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13th Meeting of the Mediterranean Commission
on Sustainable Development
Cairo, Egypt, 28-30 September 2009

CLIMATE CHANGE IN THE MEDITERRANEAN

Current state of knowledge

Delegates are kindly requested to bring their documents to the meeting.
Documents will be distributed on CD Rom

UNEP/MAP
Athens, 2009

Contents

I. Improving understanding of climate change so as to anticipate its impact more effectively in the Mediterranean

Although the Mediterranean itself has a fairly low level of emissions of greenhouse gases, climate change will result in significant changes in its environment, which will perturb a whole series of essential economic activities in the region. Anticipating these impacts involves developing a good understanding of the phenomenon and its consequences.

1. Significant climate changes in the past

The work that has been undertaken in the field of paleoclimatology in the Mediterranean, which provides results that are of a good level of reliability for the past 18,000 years, helps to understand the possible consequences of climate change.

Figure 1. The Western Mediterranean 18,000 years ago

Source: France 2 Malaterre, according to J. Guiot and R. Cheddadi, *C.R. Geoscience 336* (2004).

Eighteen thousand years ago, in the middle of a glacial period, the average temperature of the water in the western Mediterranean was 7°C lower than the current temperature, while that of the eastern Mediterranean was between 1 and 2°C lower. As a consequence, temperatures on land were between 5 and 10°C lower than they are now and the level of precipitation was around half of the present level. Steppes and prairies occupied a large proportion of current forested areas.

During this period, the climate was very variable, characterized by the alternation between cold and temperate periods (Dansgaard-Oeschger cycles) with temperature variations of around 10°C between one phase and another. These variations, linked to astronomical cycles, resulted in quasi-synchronous responses of vegetation in the Mediterranean. Accordingly, cold episodes corresponded to the development of a steppe-like vegetation in South-West Europe. Interstadial periods of the Greenland Cycles coincided with the expansion of forest composed of pines and deciduous oaks, with Mediterranean trees and bushes, such as the green oak, olive and pistachio trees. The cold phases checked the development of the forest and flora and fauna that are now typical of Mediterranean regions, while the temperate phases allowed the expansion of meso-thermophile plants from refuge areas.

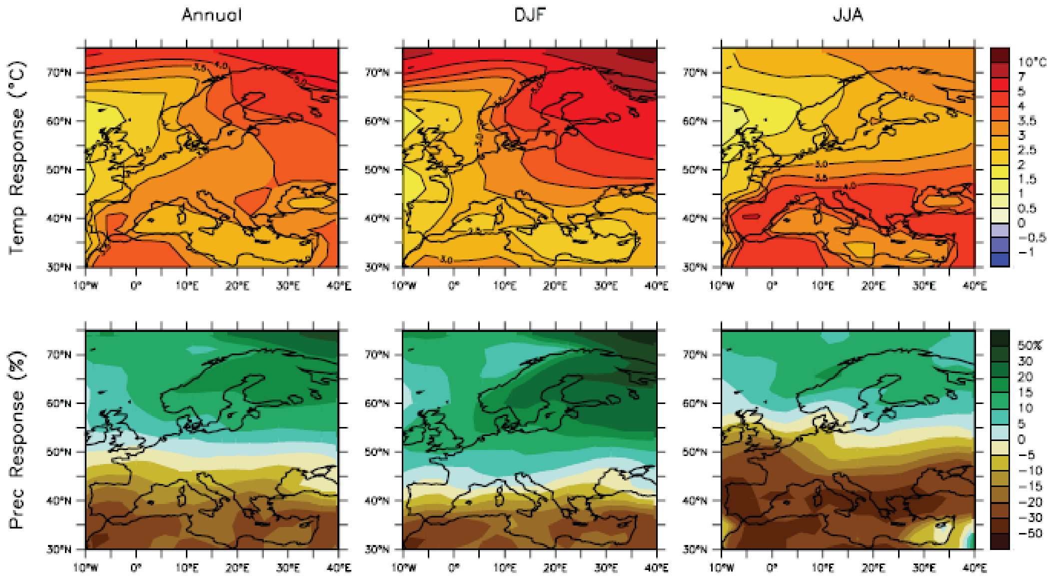
Analysis of the various periods shows the concordance between the evolution of habitats and the climate:

- In the middle of the Holocene (6,000 years ago), the maps of vegetation drawn up by Cheddadi show an extension towards the south of forests composed of deciduous trees, which extended for example right down to the Saoura Valley (southern Algeria). Average temperatures were higher (+1°C to +3°C in winter), and a greater volume of water was available for the growth of vegetation.
- During the Mediaeval Optimum (10th to 13th centuries), the northern limits of most Mediterranean crops extended to the centre of Europe and it would appear that agricultural output increased in the Mediterranean during these centuries.
- During the little ice age (14th to the beginning of the 19th centuries), corresponding to a fall in temperatures of around 1°C, there was, in contrast, a decline in the productivity of ecosystems and a higher incidence of catastrophes related to climatic events, which illustrates the significant impact of temperature variations, at even low levels.

During the 20th century, and with a clear acceleration since 1970, South-West Europe (the Iberian peninsula, south of France) have experienced warming of nearly 2°C. This warming is also perceptible in North Africa, even though it is more difficult to quantify in view of the lack of data. The only exception is Greece which, until the beginning of the 2000s, experienced a fall in its temperature. The increase in temperature is more marked in winter than in summer, and in relation to minimum rather than maximum temperatures. The range of the cycle is therefore diminishing. With regard to precipitation, rain has increased to the north of the Alps and diminished in southern Europe. In the Mediterranean, precipitation has fallen by 20% in certain regions. The trend is more differentiated in North Africa.

2. Rising temperatures, lower precipitation, a constant increase in extreme events

Figure 2. Comparison of current temperatures (in °C) and precipitation (in %) with the levels projected for 2100



Source: IPCC, fourth report

By the end of the century, the rise in annual average temperatures should be between 2.2°C and 5.1°C for the period 2080–2099 in relation to 1980–1999. The probability of warming of between 3 and 4°C is estimated at 50%. At the seasonal level, the uncertainty is much greater, with the values provided by probability ranges varying between the single and the triple.

The expected rise varies from one region to another: in sub-Saharan areas, the increase in the summer could reach 4°C. In contrast, on the northern shore, the increase should be greater in winter at around 3°C. Precipitation as a whole is likely to fall and the occurrence of heatwaves to increase (see the table below, taken from the IPCC's fourth report, and based on 21 global models).

	Temperature variations (in °C)		Variations of precipitation (in %)		Occurrence of extreme events (in %)		
Season	Min.	Max.	Min.	Max.	Hot	Humid	Dry
Winter	1.7	4.6	-16	6	93	3	12
Spring	2.0	4.5	-24	-2	98	1	31
Summer	2.7	6.5	-53	-3	100	1	42
Autumn	2.3	5.2	-29	-2	100	1	21
Annual	2.2	5.1	-27	-4	100	0	46

In greater detail, at the subregional level, simulations give four levels of temperature variations and extreme precipitation in the Mediterranean basin, based on an increase in the global temperature of 2°C:

	HIGH TEMPERATURE					LOW TEMPERATURE			RAINFALL			
	Summer days	Hot Days	Tropical Nights	Days> 90 quantile	Nights> 90 quantile	Frost Nights	Ice Days	Days< 10 quantile	Relative Var.	Dry Days	Rain 1-10 mm	Max. 3-day Rain
NW Iberian Peninsula	1	1		1	1	-1		-2		2	-2	3
South of France (Inland)	3	1	1	2	2	-1		-2	-1	3	-2	3
Coast Southern France	1		2	2	2	-1		-2	-1	2	-2	3
Corsica	1	1	2	2	2	-1		-2	-1	2	-1	2
Sardenia	1		3	2	2			-3		2	-1	1
Sicilia	3		3	3	2 / 3			-3		3	-1	3
N. Adriatic	3	3		2	2	-2	-1	-2	-1	3	-2	1 / 2
Central Balkans	3	3		2	2	-2	-1	-2		3	-3	
Central Greece	2	1	2	2	2	-1		-2	-1	2	-2	1
Peloponese	3		3	2	2			-3	-1	2	-1	2
Crete	3		3	3	3			-3	-1	2	-1	
Coastal Turkey	1 / 2	1	1 / 2	2	2	-1		-2	-1	2	-1	-1 / 2
Turkey Inland	3	3		2	2 / 3	-2	-1	-2		3	-2	
Cyprus	1		3	1	1			-3	-1	1	1	
Lebanon/Israel Nile Delta	1	1	3	3	3	-1		-3	(2)	1	-1	
E. Egypt E. Lybia	3	1	3	2	3			-3	(2)		-1	
W. Lybia	3	1	3	2	3			-3	-3		-1	
E. Maghreb	2	3	3	2	2	-2		-2	-3	2	-2	
W. Maghreb	3	3	3	2	2	-2		-2		2	-2	-1
South Iberian Peninsula	2	2	2	2	2	-1		-2	-1	2	-2	
Central Spain	3	3	1	2	2	-2		-2	-1	3	-2	-1

Large Change =at least 1 mth duration
Moderate change = 2-3 wks duration
Small Change= 1 week duration
No Change

Source: Giannakopoulos et al., WWF Report 2005.

The most significant temperature rises are in the Machrek and are emphasized by the oval sign. The red rectangles represent significant changes for a period of at least a month, yellow rectangles show moderate changes for a period of two to three weeks, and grey rectangles represent small changes for a period of a week. White rectangles represent no change. The dark oval shows the significant temperature changes in the Machrek (the Palestinian territories, Jordan, Lebanon, Syrian Arab Republic and Iraq).

The increase in temperatures should therefore give rise to summers with an increasing number of very hot days. In Mediterranean Europe, PRUDENCE simulations show a more significant increase in daily maximum temperatures than the increase in daily median values.

With regard to precipitation, the models agree on a clear increase in continental periods of drought (a fall in the number of days of precipitation, an increase in the longest periods without rain).

Similarly, the greater incidence of extreme events will result in an increase in flooding (both in terms of its occurrence and intensity).

With reference to waves and flooding due to storms, the findings of the models are preliminary, although the decrease in the number of depressions and in the wind should diminish these risks, even though this assessment has to be differentiated at the local level.

Finally, it is unlikely that real tropical cyclones will develop in the Mediterranean during the 21st century, with their development being hindered by wind shear at altitude and the small surface area of the sea.

3. An increasingly tense hydrological situation

Table 1. Water resources of Mediterranean countries

Countries	Precipitation	Resources and fluxes						Present fluxes going out of countries					Consumption and losses	
	1	2	3	3'	4	4'	5	6	7	8	9	9'	10	11
	Yearly Average Precipitation P	Internal Resources of Countries (P ETR)	Groundwater (2-3')	Surface water resources (2-3)	External Contribution from neighbouring countries (surface water and ground water)	Contribution from non Mediterranean countries (included in 4)	Total Resources (2+4)	Real Rivers discharges toward the Mediterranean sea	Groundwater fluxes toward the Mediterranean	Real discharges towards the neighbouring countries	Discharges flowing out from countries (6+7+8)	Discharges flowing toward the Mediterranean (6+7)	Final Consumption by users including effluents in the sea	Losses by evaporation of dams
Spain	112	28	10.44	17.56	0.35	0.1	28.35	14.3	0.65	0.03	14.98	14.95	10.25	1
France	123	64	32	32	8.5	8.5	72.5	66	0.2	0.7	66.9	66.2	5	0.3
Italy	290	182.5	43	139.5	6.3	2	188.8	155.1	12	0	167.1	167.1	18	
Malta	0.165	0.05	0.05	0	0		0.05	0	0.04	0	0.04	0.04	0.03	
Slovenia	6.54	4.21		4.21	0		4.21	0.25	0.15	3.8	4.2	0.4	0.003	
Croatia	26.5	18	9	9	13.7		31.7	21.2	10.5	0	31.7	31.7	0.5	
Bosnia-Herzegovina	22	14		14	0		14	0.015	0.05	13.58	13.645	0.065	0.04	
Yugoslavia	22	16	2	14	0		16	1.5	1.6	12	15.1	3.1	0.27	
FYR Macedonia	18	5.42		5.42	1		6.42	0	0	6.3	6.3	0	0.77	
Albania	42.7	26.9	6.2	20.7	15.9	2	42.8	40.7	1	0	41.7	41.7	0.6	
Greece	113.4	58	10.3	47.7	11.2	10.2	69.2	48.7	2.5	2	53.2	51.2	6	1
Turkey	140	66	20	46	3.45	2.8	69.45	50	12	0.2	62.2	62	6	
Cyprus	4.42	0.78	0.28	0.5	0		0.78	0.178	0.23	0	0.408	0.408	0.17	
Syria	13.55	5	2.38	2.62	0.83		5.83	1.33	1	0.85	3.18	2.33	1.6	0.5
Lebanon	8.2	4.6	3.1	1.5	0		4.6	2	0.72	0.64	3.36	2.72	1	
Israel	3	0.63	0.45	0.18	0.38		1.01	0	0	0.01	0.01	0	1	0.12
Palestinian Authority	1.42	0.62	0.546	0.074	0.01		0.63	0.02	0.002	0.5	0.522	0.022	0.13	0
Egypt	12	0.8	0.5	0.3	55.5	55.5	56.3	13	0.03	0	13.03	13.03	35.1	10
Libia	10	0.7	0.6	0.1	0		0.7	0.05	0.05	0	0.1	0.1	0.5	
Tunisia	33	3.7	1.15	2.55	0.32		4.02	0.65	0.2	0	0.85	0.85	1.1	0.47
Algeria	68.5	14.5	1.33	13.17	0.03		14.53	11.3	0	0.32	11.62	11.3	1.7	
Morocco	21	5	1	4	0		5	3.65	0.1	0.03	3.78	3.75	0.9	
Total	1098	519	144	378	117	81.1	636	430	43.5	41	514.5	473.5	90	13.4

Source: http://medhycos.mpl.ird.fr/en/t1.resi&gn=Margat.inc&menu=fresimf.inc.html.

The figures in this table represent most of the processes of the hydrological cycle, which will be modified by climate change in the Mediterranean.

The table below shows the average annual runoff volumes (in m^3/s) for the principal rivers and the Black Sea (fresh water runoff), applied to the model of the Mediterranean Sea for each decade developed in relation to IPCC Mediterranean scenario A2. These averages are based on data from models of precipitation for the twenty-first century and are based on OPAMED8.[1] Significant decreases in runoff volume are observed for the Rhone, the Po and the Ebro.

Table 2. Annual average discharge (in m^3/s) of fresh water from the principal rivers (and the Black Sea)

Rivers	clim	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090
Rhone	1700	1666	1615	1649	1581	1564	1530	1513	1462	1377	1360
Po	1498	1378	1288	1258	1183	1228	1228	1183	1183	1183	1213
Ebre	428	398	321	343	321	317	309	274	274	197	188
Nile	875	945	954	962	910	928	823	875	858	901	814
Black Sea	8036	6911	6027	5625	4902	4420	4661	4581	4018	2893	2330

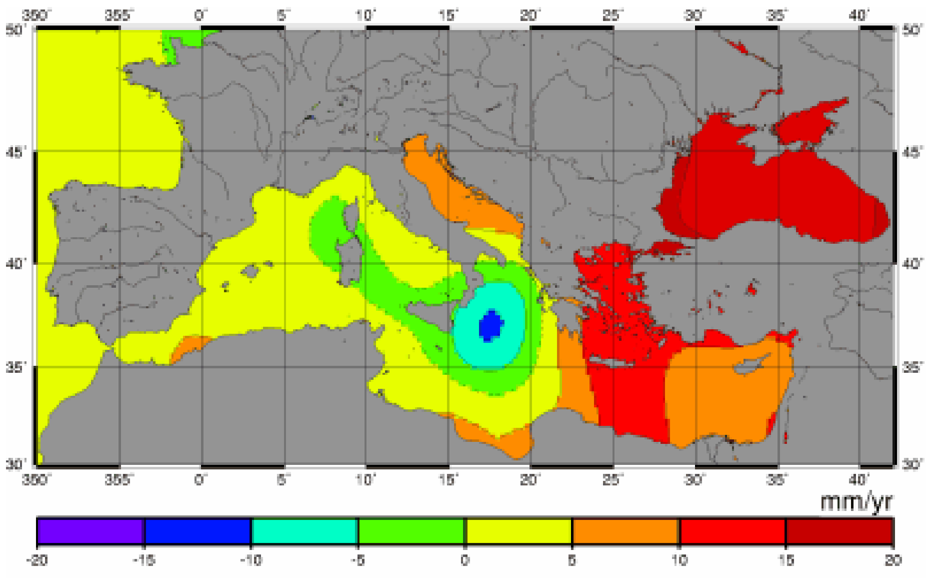
PhD thesis,
University Paul Sabatier, Toulouse, 2005.

[1] OPAMED8: A high-resolution Mediterranean version derived from OPA and NEMO to represent climate variability/change in the Mediterranean basin (from Somot, 2005).

4. A rise in the sea level, with significant consequences

Over the past seven years, the rise in the level of the Mediterranean Sea has been noted in particular to the East of the basin, with the level tending to fall in the West.

Figure 3. Variations in sea level observed over the past seven years by the TOPEX/Poseidon project in mm/year



From negative values (dark blue to dark green) to positive values (from pale green to dark red) the East-West difference is clear, with an evident trend for a rise in the sea level in the eastern Mediterranean.

Source: LEGOS-GRGS-CNES.

According to the IPCC, the rise in the sea level could reach between 23 and 47 cm by the end of the 21st century. Many regions of the Mediterranean would therefore be liable to a significant risk of submersion and erosion, which will affect several coastal areas of Mediterranean countries.

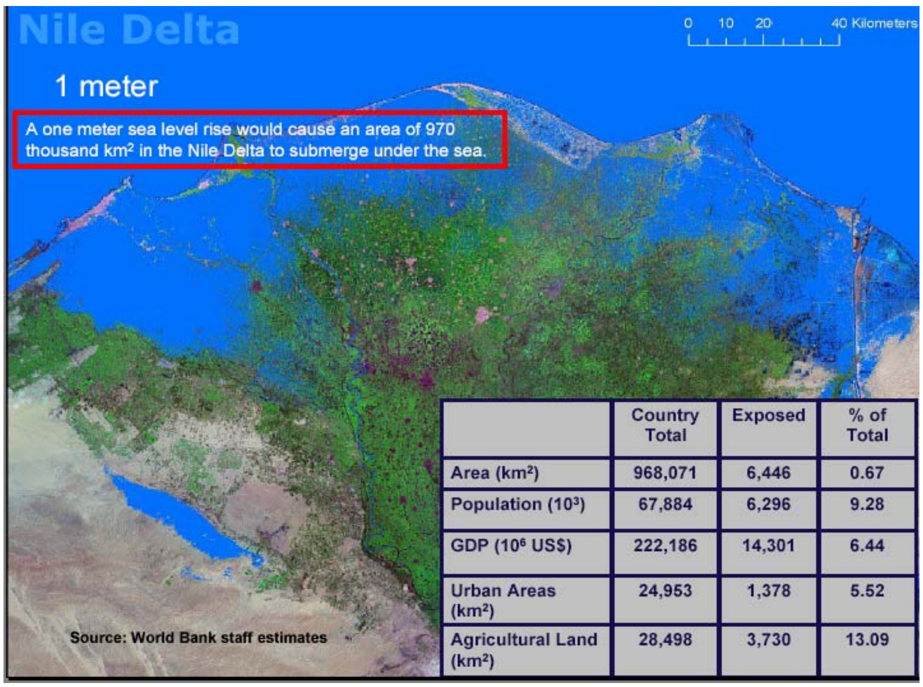
The consequences that may be feared are principally the following:

- an aggravation of flooding in low coastal areas, particularly deltas, coastal areas with lagoons, maritime marshes and certain islands;
- an acceleration of the erosion of cliffs and beaches;
- greater salinity in estuaries;
- a reduction in the volume of freshwater aquifers.

4.1. Submersion

Delta areas, with their specific typography placing them just above the sea level, which are dotted with ponds and lagoons, are the most vulnerable to a rise in the sea level. In certain cases, this is compounded by a major anthropological problem: the presence of dams. As deltas are areas in which sediment accumulates, the presence of dams upstream prevents the normal circulation of sediments, which do not come far enough downstream to reinforce the delta. This is the case of the major delta areas in the Mediterranean.

Figure 4. Evaluation of the impact on its estuary region of a one metre rise in the waters of the Nile



	Country Total	Exposed	% of Total
Area (km²)	968,071	6,446	0.67
Population (10³)	67,884	6,296	9.28
GDP (10⁶ US$)	222,186	14,301	6.44
Urban Areas (km²)	24,953	1,378	5.52
Agricultural Land (km²)	28,498	3,730	13.09

Source: *World Bank, 2007. The impact of sea-level rise on developing countries: A comparative analysis.* World Bank Policy Research Working Paper 4136.

The Nile delta plane is a sensitive area in this respect. The delta, which is the main agricultural area in Egypt and very densely populated, with 1,600 inhabitants to the km² on average, is protected from high water by a sandbank of 2 to 3 metres in height and certain defensive works in Alexandria. But this protection is fragile and a rise in the sea level would result in many changes: the lands that are seasonally flooded would be transformed into marshland, and then into peat bogs, leading to the migration of all animal, vegetable and human life. The rise in the sea level should also result in an extension and deepening of lagoons. The shoreline would accordingly be easily breached, allowing salt water to enter from the sea.

With regard to maritime marshes, in view of their position in the intertidal areas, they would appear to be particularly threatened with permanent flooding by a rise in sea levels, with three possible types of evolution: either disappearance through submersion, relocation towards the land (if not prevented by any obstacle) or extension by reason of high levels of sedimentation.

These phenomena may be reproduced all around the Mediterranean basin, although with marked inter- and intra-regional differences, exacerbated by local events, such as the sinking of southern Europe (a sinking of 5 cm is forecast by 2080) due to tectonic adjustments following the last glacial period (Parry, 2000). The spectacular example of the submersion of Venice, which has resulted in the need for highly significant and costly engineering works (Consorzio Venezia Nuova, 1997), offers grounds for reflection.

4.2. Erosion

A rise in the sea level must logically have the consequence of an increase in coastal erosion, as the greater depth of the water facilitates the movement of the swell towards the coastline.

Cliffs, which today are receding at a rate that is discernible at the scale of a human life as a result of the mechanical effect of waves, will certainly experience accelerated erosion if the rise in the sea level accelerates.

The current rise in the sea level is also responsible for the aggravation of beach erosion, and this phenomenon is likely to accelerate, particularly where it has already begun.

In addition to the direct accentuation of erosion, the warming of the climate, as a result of a modification in the effect of radiation, could result in a decline in the productivity of coastal ecosystems, particularly Poseidonia meadows, thereby accelerating erosion.

Any rise in the sea level is also likely to result in more significant penetration of higher volumes of salt water into estuaries.

With reference to the volume of underground fresh water, the rise in the sea level should result in a move inland of the area dividing continental fresh water and marine salt water, and the piezometric level of aquifers is likely to rise. In this case, the surface area for the supply of fresh water to aquifers through rainwater infiltration will be reduced as the slope of the coastal topography is reduced. There should accordingly be a reduction in the volume of underground fresh water. The progression of the salt water wedge will also be one of the major causes of the loss of agricultural land in coastal areas (for example, the Nile delta).

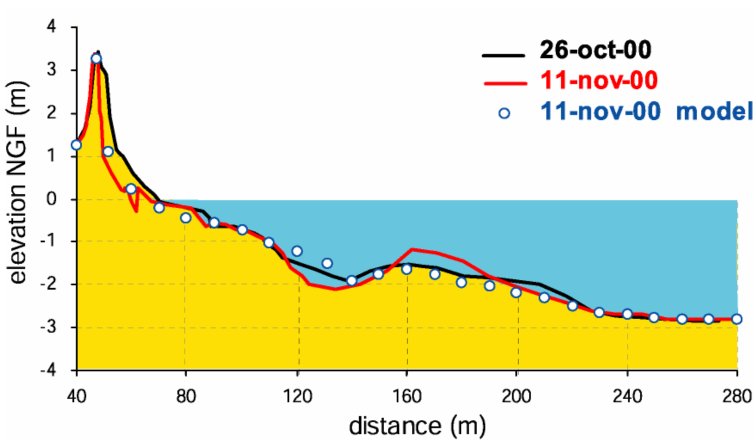
4.3. Other multiple impacts

Impacts that are less spectacular, but just as costly, could also be caused by extreme meteorological events related to storms and the possible effects of hydrodynamic resonance in the context of a rise in the sea level:

Figure 5. The impact of extreme meteorological events (storms, sea surges …) on roads and structures on the Mediterranean coastline

Source: IMPLIT project.

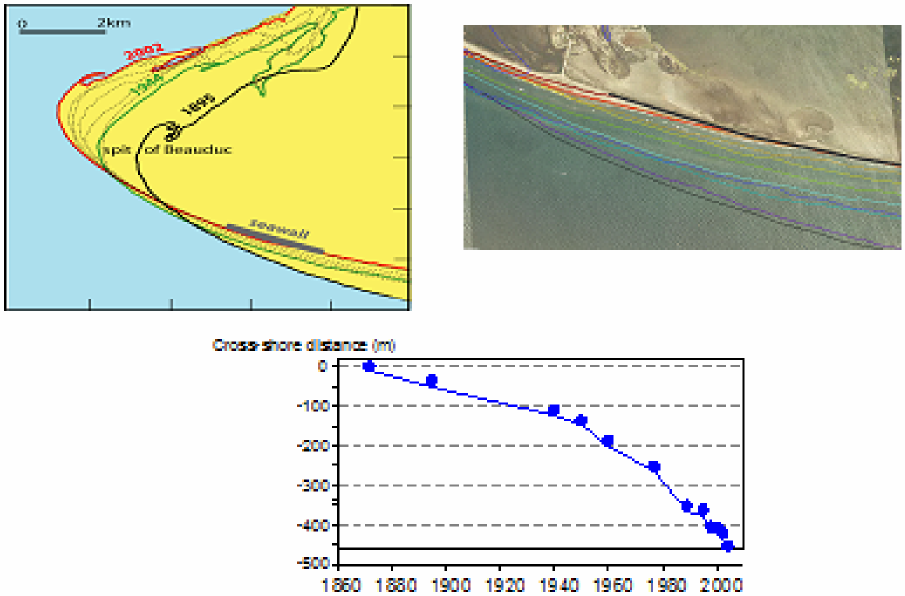
Figure 6. Erosion of sand dunes through the action of storms and sea surges, based on data from the "S-beach" model of the LITEAU programme



The elevation in metres (vertical axis) and the depth versus the distance from the shoreline, both expressed in metres (vertical and horizontal axes). The results of the model (white points) correspond fairly well to the profile observed in November 2000.

Source: MEEDDAT, France.

Figure 7. Observations over 150 years of the erosion of a coastline in the North-West Mediterranean



The isochrones (of different colours between 1995 and 2002) show the change in the coastline (above, from left to right). The decrease in the cross-shore distance is also provided in metres, with a clear increase over the last 15 years (the Beauduc spit, data from the IMPLIT project).

Reference may also be made to the direct impact of waves on exposed infrastructure on the coastline (such as the coastal barrier in the Venetian lagoon, bathing resorts on the Rhone delta) and on port installations (Alexandria, Port Said, La Goulette-Tunis). By the middle of the next century, the impact on coastal establishments and constructions (such as ports and coastal roads) could be considerable in areas situated just above the current sea level (for example, Venice). Historical sites and monuments could require special attention and costly protection measures, while solutions for other structures may imply their gradual transformation or relocation. A large number of coastal areas and lowlands in the Mediterranean basin that are not protected are already suffering from erosion and periodical flooding when the sea level is high due to the movement of depressions.

5. Threats to ecosystems

5.1. Land ecosystems

A migration of species to the North and to higher ground was observed during the 20th century. This is linked principally to the migration of their ecological niches. Changes have also been observed in the migration periods of certain animals, and the harvesting of certain types of fruit. More generally, the seasonal cycles of a large number of species have changed (for example, the early laying of eggs). In parallel with these changes, reference should be made to the appearance and/or increase of parasites. In Europe, these phenomena have been quantified fairly fully in certain countries and for certain species, although information is lacking in the Mediterranean.

However, the coexistence of these various elements is a portent of the disappearance of animal and vegetable species and a significant decline in biodiversity, either because the migration of ecological niches will happen more rapidly than that of species (in particular trees, which will be affected by parasites in a warmer climate), or because the migration of species will come up against insuperable physical barriers (the sea, mountains), or simply through the disappearance of certain niches (for example, those at altitude). Mammals in Mediterranean plain regions would appear to be at particular risk (between 5 and 10% of species threatened with disappearance by the end of the century).

As emphasized in the ACACIA European project, dry and exceptionally hot conditions can have a devastating effect on the natural environment by reducing the volume of water available both in the soil for plants and in bodies of open water for birds and animals (with an increase in brackish water). For example, Lakes Ichkeul and Bizerte, two Tunisian lagoons, will share the problems affecting delta areas and will experience important changes in their current fresh/brackish waters, which will have an influence on the land-based flora and fauna. These changes, combined with a possible reduction of wet areas, are liable to have a significant effect on the routes taken by migratory birds, which largely depend on the availability of Mediterranean habitats adapted to overwintering and of rest areas during their migrations from the North to the South.

5.2. Marine ecosystems

In the marine environment, invasive species of phytoplankton, typically found in warm tropical waters, have tended to multiply over the past ten years and toxic blooms could occur. The rise in temperatures favours the development of Lessepsian species and the acclimatization of introduced species which prefer warm climates. This “tropicalization” can be observed throughout the basin and mobile species from warmer waters (such as the barracuda *Sphyraena viridensis*) are now found in the North-West Mediterranean, while species classified as rare 30 years ago have become common (the flat lobster *Scyllarides latus*). Accordingly, ecosystems with significant biodiversity on the Mediterranean coast, including many habitats and species that are protected at the regional level, and which are identified as pollution ‘hot spots’ in the Mediterranean, are likely to be more vulnerable to biological invasions. A phenomenon comparable to the bleaching of tropical scleractinian coral was found during the summer of 1999 following catastrophic mortality affecting fixed populations of sponges, anthozoans and other invertebrates. Similarly, many species have not survived episodes of the warming of surface waters in recent years. This is the case of *Paramuricea clavata*, of which millions of individuals died on the Ligurian and Provencal coasts during the summer of 1999. Such observations have given rise to various economic quantification exercises in certain regions of the world, although this remains to be done in the Mediterranean.

Grave threats have already been identified to certain specific species, including enormous losses of gorgonians (sensitive to water temperature) in the Gulf of Genoa (where the temperature has increased by over 2°C over the past 15 years), spreading to many parts of the West and East Mediterranean. Natural and anthropogenic factors may accordingly constitute a threat for certain species, such as marine turtles, in view of their sensitivity to increases in CO_2 concentrations in water, and particularly the growing anthropogenic pressure on breeding areas.

6. Agricultural yields threatened by the decline in water resources

Analysis of the impact of climate change scenarios in the Mediterranean basin on agricultural crop yields (Giannakopoulos et al., 2005) leads to the forecast of a general fall in yields on the southern shore of the Mediterranean, where a decrease in precipitation and an increase in salinity are expected.

The adoption of certain specific agricultural methods (for example, the modification of annual schedules) could contribute to reducing the negative reactions of agricultural crops to climate change. However, such methods could require up to 40% additional water for irrigation, a quantity of water that may not be available in future (see above). Accordingly, the overall outcomes are in part in the hands of the decision-makers responsible for the management of water resources.

Based on case studies carried out in the Maghreb and in Egypt using heterogeneous scenarios, and those drawn from the third IPCC report, a reduction in agricultural productivity is expected in these two areas. Projections related to these studies envisage a variation in productivity of between -30% and +5% for vegetables by 2050, and increases in the demand for water for spring crops of between 2% and 4% for maize and 6% and 10% for potatoes. In the Maghreb, while the rise in the CO_2 content of the atmosphere may increase the yields of certain crops, this effect is countered by the risk of the declining availability of water and by the accentuation of the trend that has already started for an increase in hydric deficits. Rain-fed crops will be directly affected, and irrigation areas will also suffer from the scarcity of water, with some of them perhaps reverting to the cultivation of rain-fed crops. In any case, the rise in evapotranspiration, combined with the modification of the rain and temperature patterns, will lead to an increase in water needs in agriculture, even at constant yields. In Morocco, the CROPWAT model (FAO, 2001) applied to winter cereal crops, under the scenarios of the third report, shows a decline in yields of around 10% in a normal year and 50% in a drought year by 2020, and national production falling by 30%. Algeria anticipates average yield reductions of between 5.7% and nearly 14%. Climate change will also affect vegetables, for which crop yields will decrease by between 10% and 30% in Algeria and nearly 40% in Morocco by 2030. These changes will evidently be very variable in spatial terms. In Egypt, national studies undertaken in the context of the country's national communications to the Climate Change Convention envisage a fall in production for several crops by 2050 (between -11% for rice and -28% for soya). In contrast, cotton yields are expected to increase. At the same time, water needs for summer cereals will rise by 8% for maize and 16% for rice by 2050.

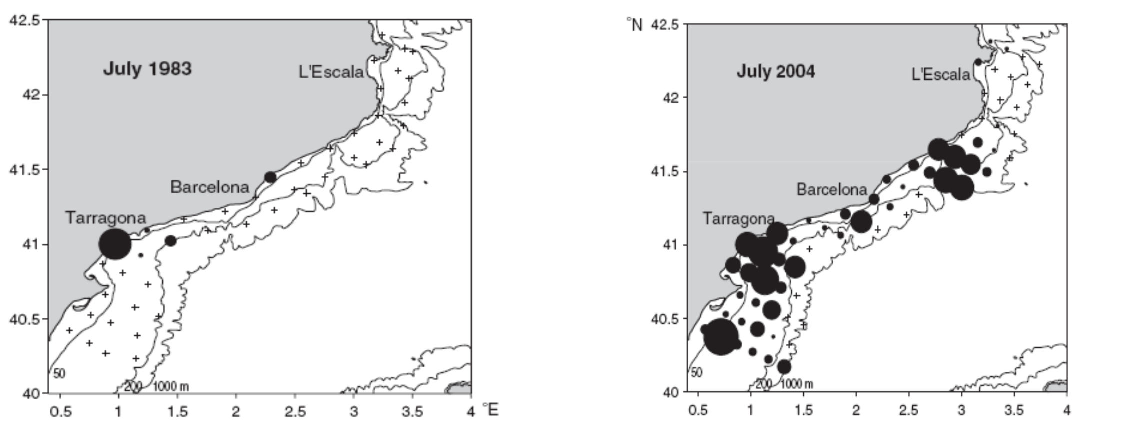
The increased incidence of certain extreme events during specific stages of crop cultivation (for example, heat stress during the flowering period or rain at sowing time), and the greater intensity of precipitation and longer dry periods are expected to reduce summer crop yields. Another factor in the fall in agricultural yields is the emergence of new parasites and pests. Over the past few years, mild and wet winters have enabled insects from warm countries to settle in temperate countries.

Changes in the bioclimatic environment are likely to transform the geography of potential crops and lead to a modification in their geographical concentration. They will accentuate trends that are already discernible, resulting in a displacement of agricultural limits towards the North. At the global level, the findings of agricultural projections show an increasing deficit between the need for cereals and potential agricultural production. Export crops from the countries of the East and the South will be affected, since typically Mediterranean crops such as olives and lemons could progressively be introduced into vast areas of southern Europe, with an intensification of market gardening, thereby hindering the development of exports from the southern Mediterranean. An advantage would be that the Mediterranean climate could become conducive to certain tropical crops.

7. Fishing in jeopardy

The role of hydro-climatic variations in regulating the abundance of fish populations is now acknowledged. Accordingly, the structure and dynamic of the fish populations of the continental plateau in the Mediterranean are likely to be sensitive to both the effects of human activity (fishing) and climate change (global warming), with consequences for the fisheries that exploit them. An illustration of these consequences is provided by the changes between 1983 and 2004 in the reproduction areas off the Catalan coast of a species of sardine (*Sardinella aurita*) which favours warm seas.

Figure 8. Reproduction areas of *Sardinella aurita* in 1983 and 2004



Source: Sabatés, Martín, Lloret, Raya. 2006. *Sea warming and fish distribution: The case of the small pelagic fish, Sardinella aurita, in the western Mediterranean*. Global Change Biology 12, 2209–2219.

The impact of climate change on fishery activities will not be the same throughout the Mediterranean basin. The Mediterranean is an almost closed sea, but which is linked to the Atlantic Ocean through the Strait of Gibraltar. Mediterranean waters are generally warm and oligotropic (that is, they have relatively low concentrations of nutrients and a low productivity rate), except near the mouths of rivers where fluvial discharge brings nutrients into the sea, and also areas where aeolian action and coastal upwelling result in the vertical transport of nutrients. The most productive areas are in the North-West of the Mediterranean due to the significant discharges from the Rhone and the Ebro, as well as significant stirring by the wind. The annual discharges of these rivers appear to vary inversely in relation to the North Atlantic Oscillation (NAO): discharges tend to be lower during periods of positive anomalies to the NAO. It is very probable that the regional effects of climate change (such as the warming of the sea, the rise in the sea level, reduced river discharge volume, etc.) will result in changes in fishery activities in this region, where pelagic, demersal and benthic species are strongly targeted by artisanal, semi-industrial and industrial fleets. All the elements described above are linked to the disappearance of fish habitats as a result of climate change and other anthropogenic effects (such as tourism, trawling and pollution; Lloret et al., 2004).

8. Increasingly frequent situations of water stress

The changes in temperatures and precipitation described above will result in an increase in evaporation, hygrometry of the air and finally an intensification of the water cycle. Mediterranean regions, which already suffer from significant water stress, will be particularly exposed to reductions in their water resources. In parallel, certain local hydrological models which include climatic scenarios point to a significant decrease in discharges. One of the immediate consequences of these changes in the water cycle is the increase in the Mediterranean population in a situation of water scarcity (less than 500 m^3 per person per year). According to certain projections used by the Blue Plan for its prospective work, this figure will rise from 59 million at the present time (2005) to 292 million (under scenario B1 by 2050). In certain countries, this type of development could result in situations of acute crisis. For example, in Egypt, the rise in temperatures is likely to increase the water needs of agriculture. Taking into account the uncertainties related to the volume of the Nile's discharge (the only source of water) and the increase in the population, it is estimated that between 115 and 180 million people could be in a situation of water stress. The increase in irrigated areas could also prevent the country from managing these variations in water flow. The deterioration in the quality of water would give rise to health problems and result in malnutrition, the enormous costs of which would jeopardize poverty alleviation. Certain sources of water could become unusable due to penetration by saline water in rivers and coastal aquifers. Water pollution already constitutes a major risk to health in the Mediterranean, but would grow worse as the concentration of pollutants increases, as a result of the reductions in the discharge volumes described above.

Another consequence of this increase in water stress, combined with the greater frequency of extreme climatic events, is the reduction of the hydro-electric and cooling potential of thermal power stations.

Hydro-electric production suffers directly from the decrease in flow volumes. Falls in the production of primary energy by a good number of hydro-electric power stations related to a decline in the volume of the rivers concerned have already been observed. The security of installations also has to be integrated into these climatic developments. The design of security reservoirs depends largely on estimates of peak flow. However, these have to be evaluated not only in terms of time, but also of volume. A small reservoir may not be adapted to a very high peak flow, although if it lasts for a long time, even a large reservoir may be unable to cope. A more unstable and less predictable climate may therefore render obsolete the calculations concerning the size of such installations and lead to a fall in the hydro-electric potential of a country.

Electrical power stations often use water from rivers for their cooling. When the temperature of the rivers exceeds certain thresholds, the power stations are obliged to comply with the maximum temperature values of water in the rivers that are used, and are compelled to stop production. This happened in southern Europe during the hot summers of 2003, 2005 and 2006.

The increase in greenhouse gases will have three main effects on soil:

- the effect of “carbonated fertilization” through CO_2 will increase the production of vegetation, as occurs in certain cases of forcing in greenhouses, and will increase the return of carbon to the soil. This may already have affected certain forest ecosystems since 1940, according to certain authors (France, Morocco, Spain);
- the rise in temperature and in the range of variations is likely to increase the speed of microbial activity, and particularly the biodegradation of organic matter in the soil; and
- finally, climate change is accompanied by changes in the frequency of precipitation and the humidity of the soil, affecting both vegetation and micro-organisms.

Moreover, in cases of increased drought, the effects of aeolian and water erosion will be more significant:

- **Aeolian erosion**. Wind erosion, moving sand dunes and silting are characteristic of many countries in the region, even though the rhythm, areas affected and scope of the environmental effects of these phenomena vary from one country to another. Aeolian erosion is one of the principal causes of land degradation. If the natural coverage of vegetation is affected by global warming, the displacement of sand by the wind will contribute to making soil more arid and will strengthen erosion.
- **Water erosion**. National reports from six Mediterranean countries (Lebanon, Syrian Arab Republic, Egypt, Libyan Arab Jamahiriya, Algeria and Morocco) emphasize that, despite the aridity that affects them to varying degrees, water erosion is another significant factor in soil degradation. Physiographical characteristics, violent downpours and short episodes of sporadic torrential rain, which are typical of the variability of precipitation in the region, and the degradation of the natural covering of vegetation due to the frequently ineffective management of land resources, are all factors that contribute to soil erosion. Very frequently, these processes lead to the loss of the materials that make up the top layers of soil, which has harmful effects on sites and environments. The erosion of soil by water is likely to give rise, in the event of the warming of the climate, to a general silting up of dams and reservoirs and the loss of a significant area of marine and coastal land. Despite the low level of precipitation, the large areas of the water tables favour the development of flooding, with water likely to rush down strongly and rapidly into wadis and dry areas, damaging installations, infrastructure and agricultural land. These flash floods are already occurring, for example, in Sinai, in Egypt, where the large surface of the water table, despite the low level of precipitation, facilitates significant flooding and water running off into the Gulf of Suez and the Gulf of Aqaba.

9. Increasing sensitivity of forests

The rise in the level of CO_2 itself changes the functioning of all vegetation through its action on photosynthesis. A doubling of the concentration of CO_2 may increase by 20% to 30% the photosynthetic production of forests. However, this potential trend may be affected, or inverted, by excessive temperatures, episodes of drought and ozone deposits. In general, it would appear that the increase in production will be more significant in the areas to the North rather than to the South of the Mediterranean.

FAO estimates describe a migration of 100 km towards the North of many Mediterranean species, with "*matorralisation*" (degradation) progressing at the same time. The example of France is illustrative in this respect.

Figure 9. French forests now and in 2100 with warming of 2.5°C

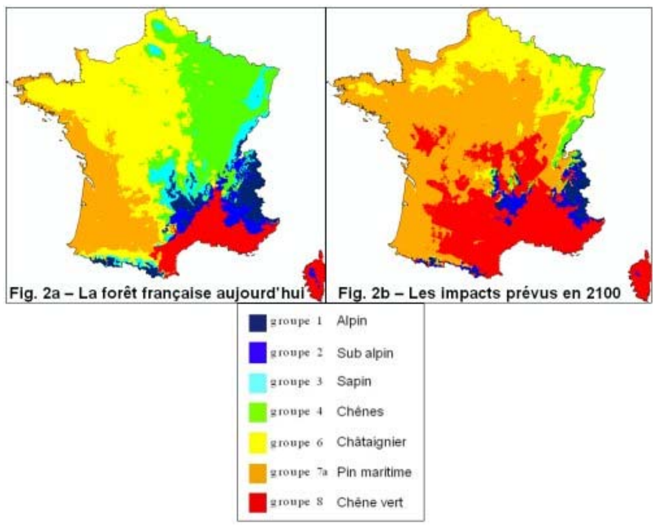


Fig. 2a – French forests today
Fig. 2b – Impacts foreseen in 2100

Key: Alpine, Subalpine, Spruce, Oak, Chestnut, Maritime pine, Holm oak

Source: *CARBOFOR project. Tâche D1: Modélisation et cartographie de l'aire climatique potentielle des grandes essences forestières françaises*". June 2004. Vincent Badeau (INRA), Jean-Luc Dupouey (INRA), Catherine Cluzeau (IFN), Jacques Drapier (IFN) and Christine Le Bas (INRA).

Another parameter linked to temperature change will be the emergence and development of parasites. An emblematic illustration is ink disease in oaks. According to the selected climate change scenario, simulations show an expansion of high-risk areas of around 100 km per century and a general increase in risk levels in most areas.

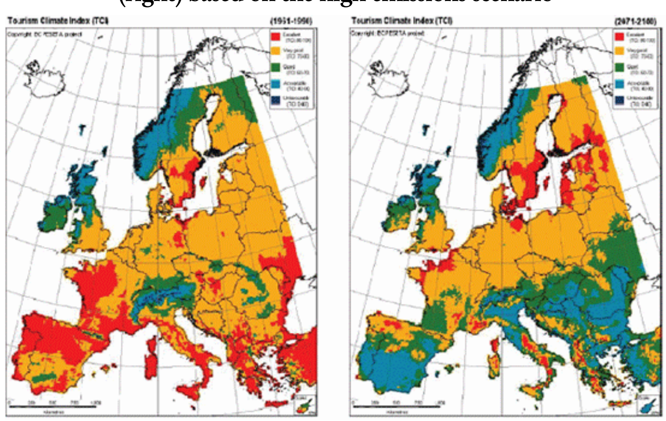
Finally, in the case of warming, forests are likely to be more affected by the risk of forest fires. In the Mediterranean areas of Europe, the number of days at risk of forest fires has clearly increased over the period 1958–2006. The summer of 2007 in Greece showed that the human and socio-economic costs of these fires can be very high.

10. A less attractive region for tourists

The climate is an essential component of the choice of destination of international tourists. If heat waves and summer temperatures increase, the attraction of Mediterranean regions could diminish, while that of more northerly areas increases.

Certain estimates indicate that warming of 1°C by 2050 could result in a decrease of 10% in tourism on the southern shore. Harsh natural events or a significant increase in the price of transport related to programmes to prevent global warming could also have a damaging impact on tourism, in the same way as potential conflicts with other users arising out of the scarcity of water resources. Taking this problem into account, an index called the Tourism Climate Index (TCI) has been developed and classifies the various tourist destinations. The application of this index to Europe clearly shows an unfavourable trend for the Mediterranean.

Figure 10. Calculation of the TCI for summer tourism in Europe for the period 1961–1990 (left) and 2071–2100 (right) based on the high emissions scenario



Source: **JRC/IEC/EU.**

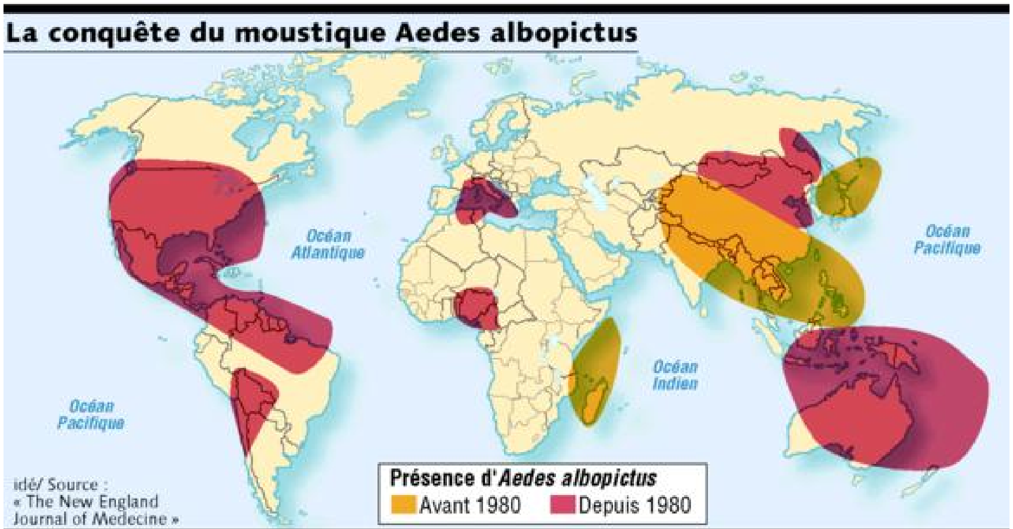
11. Health impacts

Health impacts may be categorized into indirect effects in the form of the expansion of areas in which certain parasitic and infectious diseases are present and direct impacts in the form of an increase in heat stress.

11.1. Indirect effects

Without it being possible to draw up an inventory of the health consequences of changes in the climate as foreseen by the IPCC scenarios, a typical example is that of the progression of

Aedes albopictus. This mosquito of Asian origin is at the origin of infections which can degenerate into serious cases of meningoencephalitis.



Title: The conquests of the mosquito *Aedes albopictus*

Presence of *Aedes albopictus*

Before 1980

Since 1980

Another example is that of malaria, in the case of which a rise in temperatures would have the effect of shortening the time needed for the development of the parasite in its vector, the anopheline mosquito.

This could result in an extension of the latitude of the malaria endemic zone. In the Mediterranean, fears are also well founded for the north of the Sahel, most of the Maghreb, Turkey and the Near and Middle East. Another significant risk is that of the extension of the disease towards higher altitudes, whereas Mediterranean mountains are today mostly unaffected.

11.2. Direct effects

A study carried out in 2004 (the PHEWE project) on higher mortality rates linked to temperatures above the seasonal average in summer in Europe shows a greater vulnerability of Mediterranean cities to temperature peaks:

Figure 11. Comparison of mortality related to summer heat waves for the period 1990–2000 between Euro-Mediterranean cities and northern European cities

	Mediterranean cities			Continental cities		
Total mortality						
	% variation	95% CrI		% variation	95% CrI	
All ages	3.12	0.60	5.73	1.84	0.06	3.64
15-64 yrs	0.92	-1.29	3.13	1.31	-0.94	3.72
65-74 yrs	2.13	-0.42	4.74	1.65	-0.51	3.87
75+ yrs	4.22	1.33	7.20	2.07	0.24	3.89
Cardiovascular mortality						
	% variation	95% CrI		% variation	95% CrI	
All ages	3.70	0.36	7.04	2.44	-0.09	5.32
15-64 yrs	0.57	-2.47	3.83	1.04	-2.20	4.92
65-74 yrs	1.92	-1.49	5.35	1.50	-1.12	4.62
75+ yrs	4.66	1.13	8.18	2.55	-0.24	5.51
Respiratory mortality						
	% variation	95% CrI		% variation	95% CrI	
All ages	6.71	2.43	11.26	6.10	2.46	11.08
15-64 yrs	1.54	-3.68	7.22	3.02	-1.55	7.42
65-74 yrs	3.37	-1.46	8.22	3.90	-0.16	8.92
75+ yrs	8.10	3.24	13.37	6.62	3.04	11.42

Source: ec.europa.eu/research/environment/pdf/env_health_projects/climate_change/cl-phewe.pdf.

Everything will depend on the brutality of global warming. A relatively slow progression, allowing gradual acclimatization, would undoubtedly have few harmful health effects, with a minimum level of somatic and psychological disturbance. However, if the progression consists of relatively violent jumps (and the climate simulations for the twenty-first century do not exclude this), the consequences may be much more worrying.

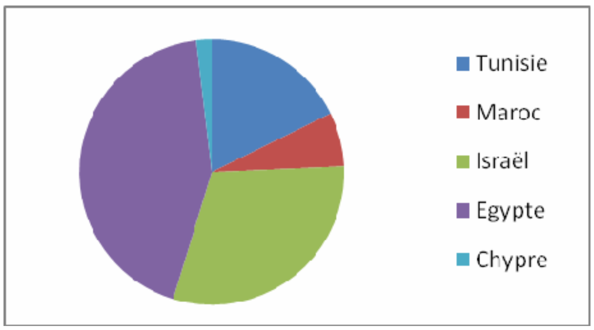
II. The actors in climate change

1. Financial instruments rarely used in the Mediterranean

Until 2007 (the Bali Conference), the implementation of the Kyoto Protocol was essentially focused on efforts to reduce greenhouse gas emissions, even though the Mediterranean accounts for a low proportion of global emissions and only a minority of Mediterranean countries are covered by obligations relating to the reduction or stabilization of greenhouse gas emissions.

Accordingly, the Clean Development Mechanism has remained little used in the Mediterranean: 0.14% of emission credits registered by the Secretariat of the Climate Change Convention in June 2008 were issued by five Mediterranean countries.

Figure 12. Registered emission credits sold (situation as at 1 June 2008)

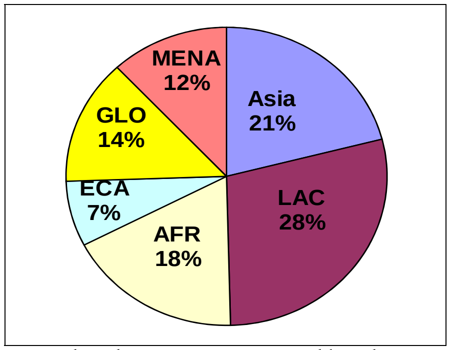


Source: Blue Plan at http://cdm.unfccc.int/Statistics/index.html.

Tunisia, Morocco, Israel, Egypt, Cyprus

With regard to the adaptation funds available from the GEF, the situation in the MENA region, although more favourable, is not yet sufficiently developed. In practice, the Strategic Priority on Adaptation (SPA) fund, the Least Developed Countries Fund (LDCF) and the Special Climate Change Fund (SCCF) mobilize 320 million dollars for adaptation. Furthermore, the implementation of the Kyoto Protocol's Adaptation Fund could increase this sum by between 80 and 300 million dollars a year through a 2% levy on all Clean Development Mechanism (CDM) projects and from voluntary contributions.

Figure 13. Distribution by region of projects financed by the SPA



Source: Blue Plan Presentation at World Bank Seminar "Climate Change in the Mediterranean", October 2008.

Up to the present, of the SPA projects for a total value of 47 million dollars, only 12% have been attributed to the MENA region and 7% to the Central and Eastern European region. Priority is given to the sectors of biodiversity, land degradation, international aquifers and climate change. The LDCF, with its National Adaptation Plans of Action (NAPAs), and the SCCF, give priority to development and poverty issues by focusing their efforts on problems related to water management, food security and coastal management.

2. A large diversity of actors

Analysis of a questionnaire with responses from coastal countries shows three major groups of actors involved in action relating to climate change:

1) scientists, with three disciplines: *meteorologists*, whose objective is to construct forecasting models with a resolution of around 1 km by 2020; *specialists on the impact ofclimate change*, who are seeking to define indicators as a basis for determining the vulnerability of environments and living beings in relation to climate change; and *economists*, whose aim is to address the consequences of this increased vulnerability on economic activity;

2) political decision-makers, who have objectives to achieve in terms of emission reduction and adaptation strategies; and

3) the private sector, which is concerned to maintain competitive levels in a changing physical environment.

In the Mediterranean, the first group of actors, namely **scientists**, is fairly well structured. Without attempting to draw up an exhaustive inventory of major regional programmes, reference may be made to the following:

- for meteorologists: NEMO-MED, the MORCE-MED modelling platform in France, the IPCT Trieste models in Italy and the activities of the Institute for Environmental Research and Sustainable Development in Athens;
- for scientific knowledge concerning impacts: several major regional research programmes, such as HyMeX for hydrology and CIRCE (Climate Change and Impact Research: the

Mediterranean Environment), a European project to identify the impact of climate change and possible adaptation measures for the Mediterranean (including Europe, North Africa and the Middle East). Much work remains to be done on the definition and development of monitoring indicators;

- for economics: while several analyses address the issue (for example, the work of CIHEAM on agriculture, the Blue Plan study on Climate Change/Energy, etc.), significant consolidation work is still necessary, requiring a quantification of the vulnerability of the environments and societies concerned.

Reference may be made to the following subregional research programmes:

- PASETA (Projection of Economic impacts of climate change in Sectors of the European Union based on bottom-up Analyses), in which Croatian teams have played a significant role;
- ACCRETe (Agriculture and Climate Changes), led by a Slovenian team.

Among national programmes, reference may be made to:

- the development of Egyptian emission plans associated to global models;
- the Turkish project “Enhancing the Capacity of Turkey to Adapt to Climate Change”, undertaken in collaboration with the United Nations Agencies present in Turkey with the objective of integrating adaptation issues into the country’s economic development plans;
- the development of the PRECIS regional climate model by Turkish teams;
- the monitoring of invasive marine species by Croatian teams in the Adriatic;
- the national simulation for Croatia using a regional model; and
- the project “Adapting Vulnerable Energy Infrastructure to Climate Change”, developed by the World Bank Office in Tirana.

Political decision-makers in the broadest sense of the term include the Focal Points of the Climate Change Convention in each country (all Mediterranean countries are signatories), those of the MAP and the Blue Plan and, since the implementation of the Kyoto Protocol flexibility mechanisms, the designated national authorities ascertaining the implementation of the investments made with a view to reducing greenhouse gas emissions.

In each country, around this “hard core”, the Ministry responsible for the Environment is generally responsible for taking the lead. In Turkey, Bosnia and Herzegovina and France, specific inter-ministerial authorities have been established to coordinate the efforts made in each sector, monitor developments in international negotiations and formulate mitigation and adaptation strategies.

In the Mediterranean, the priority for the countries remains adaptation. Certain countries have already implemented programmes of action in this field. For example, Bosnia and Herzegovina implemented a series of measures to give effect to the Climate Change Convention over the period 2002–2006. Egypt has carried out technical and economic simulations in the field of agriculture to identify the best dates for sowing and harvesting crops based on the future climate, the crop varieties to be retained or set aside in view of their need for water, etc. Reflection is also being undertaken on the establishment of an environmental information system on the management of coastal zones under more severe climatic conditions and various early-warning systems are currently being established for health problems that may be related to the climate. Slovenia already has an adaptation strategy. France has created a National Observatory of the Effects of Climate Change (ONERC), which is producing a series of impact indicators and is providing support to local communities wishing to adopt adaptation measures

Most countries do not have specific mechanisms to monitor progress in relation to the prevention of or adaptation to climate change. There is strong demand among Mediterranean decision-makers for indicators of impact and the formulation of adaptation strategies. Similarly, there is broad consensus on the need for better regional cooperation. At the level of NGOs, Climate Action Network, in the same way as Greenpeace and the WWF, have included the issue of climate change in their medium-term programmes.

In 2007, the Cleaner Production Regional Activity Centre (CP/RAC) launched a programme of work to address the problem of climate change from the viewpoint of final consumers and associated trade models in the Mediterranean region. This type of analysis, particularly through the calculation of carbon footprints, takes into account the emissions of greenhouse gases produced to meet the needs of the population (households, food, mobility, leisure, etc.), and therefore includes emissions associated with the manufacture and transport of products that are imported from other countries. In the context of a globalized economy, at both the national and international levels, the consumption perspective provides new elements for the design of climate change mitigation strategies. Moreover, analysis of emissions from the perspective of consumption provides a framework for measuring the responsibility of consumers, an aspect which may be highly significant in negotiations for the formulation of international policies on climate change.
Finally, through the GRECO initiative (green competitiveness), the **private sector** is involved at the regional level in emission reduction and energy-efficiency experiments. This initiative, led by CP/RAC in collaboration with the principal Mediterranean actors working in the field, is intended to promote another approach to doing business through the inclusion of an environmental approach and to assist Mediterranean enterprises in the application of preventive environmental techniques.

In the field of adaptation , many initiatives have been launched at the regional level. Among others, following ones have to be quoted :

.The Strategy for Adaptation to Climate Change in Forest Conservation and Management of the IUCN Malaga. This strategy will identify climate change adaptation strategies and options to stop, recover from and even reverse, the catastrophic environmental, social and economic impacts related to more intense and frequent weather related events, such as heat waves, large scale forest fires and intense drought and forest die back periods. This strategy defined by IUCN and WWF in close cooperation with the Mediterranean countries is now under discussion with them.

. The end products of CIRCE will be the Final Report - Regional Assessment of Climate Change in the Mediterranean (RACCM), a decision support system tool for adaptation and mitigation strategies tailored specifically for the Mediterranean environment. The RACCM will be produced in close consultation with stakeholders, also through workshops, consensus conferences and focus groups, in order to take into account the different needs of the Mediterranean region

.The MELIA (Mediterranean Dialogue on Integrated Water Management) Guidance on water and adaptation to climate change has two main goals : (a) assess information needs for elaborating such adaptation strategies based on well-informed data and information, and (b) especially address the benefits of and mechanisms for transboundary cooperation in adaptation activities.

.The MCSD is currently working also on the adaptation and climate change and will elaborate operational recommendations throughout the EMWIS network.

III. Table of illustrations