g. water) will have to be part of this enabling framework for adaptation.

These existing instruments, to which we could add the processes of consultation and public information, should be used to the best of ability, which is far from being the case. However, beyond the "traditional" instruments of public action, other dimensions of the problem will increasingly require a broader palette of action levers. Firstly, public authorities will have to convince people to make production decisions that have usually been down to the individual: choice of agricultural production, diversification of tourism and reduction of seasonality... The aim is to develop less climate-sensitive activities or at least with contrasting sensibilities, but also activities that are less demanding in resources. Reorientation of the supply and demand are of course inextricably linked, and intervention by the authorities often seems necessary so that the supply and demand meet in a more sustainable areas of production.

4.4.2. Target populations

A central issue that arises for any decision-maker is to prioritize the populations that must be targeted for adaptation policies, at all spatial scales. This question involves the assessment of the vulnerability of a population or area: who is most vulnerable, what is this vulnerability based on, can we measure and monitor it over time? (Bankoff *et al.*, 2004; Adger, 2006; Berkes, 2007; Magnan, 2009). We often divide vulnerability into a physical component: exposure, and a human component: adaptation ability. The exposure describes the situation of a population facing the probability of natural hazards, particularly climate impacts. For example, the exposure of Venice to the rise in water level is higher than that of Damascus. Thus, for an equal adaptation capacity, a given population is more vulnerable if it is more exposed. Adaptation ability describes the degree to which a population is able to adapt, to adjust to an external stimulus (natural disturbance, particularly climate). In the same way, for an equal exposure, a population is more vulnerable if it has a low adaptation ability. Clearly, we can see that vulnerability is not a simple concept, especially in the context of climate change: on the one hand, the impacts of climate change (and therefore future exposure) are uncertain, particularly at the local scale; on the other hand, there is currently no consensus on the determinants of adaptation capacity, which seems largely contextual, limiting the value of large-scale comparison.

Despite the complexity of the concept, the identification of target populations is closely linked to their vulnerability: the most vulnerable populations are given priority in the creation of current projects, programmes or adaptation strategies. For practical reasons and in the absence of a better solution, the architects of these projects, programmes and strategies often confuse vulnerability with the level of wealth. In other words, they restrict the adaptation capacities to economic and technological areas. If this shortcut is justifiable, given the need to focus on the poorest, it is arguable that doing so is optimal in terms of adaptation to climate change. Indeed, the poor may also have other forms of adaptive capacity that are not directly related to levels of economic wealth, but which are nonetheless real. Some communities may, for example, demonstrate social links that can prove fundamental in the event of an environmental crisis (solidarity during an emergency) or in implementing anticipation policies.

To ignore these other forms of adaptation capacity could lead to their erosion – usually by automatically bringing standardized solutions that are imported from other contexts – which goes against the objectives of adaptation. Similarly, wealthier populations may be particularly vulnerable, as evidenced by the recent increase in costs related to natural disasters in OECD countries. Focusing on the poor can therefore result in the vulnerabilities of other population categories being overlooked, which runs the risk of reducing the effectiveness of a territory’s adaptation as a whole. At the level of the Mediterranean in particular, it would be erroneous to believe that adaptation only concerns the countries of southern and eastern shores. It would also be counterproductive to apply European models to reduce the vulnerability of these countries, a process that risks obscuring potentially innovative adaptation capacities. Finally, the most developed countries should not think they can do without adaptation strategies, and must investigate further how their populations can adapt. Adaptation is not a question of economic capacity.

It appears therefore that different populations require different approaches to adaptation and that, ultimately, they must all be considered as target groups. The ability to implement simultaneous solutions to suit all, however, is limited and the authorities concerned will have to prioritize. This brings us back to common issues in public decision making. Indeed, the prioritization of adaptation cannot solely be based on levels of vulnerability, but must also consider other issues, including spatial (are there priority areas?), temporal (what adjustments must be implemented now, which can wait?), equity (should there be an equitable distribution of adaptation actions, and on what criteria?) or economic optimization (on which target does one Euro spent generate the highest return on investment?).

4.5. Climate-induced migration in the Mediterranean: true issues and false debates

Among the possible consequences of climate change impacts in the Mediterranean, several recent studies point to the possibility of increased migration, both within countries bordering the Mediterranean, but also from North Africa to Europe (Afifi, 2009; Fermin, 2009a; Fermin, 2009b; Brown, 2008). Governments themselves have also raised this possibility, notably the Algerian government at COP 14 in Poznan.

It is crucial, however, not to reduce migration to a causal relationship between environmental degradation and forced migration, but to overcome this deterministic perspective in order to address the issue of migration as a whole. Environmental factors are often combined with other migration factors, mainly socioeconomic, in a relationship of mutual influence. A given impact of climate change may thus have different migration consequences in diverse socioeconomic contexts. While acknowledging the growing importance of the impacts of climate change in making the decision to migrate, it is therefore important not to consider this decision in this single dimension: isolating the environmental factors from socioeconomic factors is often useless, without empirical justification. Moreover, the nature and extent of migration depend heavily on the immigration policies in place, and not only the nature of the factors that determine migration. Zolberg (1989) and others have shown the limitations of the "push-pull" approach as an explanatory model of migration.

4.5.1. Migration and Adaptation

Although it seems difficult for the above reasons, to identify a specific category of "climate migrants" in the migration ongoing in the Mediterranean, empirical studies converge towards the conclusion that the impacts of climate change will in future be an important determinant of migratory behaviour, that can transform current migration movements for the long term. In other words, if climate change is not necessarily the only trigger for migration, it will surely be one of the major contributors. It therefore follows that the relationship between migration and adaptation is necessarily complex and ambiguous, as migration can sometimes be considered as a failure of adaptation, and sometimes as a catalyst.

Migration is regularly presented as a sign of failure of adjustment policies, a last resort for people who don't have any other choice. However, the behaviour of migrants is infinitely more complex. In many cases, effective adaptation policies can indeed limit the impact of climate change for society, and thus reduce migration pressures. In other situations migration can be developed as a real adaptation strategy, mobilized by the migrants themselves. The timing, duration and destination choice of a migration can be directly chosen by the migrants, allowing them to minimize the impacts of climate change on their everyday lives. For example, seasonal migrations will allow populations to diversify their economic activities (and hence their sources of income), which acts as a risk reduction strategy for the community.

The cost of such migration, however, should not be overlooked: we observed that the populations most vulnerable to environmental degradation generally lack the resources – both in terms of economic and social capital – that are required for their migration (Jaëger *et al.*, 2009). In order for migration to be developed as an actual adaptation strategy, it will be necessary to establish policies and methods that allow the mobility of the most vulnerable populations. In this case, migration may also result in macro-economic benefits, including an increased amount of savings sent to the region of origin. Thus, members of the community that migrate can assist the adaptation of those who remain.

Finally, migration policies should not be limited to regions of origin, but also cover destination areas. Migration, especially on a massive scale, can induce an increased demographic pressure on resources in the destination, resources that will potentially be reduced under the influence of climate change. If this pressure exceeds certain thresholds, it can lead to civil unrest and threaten human security.

4.5.2. Impacts of climate change and the geography of migration

Two main types of climate change impacts, rising sea levels and the scarcity of drinking water resources, are likely to have significant influence on Mediterranean migration. These changes will not however produce similar migration, and will not require the same adaptation strategies.

Firstly, rising sea levels, will mainly affect the coastal and deltaic regions, the first of which is of course the Nile Delta. This delta is one of the world's largest, home to nearly half of the Egyptian population, i.e. approximately 38 million people. It is an extremely fertile region and the site for about half of the country's crop production. However, this delta is directly threatened by rising sea level (Figure 8). A World Bank study (Dasgupta *et al.*, 2007) showed that a rise of one metre in the level of the Mediterranean by the end of the century would destroy the sand barrier that protects the delta, which has already been considerably weakened by the construction of the Aswan Dam in 1970. Fisheries, cultures and tourism would be affected for the long term. The impact on the population would be considerable, the World Bank estimates that a rise in sea level of 1 m would affect just under 10 % of the population, which is about 6 million people, resulting in a loss of over 10 % in arable land. Therefore, the region has a high migration potential, which could result in a shift of the Nile Delta population to both the south and also to neighbouring countries and Europe.

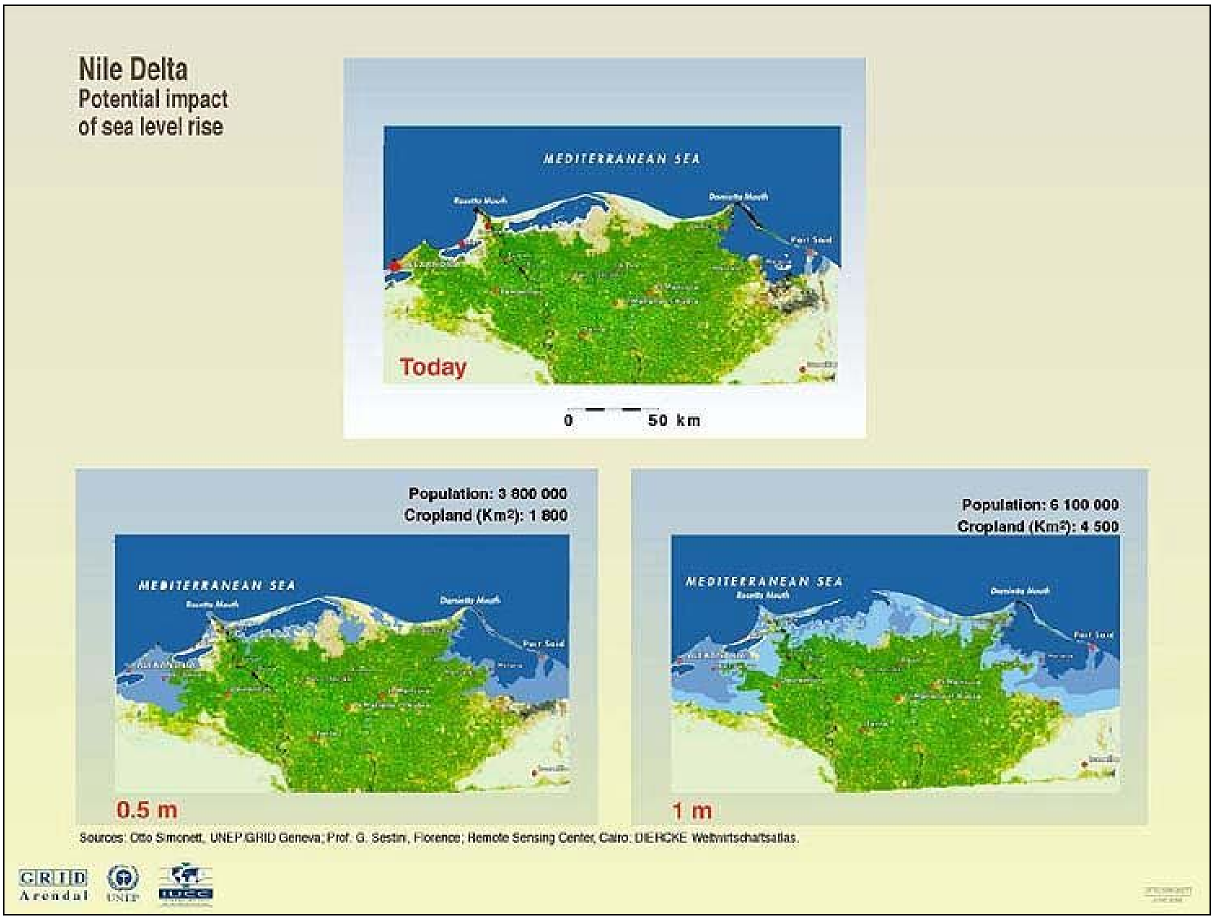


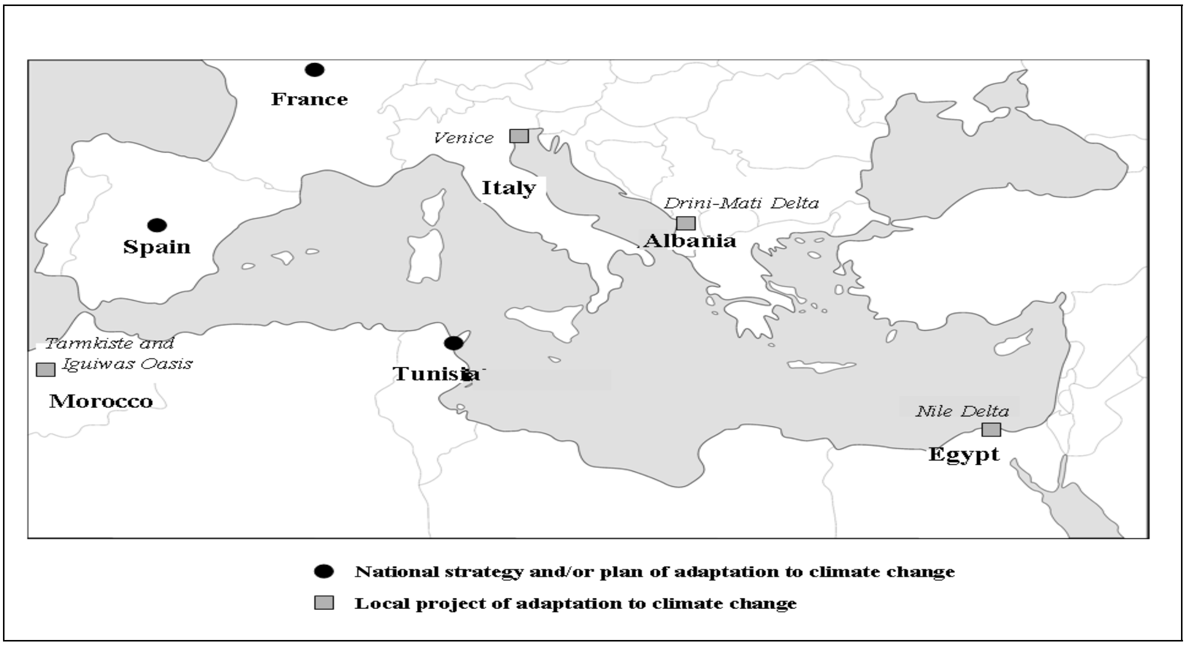
Figure 8. The expected consequences of rising sea level on the Nile Delta.
(Source: UNEP/GRID-Arendal)

Europe is experiencing a similar phenomenon, with internal migrations observed in parts of Spain that have been affected by soil degradation and a decline in drinking water resources. Eventually, one can imagine that these people will move to Northern Europe, especially if the constraints to mobility are less numerous. Regarding migration from sub-Saharan Africa, this will probably increase, both to countries of the Maghreb and to Europe, according to similar mechanisms. An important caveat is needed here: much empirical research has shown that while a phenomenon of desertification results in the long term in increased migration, however, a sudden drought has the opposite effect by reducing migration flows, as families have no resources to utilize for their mobility (Van der Geest, 2008). Moreover, it is important to note that migration policies aimed at North Africa and sub-Saharan Africa will be a critical influence on this potential migration, which is linked to the impacts of climate change.

5. Implementation of climate change adaptation in the Mediterranean

5.1. Elements of assessment of current efforts in terms of Mediterranean adaptation

Several years ago, Mediterranean countries began to examine how climate change would affect them. Without mentioning all the initiatives developed at various scales, by different stakeholders (research centres, local communities, governments, international organizations...) and on various themes (water, agriculture, coastal...) it seems important to have a closer look at what is currently being done through the various initiatives grouped under the banner of "adaptation to climate change." We therefore briefly present here a few of these initiatives, which are of two types and reflect concerns at two spatial scales: national (Spain, France and Tunisia) and international (Europe) strategies and plans on one hand, and local projects (Morocco, Egypt, Albania and Italy) on the other. Map 1 shows the location of these initiatives.



Map 1. Localisation of adaptation plans/strategies and projects presented here.

5.1.1. National and regional strategies and plans

- ***Spain:*** *National Plan for Adaptation to Climate Change (2006)*[14]

The National Plan for Adaptation to Climate Change provides a reference framework for the coordination of government activities on impact assessment, vulnerability and adaptation in Spain. As a result of public consultation, the plan was approved in 2006. It determines the overall structure of sectorial, systemic or regional assessments and is based on the learning principle to identify relevant adaptation options, whether sectorial, multi-sectorial, regional or cross-sectional. It identifies in particular information, communication and training actions as essential for its own coherence.

The Plan puts forward a vision of participatory adaptation even though the development of the strategic framework or some assessments of leading sectors can be regarded as top-down processes, however the definition of adaptation options at the level of Spanish sectors, systems and regions must be fulfilled by a decentralized and bottom-up approach. The adaptation plan also stresses the importance of synergies with other environmental issues, and also with many of the standard planning instruments. The integration of polices for the fight against climate change into public policies as a whole, is therefore considered as essential.

The Oficina Española de Cambio Climático (OECC) coordinates the implementation of the Plan of adaptation. It supports in particular the generation of data, tools and information relevant to the development of impact assessments and facilitates the participatory process.

- ***France****: National Strategy for Adaptation to Climate Change (2006)*[15]

The national strategy for adaptation expresses the view of the French State on how to address the issue of adaptation to climate change. This national adaptation strategy was developed through wide consultation, conducted by the National Observatory on the effects of global warming (Observatoire National sur les effects du réchauffement climatique, ONERC). The strategy was validated by the Inter-ministerial Committee for Sustainable Development, organized on 13 November 2006 by the Prime Minister.

Four major objectives are identified in this strategy for climate change: security and public health; social aspects: unequal exposure to risk; cost minimization, making the most of advantages; and to preserve natural heritage. Some courses of action are proposed as prerequisites for the future development of a national plan for adaptation, which aim to identify a group of specific measures to be decided at different levels.

- ***Tunisia****: National Strategy for the adaptation of Tunisian agriculture and ecosystems to climate change (2007)*16

Assisted by the GTZ (German Technical Cooperation), Tunisia has established in 2007 a national strategy for adaptation to climate change that is specific to the agricultural sector and integrates concern for ecosystems. In addition to the initial communication of Tunisia to UNFCCC, it has enabled the Tunisian ministries to have an in-depth report on the regional implications of climate change (climate trends and impacts to be expected on different environments). The adaptation strategy was conducted in consultation with all sectors and institutions involved, which has greatly helped raise awareness of the fact that climate problems facing agriculture cannot be solved in this sector alone, and that their resolution therefore requires a broader approach incorporating the issues of other sectors and stakeholders. This resulted in the development of a national strategy for adaptation in the agricultural sector, which now offers detailed guidelines and concrete measures to the institutions involved, on the way in which adaptation must be considered and implemented.

[14] http://www.mma.es/secciones/cambio_climatico/areas_tematicas/impactos_cc/pdf/pna_v3.pdf
[15] http://www.ecologie.gouv.fr/Adaptation-au-changement.html
[16] http://www.gtz.de/de/dokumente/en-climate-results-adaptation.pdf

The next step, currently ongoing, is to transpose the evidence obtained onto the health, coastal protection and tourism sectors. Work on the adaptation strategy has also stimulated great interest among the Tunisian population, promoting public awareness of climate change.

- ***European Union***: White Paper for adaptation to climate change (2009)[17]

The White Paper of the European Commission provides a framework for action and adaptation policies in order to reduce the vulnerabilities of the European Union to the impacts of climate change. The report positions itself as a preparatory work for the development of an adaptation strategy at the European level. Respecting the principle of subsidiarity and recognizing that much of the adaptation measures will be made at Member State level, it lays the foundations for the European Union as a facilitator of national efforts, especially for cross-border issues and European policy. The White Paper proposes the establishment of a *Clearing House Mechanism* by 2011 to serve as a platform for discussion on the impacts of climate change and best practices. It also announces that adaptation to climate change will be integrated into all EU policies, and clearly reflected in its foreign policy.

5.1.2. Adaptation projects

- ***Tunisia****: Development of a strategy for adaptation to climate change in Tunisian agriculture*[18]

In April 2005, the GTZ, under Tunisian-German cooperation, was assigned the task of providing support to conduct the necessary analyses to obtain more precise data on the impacts of climate change in Tunisia. The main themes were the agricultural sector, the vulnerability of ecosystems and the development of water resources. Under the auspices of the Tunisian Ministry of Agriculture and Water Resources (MARH), various ministries and administrative authorities in Tunisia have cooperated with GTZ through a 2-year process of analysis. In addition, many NGOs have taken part in the development of the adaptation strategy. In total, about 1,500 participants attended three conferences and twelve meetings.

In a first phase, the impact of global warming on the climate has been analyzed with the support of an international research team. In a second step, the analysis focused on the resulting implications for society and the Tunisian economy. The objective was to produce a national adaptation strategy for the agricultural sector that will lead to the development of an action plan. The evidence thus obtained, which was presented in a study in 2007, shows how the impacts of climate change are potentially serious in Tunisia, but also show that these implications are very different according to the regions.

- ***Morocco****: Adaptation of oasis ecosystems to climate change*[19]

Two projects have been initiated in Morocco within the framework of the UNDP's Community-based Adaptation programme. These projects are both located in the central-west area of the country, the first in the oasis of Tarmkiste (Guelmin province), the second in the oasis of Iguiwas (province of Tata). The projects are funded by GEF and aim to integrate climate change into the sustainable management of oases. They focus on encouraging community involvement in better water management, the strengthening of the agro-forestry system and the establishment of a local dialogue policy.

Broadly speaking, the UNDP Community-based Adaptation programme works on the principle that small communities are likely to be the most affected by climate change. Its purpose is to implement adaptation projects in these communities in order to increase their resilience, and to participate in a learning process on the small-scale implementation of adaptation.

[17] http://ec.europa.eu/environment/climat/adaptation/index_en.htm
[18] http://www.gtz.de/de/dokumente/en-climate-results-adaptation.pdf
[19] http://sdnhq.undp.org/gef-adaptation/projects/websites/index.php?option=com_content&task=view&id=258&sub=1

- *Egypt:* Adaptation of the Nile Delta to climate change through integrated coastal zone management (UNDP-GEF)[20]

A large proportion of Egypt's infrastructure and economic activity is concentrated in the Nile Delta and its coastal zone. As a result, floods and salinity intrusion due to rising water levels will have a direct and crucial impact on the economy as a whole.

Despite the measures implemented by the government, there are still many constraints to the effective implementation of integrated coastal zone management and adaptation to the rise of sea level. The project aims to improve Egypt's resilience and reduce its vulnerability to climate change. To do this, the objective is to integrate the management of risks associated with rising sea levels into the development policies of the Nile Delta.

- *Albania: Identification and implementation of adaptation measures for the Drini-Mati deltas (UNDP-GEF)*[21]

The deltas of the Drini and Mati rivers on the Adriatic Sea have a biodiversity that may be significantly degraded by climate change. The project aims to develop and implement strategies to moderate, to cope with, and to make the most of the impacts of climate change, by increasing the adaptation capacity and the resilience of ecosystems and local communities.

To achieve this goal, the project will develop community and institutional capacities to document and respond to climate change impacts in the river deltas. A supporting objective will aim to integrate the management of climate change into local development policies. Finally, this project will seek to promote learning by experience and also encourage adaptive forms of management and assessment.

- *Venice: Protection of the lagoon against the rise in water level*[22]

The lagoon and the city of Venice are highly vulnerable to rising water levels. In response to the increased frequency of floods, the Consorzio Venezia Nuova launched an intervention plan in 1984 to defend Venice against high tides and storms and restore the lagoon's structure, and the quality of the water and sediment. The construction of the main protection facility, a set of three mobile barriers to block the high waters outside the lagoon, began in 2003 and should be completed in 2014. The plan also includes a programme of street elevation, coastal protection infrastructure, an urban maintenance programme...

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[20] http://gefonline.org/projectDetailsSQL.cfm?projID=3242
[21] http://www.undp.org.al/index.php?page=projects/project&id=177
[22] www.salve.it

Project	Country	Duration	Budget ($)	Sectors	Funder	Project Executor
Development of an adaptation strategy for climate change in Tunisian agriculture	Tunisia	2005 - 2007		Agriculture, tourism, environment	GTZ	Ministry of Agriculture and Water Resources (MARH)
Adaptation of the Tarmkiste Oasis to climate change	Morocco	2009 - 2011 (2 years)	172,000	Ecosystems, Agriculture	UNDP-GEF	Rural Area Association Tarmguist
Adaptation of the Iguiwas Oasis to climate change	Morocco	2009 - 2011 (2 years)	114,000	Ecosystems, Agriculture	UNDP-GEF	Tiflis Association for Development
Adaptation of the Nile Delta to climate change through integrated coastal zone management	Egypt	Sept 2009 - June 2014 (5 years)	16 million	Coastal areas, all sectors	UNDP-GEF	Ministry of Water Resources and Irrigation
Identification and implementation of adaptation measures in the Drini-Mati deltas	Albania	May 2008 - May 2012 (4 years)	2 million	Ecosystems	UNDP-GEF	Ministry of Environment, Water and Forest Administration
Venice Safeguard Project	Italy	1984 - ?	15 billion	Coastal areas, infrastructure	Multiples	Multiples

Table 2. Examples of adaptation projects developed in the Mediterranean basin.

While the chosen sample is small, arbitrary and is not intended to be representative of all the adaptation initiatives in the Mediterranean, it can nevertheless allow an insight into the diversity of issues that these initiatives are expected to cover: future climate change, current climate variability, but also other environmental stresses (deterioration of biodiversity) and human stresses (unsustainable paths of development). The sample presented here reflects how difficult – but also how valuable – it is to initiate a process of adaptation, in the sense that adaptation is not a sector in itself and must not be an answer to a single stimulus. This twin characteristic makes it a preferred application field for cross-sectional and multidisciplinary efforts. However, these observations allow the identification of a certain "trend" that tends to label a growing number of development projects as "adaptation" although the link with climate change is not always evident.

The main interest of this schematic interpretation of the various initiatives is to show that diverse processes have been launched in the Mediterranean, but more interestingly, it also shows that these processes are not all conducted on the same basis, and that sectorial, but also intersectorial and territorial actions are carried out. However, this diversity of experience makes the Mediterranean an interesting laboratory for the implementation of adaptation to climate change because, for example, it is it not obvious *a priori* that addressing this issue from a sectorial angle is better than a multi-sectorial approach, and vice versa. Increasingly, debates on adaptation show that the contextualisation, according to the characteristics of societies and territories, of approaches and recommendations is essential, and that it is the consideration of the specificities at the scale in question that must prevail. If general principles can emerge from diverse experiences (such as those proposed in the following pages), their practical significance is a result of this important contextualization work.

5.2. How to achieve the aims?

While there is no doubt that the Mediterranean economy will be affected by climate change, the extent, nature and location of these impacts within the Mediterranean basin remains unclear. The historical weakness of the research on adaptation means that experts tend to focus discussion mainly on the risks and offer few solutions. This dialogue, although important, is often misunderstood by those directly involved. Furthermore, even when describing the risks, the need arises for more local modelling and information, which is usually at a global or at best a regional level (see above). For example, estimates of the costs of impacts or adaptation measures in terms of GDP reflect only partially the real vulnerabilities (who is going to lose, when and where?), which are however crucial to develop appropriate public policies and those that are in favour of the "most vulnerable".

It also represents an important limitation to the ideas presented in this document – which is probably less important once it has been acknowledged – but it is clear that at present the scientific work on vulnerability to climate change and on the adaptation capacity of territories and societies has not yet reached a stage of maturity sufficient to provide concrete and consolidated answers[23]. This does not however mean that nothing can be done: a series of recommendations can be put forward, which are essentially general principles in favour of an adaptation to climate change that are relevant if combined. Note that these discussions are mainly based on the work of the Stockholm Environment Institute[24], the CIRED[25] and IDDRI.

5.2.1. Do not rely on climatologists to do all the work and accept climatic uncertainty

Climate change is much more than change in the weather: for the decision maker it is above all a new source of uncertainty that reinforces a common constraint in terms of public decisions. Firstly, there is a distortion between the time scales used by climatologists (long term) and that of the existing decision making frameworks (short to medium term). Secondly, it is clear that communication between the spheres of climate science and decision making in the public and private sector is not efficient: if the former misunderstands which data are directly relevant to the decision making process, the latter struggles to understand the complexity of climate modelling and its results.

Meanwhile, as we have seen, climate science is constrained by many uncertainties. Thus, we cannot turn to climate scientists for information about the climate in the long term future, as we would do today with meteorologists for the weather forecast for the coming days. Indeed, it has not been shown that advances in climate science will lead to a reduction of all the uncertainties[26]. One of the reasons is that the future climate will depend largely on future emissions of GHG (Parry *et al.*, 2008, Solomon *et al.*, 2009), which are based on decisions that have not yet been taken. It is therefore unrealistic to assume that the uncertainties concerning the impacts will inevitably be reduced and that waiting to make decisions is a wise and effective strategy.

The implementation of adaptation strategies requires improvement in the way that the climate, and therefore the uncertainties, are taken into account when considering decisions regarding investment and planning. The aim is essentially to choose solutions that integrate the uncertainty rather than solutions that are designed around a single figure (generally the average of projections)[27].

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[23] Some questions that appear simple remain unanswered: what characteristics of the system (a territory, a society) make it more able to adapt than another? What are the mechanisms to be encouraged, and what pitfalls should be avoided? What lengths of time should be considered to facilitate action and the implementation of effective policies? Etc.

[24] T. Downing and others, see www.weadapt.org

[25] S. Hallegatte and others (cf. Hallegatte, 2009)

[26] For example the recent work of J.E. Hansen (2007) on the increase in sea level

[27] Once more, the majority of work is based on the A1B scenario because it is the average scenario, but the IPCC is clear: this scenario is not more likely than the others. The recent findings of an international conference on climate held in March 2009 in Copenhagen ("Climate congress: global risks, challenges and decisions") states that the current trajectory of GHG emissions is beyond that of the most pessimistic scenarios, to which A1B does not belong.

As S. Hallegatte (2009), we can suggest a few directions to explore that will lead towards more appropriate decisions:

– The institutionalization of long term planning (e.g. for the management of coastal zones or water at the regional level), in addition to a process of regular review according to new information. Adaptation is a continuous learning process;

– Promotion of "no regrets" strategies, i.e. strategies that are beneficial even without considering the impacts of climate change. For example: restoration of coastal dunes (which are buffer zones facing risks linked to the sea), implementation of plans to prevent natural hazards, etc;

– Introduction of robust solutions, i.e. those that are relevant to a broad range of future climates. For example: including the consideration of the most "pessimistic" outcomes in the design phase of infrastructure, rather than having to intervene after it has been put in place;

– Encourage reversible strategies rather than irreversible ones, to minimize the cost of an inaccurate estimate of climatic changes. For example: it may be better to reject urbanization plans for an area of coastline, based on the fact that if climate information one day becomes more precise, it will be possible to reverse the decision at a low cost; and from the opposite perspective, choosing to urbanize despite uncertainties will bring immediate benefits, but can lead to a future situation where the choice is between heavy protection and taking a step backwards, two options that are often cost-prohibitive and not always feasible;

– There should not be a focus on technical solutions to adaptation; in some cases, institutional or financial instruments may be more appropriate. One example is easy access to insurance systems (agriculture) or the establishment of early warning systems, rather than heavy coastal protection. The main interest of these "soft" options of adaptation is that they have much less inertia and irreversibility.

In summary, the fundamental uncertainty relating to climate change will not disappear in the coming years, thus policy makers should not rely on climate scientists, economists and other modellers to avoid having to make difficult decisions in an uncertain context.

5.2.2. Adopting a two-way integrated approach

While climate change will have indirect effects on the development of future societies, we now know that current modes of development affect climate evolutions and will continue to do so. Therefore, there are chains of feedback between development and climate change, which must be taken into account in the actions and policies that must now be promoted. Thus, insofar as adaptation strategies can have negative impacts for the environment or in terms of GHG emissions, it is important to develop adaptation approaches known as "integrated", that include for example, impact studies on the environment and climate. Furthermore, it is equally important that interventions that do not directly aim to fight against climate change, should take into account issues of adaptation, and will not therefore lead, even unintentionally, to a progressive reduction of the range of adaptation possibilities. This requirement, which also applies to the logic of reducing GHG emissions, is also important for example in the forefront of major infrastructure implementation (highways, dams…), referring indirectly to the issues of robust solutions.

Figure 9 shows this dual relationship of integration, which is on one hand the integration of climate change concerns into development issues – referred to as "mainstreaming" – and on the other hand those of sustainable development that are integrated into the fight against climate change.

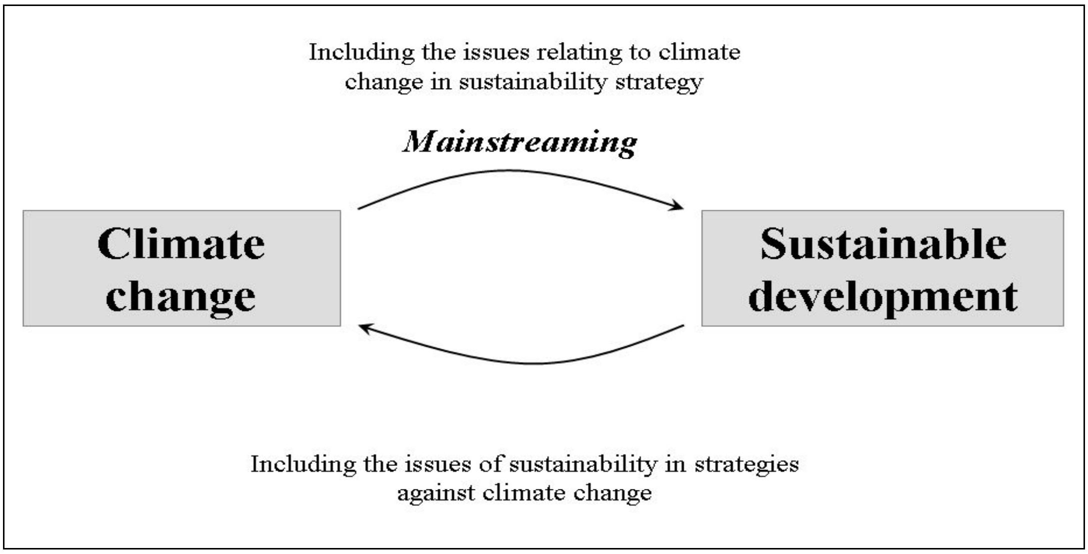

Figure 9. Fight against climate change and implementation of sustainable development: a two-way relationship.

5.2.3. Taking into account the range of possibilities (action areas and stakeholders)

Adaptation can be applied at many levels, not only technical but also behavioural, economic, financial, political, institutional… We often reduce adaptation capacities to economical and technological attributes, but the modes of social organization or the political-administrative structure, for example, are also important elements of a region's capacity (i) to respond to a crisis or a succession of crises and (ii) to anticipate potential future crises.

Thus, conceivable practical solutions do not only concern transfers of technology or instruments of wealth creation, even if they obviously have a role to play. For example, we can consider actions in favour of maintaining social links as an indirect way to strengthen the capacities of a society to show cohesion during a crisis (social support, insurance…) and to implement collective anticipation policies (developing irrigation networks, strengthening structures and relief organizations…).

Finally, while considering a wide range of intervention fields in terms of adaptation, we should also underline that actions can be implemented at multiple scales, from small measures in a single urban district or on a few agricultural fields, to national and international policies (agricultural, commercial, weather…), and including development redeployment planning of local and regional areas (economic reorientations, peri-urban dynamics, preservation of ecological areas, use of renewable energies…). This echoes the two-way relationship between the fight against climate change and sustainable development. It implies that all stakeholders are involved in adaptation. Adopting an optimistic outlook, we can see in this complexity a proliferation of reference points for the implementation of adaptation (which means a multiplicity of actions and stakeholders).

5.2.4. Using what already exists

In the same way, we must be aware that we are far from being deprived of possible courses of action. Indeed in many cases, legal, institutional and technical instruments, for example, already exist and can be mobilized for the implementation of robust adaptation strategies. This is typically the case in the field of risk management through prevention plans. Just as some countries also have social policies that have potential benefits. It is therefore important to fully utilize existing facilities, before seeking innovation in response to "new" climate change problems – because if we consider the consequences of this problem, we realise that it is only partially new, in the sense that the impacts of climate change refer more broadly to an area of management and prevention of natural hazards. This refers to the state of mind previously mentioned "start doing well what we do badly", and therefore the idea that there currently exists diverse ways of avoiding (at least partially) uncertainty.

For example, the Mediterranean has developed under the framework of the Barcelona Convention (signed in 1976, revised in 1995) a unique device that aims at the preservation of biodiversity, the fight against pollution, integrated coastal zone management (ICZM)… In its various components, including the new Protocol on ICZM (Billé and Rochette, 2008), the Convention has a key role to play in adapting to climate change.

5.2.5. Recognize differences of interest

While the multitude of stakeholders and types of actions that may affect the logic of adaptation can constitute an opportunity for the implementation of adaptation, it also calls for the recognition of the existence of divergent interests and links between stakeholders, and thus potential conflicts around the adaptation strategies to be implemented. A classic example is the sharing of water between agriculture and energy sectors. It is essential that we do not pretend to ignore this issue, but to recognize and address these issues with the whole range of available instruments: participation, negotiation, mediation, communication, consensus building, but also to arbitrate in favour of certain interests to the detriment of others. Adaptation as well as emissions reduction, while they have strong technological and scientific attributes, are still fundamentally political processes around which issues of power and power relations will be expressed.

5.2.6. Adapting interventions to local contexts

In its implementation phase (preparation of a strategy, identifying concrete measures…), adaptation is a process of decision and intervention that is specific to a given territory, and therefore indirectly specific to one or more stakeholder(s) who act in a particular context characterised by specific threats and opportunities. There is no unique process of climate risk management, nor any generic solutions that can be applied regardless of context. This invites careful consideration of "good practices" which, although attractive *a priori*, often obscure combinations of factors specific to a particular case that are important for a project's success. Thus, the common mistake is to consider these experiences as "recipes" that can be transferred without modification, rather than as simple examples of the implementation of general principles.

6. Conclusion

6.1. We will have to act quickly… and for a long period of time

The multitude of possible impacts of climate change makes this problem one of the greatest concerns for the future of the Mediterranean in the medium and long terms. The challenge is both to reduce GHG emissions, and to adapt to changes that are already ongoing and those to come in future, in order to reduce the vulnerability of societies that may be dramatically changed over the coming decades. Generally, this issue is seen as a matter of balance – and therefore, among other things, as an issue of allocation of costs – between emissions reduction and adaptation. In the Mediterranean, the problem cannot really be viewed in these terms because while the region is substantially involved in international efforts to reduce GHG emissions, it remains in itself a relatively marginal emitter at the global scale[28], and the impacts that it will endure are mostly related to emissions from all industrialized countries – current and those to come. This justifies the fact that in terms of adaptation, the Mediterranean countries must mobilize now and for a long period of time, because there are fewer uncertainties about the irreversibility of the changes already underway. The phenomenon of latency in climatic processes plays an important role in the explanation of the fact that the GHGs that have been released into the atmosphere by human activities since the industrial era will continue to have consequences on the functioning of the global system for the long term. A recent study very clearly shows, for example, that even if we stopped all GHG emissions by 2100, its concentration in the atmosphere would remain high at least until the year 3000, which implies a warming of the atmosphere and a rise in sea levels that is unavoidable (Solomon *et al.*, 2009). The irreversibility of the trend is also shown at shorter time scales (from decades to the whole of the current century) (IPCC, 2007a; Rahmstorf, 2007, Parry *et al.*, 2008).

[28] Although it is clear that even within the basin, all countries do not have equivalent emission levels.

We will therefore have to manage what is already inevitable, while taking care not to consider climate change as the only engine of change. It is important to consider the impacts of the future climate on the future society, and not on today's society, even if this adds to the complexity. Long term cross-projections are necessary.

6.2. An emerging framework of action…

The aim of this document was also to demonstrate that while this issue of adaptation may appear to be new, policy makers, planners and stakeholders are not deprived of solutions. Instruments exist, and experiments are ongoing which, although not always specifically targeted to the fight against climate change, can provide a serious contribution. Five points are listed here:

1. In terms of adaptation, one of the aims is to achieve success in areas where we have largely failed so far: control of urbanization, environmental protection, reduction of inequality… In many cases, the current or short-term foreseeable situation is not sustainable, even without taking climatic impacts into account. Consequently, we see that climate change reinforces existing problems, more so than it creates new ones. According to this view, climate change may also provide opportunities to solve existing problems. While few examples of these opportunities are currently available, the fact remains that any progress towards more sustainable paths of development will be an important initial step in adaptation, as well as for mitigation. In other cases, however, particularly in agriculture, it seems impossible to manage the climatic impacts without a radical change of the dominant agricultural development model – which implies that the leeway in this area is already significantly reduced;
2. This should not however constrain innovation, because the stakeholders, both public and private, must now improve their use of climate information, i.e. greater integration of such data in their policies, development plans, business plans… In many cases, information and knowledge, even imperfect, seems to provide a sufficient basis for action, but it is slow to permeate into the decision-making sphere;
3. Whether we consider the implementation of existing measures or the innovation of new ones, attention should logically focus initially on the orientations and measures that are "without cost or regret." Many of these can have positive impacts in terms of mitigation and adaptation while allowing a return on investment in the short term. However, synergies are limited and in some cases will be confronted with necessary decisions that require prioritization of the choice between emission reduction and adaptation;
4. The policies and adaptation measures should be considered at the intersection of climate scenarios and socioeconomic projections. They should not only be derived from climate and impact scenarios, but be based on the intersection between climatic and non-climatic conditions. Indeed, imagining the impacts of climate change in 2050 on the basis of the current socioeconomic situation makes no sense because we know well that this situation will change. In the same way, studying the changing living conditions of future generations without taking into account climate change appears unproductive;
5. We consider that this current context of the emergence of a real consideration of climate change issues (reduction of emissions and adaptation) constitutes an opportunity – that is however not without constraints – for the Mediterranean states to revisit their development strategies for the medium and long terms and to integrate sustainable paths of development.

This thought process must be rapidly conducted, without losing sight of some key points that we too often forget:

- For many stakeholders, climate change is synonymous with hypothetical problems that may occur in 20 to 30 years (or more), whereas their actions are driven by real problems faced today;
- According to most of the available climate and economic models, the desire to limit the increase in average temperatures to +2 °C (as expressed by the European Union) means drastic cuts in GHG emissions and also major changes in our development patterns. All measures that can be

suggested for the medium and long terms must therefore be considered either in a society profoundly transformed by this objective, or in one with much more radical climate change;

- However, the main change that global warming will lead to may not be climate change itself, but (i) uncertainty about future climatic conditions - which over the past centuries has been marginal and could be neglected in decision making; and (ii) the uncertainty regarding future policies to reduce GHG emissions and their restructuring effect on all economic sectors.

6.3. ... that remains incomplete

In scientific terms, three areas must be investigated further. The first aims to develop the evaluation and monitoring of the levels of vulnerability to natural risks and climate change, at different territorial levels, from national situations to more local areas. A second area consists of the development of scientific knowledge on adaptation capacities, particularly on two themes: influencing factors (economic, sociocultural, environmental and politico-institutional; endogenous/exogenous), the relevant spatial and temporal scales. Finally, the third direction concerns which adaptation strategies to promote, and again the issues of spatial and temporal scales are raised, as well as those relating to funding (source, distribution, assessment of fund distribution efficiency…).

On the issue of financing, a number of international mechanisms are already at work. The United Nations Framework Convention on Climate Change (UNFCCC) has already established three funds for adaptation, which account for a total of approximately $200 million. The Global Environment Facility (GEF), which manages three funds, also dedicates a part of its own financial resources to adaptation. Bilateral cooperation also plays a role in the matter, and an increasing number of cooperation projects focus on adaptation. However, the amounts involved are still far short of cost estimates for adaptation that are suggested by some economists, who estimate them to be at tens of billions of dollars a year. Despite the obvious limitation of these assessments, which are mainly due to the methodology used and our ignorance of what are the true costs of adaptation, it seems clear that the current funding is not sufficient for the challenges ahead. The debate on funding should not however hide the fact that many adaptations can already be achieved at a low cost since they only require things to be done in a different way than we do today, without taking into account climate change.

Finally, it is becoming increasingly clear that serious efforts are still required for the establishment of operational interfaces between scientists and public and private stakeholders, so that the latter can make the best possible use of research undertaken in climate science and social science.

6.4. What are the needs of regional coordination for adaptation in the Mediterranean?

If regional activity on climate change has so far concentrated mainly on reducing GHG emissions, it is because the latter is much more direct and concrete to deal with in terms of international coordination. The implementation of adaptation measures by one country or community does not *a priori* benefit its own population, which is not the case regarding mitigation where the efforts of all contribute to a shared goal. However, it appears that collective Mediterranean adaptation frameworks are crucial for several reasons.

First, the need for sharing experiences and tools for adaptation is increasingly important at the regional level as the work develops on the field. Although vulnerability and adaptation capacity to climate change varies widely depending on the context, as are the initiatives to be undertaken, the need to share experiences and of capacity development encourages the issue to be put on regional agendas. This issue could among other things lead to more effective regional exchanges in the preparatory stages of climate negotiations, even if we cannot envisage that Mediterranean countries will systematically negotiate on common positions.

In addition, the financial needs are high and many Mediterranean countries, especially outside the European Union may not be able to meet these costs on their own. Even if the climate convention does not legally designate a "leader", the Annex 1 countries[29] have pledged to provide financial support for adaptation in their development partners (Article 4 of the Convention, Article 11 of the Kyoto Protocol, Marrakesh Agreements). The establishment of such funding, discussed globally within the framework of climate negotiations, requires in the Mediterranean a continuous and informed dialogue, more in line with regional and local specificities, and the related needs. Bilateral and multilateral development agencies are logically placed on the front line. Their role is all the more important as fundamental synergies exist between development (through the Millennium Development Goals) and adaptation. These synergies are such that it is often difficult to concretely distinguish between what is related to one area or the other - and that it is therefore conceptually unfeasible to present adaptation as an "incremental cost" in relation to development.

Also, even if Mediterranean countries are competing amongst themselves on various sectors, each also has a certain interest in the fact that its neighbours could become stable and dynamic partners over the long term: growth and economic trade, management of migration flows, constructive contribution to regional and global governance and international security.

Finally, we have seen throughout this report how issues of environmental conservation are closely linked to those of adaptation. Within the framework of the Barcelona Convention, the Mediterranean has developed a unique instrument that has, as we have seen, a crucial role to play in its various components, in terms of adaptation to climate change.

[29] i.e. all industrialized countries (mainly those in the OECD), plus countries with transition economies (Russia, the Baltic States, countries of central and eastern Europe).

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The Future of the Mediterranean

From Impacts of Climate Change to Adaptation Issues

This summary report has been produced at the request of the Sustainable Development General Commission (CGDD) of the French Ministry of Ecology, Energy, Sustainable Development and Territorial Development (MEEDDAT). It also received the support of the European Commission (DG Research, Circe project – "Climate change and impact research: the Mediterranean environment", FP 6) and the Région Ile de France (R2DS project). Drafted by IDDRI, in collaboration with CIRED, this document provides up-to-date information on conceivable climate trends and on their potential impact on natural resources and the different major sectors of activity for the Mediterranean. Principles and recommendations are also put forward to guide the design and implementation of adaptation strategies, at different levels and in different fields.

IDDRI is an independent institute which aims to bridge the gap between research and decision-making. It examines sustainable development issues that require international coordination, such as climate change or the depletion of natural resources. Its research focuses on global governance, North-South relations and international negotiations. As it creates a platform for dialogue between stakeholders whose interests are often at odds, IDRRI promotes a common understanding of concerns, while at the same time putting them into a global perspective.

CIRED investigates strategies to improve the relationship between environment and development. This involves highlighting dynamic links between economic regulations and the development of technical environments that have a material impact on growth in public policies. The aim is to understand how institutions, economic incentives and social conventions condition technological choices and consumption styles, and then to analyse the economic and social feedbacks of their impacts on the environment. As part of its research, CIRED has been focusing more specifically on climate change.

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