WATER, WETLANDS AND CLIMATE CHANGE

BUILDING LINKAGES FOR THEIR INTEGRATED MANAGEMENT

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BIOPHYSICAL AND SOCIO-ECONOMIC IMPACTS OF CLIMATE CHANGE ON WETLANDS IN THE MEDITERRANEAN

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THE MEDITERRANEAN WETLANDS INITIATIVE
L'INITIATIVE SUR LES ZONES HUMIDES MEDITERRANNEENES
LA INICIATIVA PARA LOS HUMEDALES MEDITERRANEO

IUCN Centre for Mediterranean Cooperation	Global Water Partnership – Mediterranean	The Mediterranean Wetlands Initiative

PREFACE

The Global Water Partnership (GWP), the Dialogue on Water and Climate Change, and IUCN-The World Conservation Union, have joined forces to facilitate an exchange of views on the common challenges faced by Mediterranean societies in enhancing their capacities to adapt to climate change.

Scientific consensus is that climate change would have a pervasive influence on the future demand, supply and quality of fresh water resources in the Mediterranean, and would add pressure to water and environment resources, and coastal systems currently under stress. All sectors of the economy, environment and society may be vulnerable to one degree or another, where steps to increase the capacity to adapt to greater hydrological variability, including more frequent flood and drought extremes are required.

Under Article 4 of the UNFCC, it was agreed all Parties would develop short, medium, and long-term strategies for climate adaptation in a phased manner, taking into account the different socio-economic contexts. A number of Mediterranean countries are now at the preliminary stages of identifying and formulating specific climate change adaptation strategies and responses, while others have yet to start.

This document is one of twelve country base-line studies and thematic papers prepared as background material for a Roundtable meeting in Athens, Greece in December 2002, to discuss key linkages between climate change, water and wetlands resource and management in the Mediterranean. While the primary aim is to exchange views, perspectives and experience on climate change adaptation planning, the discussion would also explore the opportunities to enhance synergies in responses to the UNFCC and Ramsar Conventions.

Eight country base-line studies were prepared for:

Cyprus	Morocco
France	Spain
Greece	Tunisia
Italy	Turkey

The four crosscutting thematic papers are:

Mediterranean Water Resource Planning and Climate Change Adaptation

National Approaches to Drought Preparation in the Mediterranean

Adaptation Strategies for Improved Flood Management in the Mediterranean

Biophysical and Socio-Economic Impacts of Climate Change on Water and Wetlands in the Mediterranean

Electronic copies of the reports and paper noted above may be downloaded from the web page of The IUCN Centre for Mediterranean Cooperation at www.uicnmed.org. Project funding for this initiative was provided by the Global Dialogue on Water and Climate Change. The IUCN Centre for Mediterranean Cooperation receives core funding from the Spanish Ministry for Environment and the Junta of Andalucia.

SUMMARY

Wetlands evokes generally water and water resources or water systems which evokes water cycle which evokes ultimately climate. They provide globally significant social, economic and environmental benefits, into the extent that they have been subject to increasing human pressure over the time, leading to loss and degradation of valuable resources.

Climate change has been also identified as a notable factor contributing to loss and degradation of wetlands, but there has been little attention given so far by policy-makers to the relationship between climate change and the wise use of wetlands.

Within the framework of the implementation of the UNFCCC, the projected changes in climate are likely to affect wetlands significantly, in their spatial extent, distribution and functions. Indeed, since the IPCC SAR, various investigations have led to greater confidence in the ability of models to project future climate, which allowed the TAR to confirm many established facts observed over the 20th century, and to confirm the role of effect of GHG emissions and aerosols due to human activities in altering the atmosphere in ways that are expected to affect the climate. Thus, under the IS92a scenario, the projected changes in climate are likely to cause a globally averaged surface temperature increase by 1.4 to 5.8°C over the period 1990 to 2100, and a globally mean sea level rise by 0.09 to 0.88 metres between 1990 and 2100 for the full range of SRES scenarios.

As far the Mediterranean region is concerned, **sub-regional climate change scenarios** have been derived from the global and regional ones constructed under different emission scenarios using various models and leading methodologies. The results under both SRES and IS92a emissions scenarios, which were then assessed for inter-model consistency, suggest that the warming will be is in excess of 40% above the global average, that for Precipitation , in spite of disagreement between scenarios, there is a consensus about the presumption of a greater contrast of the climate: In the South, the risk of a more arid climate during the XXIst century, and in the North, climate will be more contrasted, rainier in winter and dryer and more irregular in summer, and that for Sea level change, the rate of local sea level rise in the 21st century is projected to be greater than in the 20th century at the great majority of coastal locations.

Water and wetlands in the Mediterranean: water either as a resource or as an environment, is at the heart of interactions and tenseness, even conflicts, between the environment and the development, particularly within the Mediterranean region. **As a resource** water, which refers to total freshwater renewable resources, is rare, more and more solicited and submitted to anthropogenic pressures and it is very prone to climate change effects and consequences. Furthermore, during the 21st century, the projected differences in the demographic increase of Northern and the Southern countries will sharpen water shortage within the less supplied countries such as Algeria, Morocco and Tunisia.

Water as an environment refers to all marine/coastal and terrestrial natural wetlands, as well as to artificial water reservoirs. Within the Mediterranean basin, water is a valuable, but a fragile environment, which has been taped over time for various purposes. In addition, the Mediterranean Sea itself, which is a common patrimony for most of the surrounding countries, determines largely the climatic characteristics of terrestrial and coastal biotopes and ecosystems.

Mediterranean wetlands are defined and determined by three main environmental factors: (i) The Mediterranean climate that acts through regional and sub-regional variations, in

particular the great year-to-year variation in the timing and quantity of rainfall; (ii) Topography and geology in through the existence of coastal plains and lowland. In fact, most of wetlands occur on these coastal plains and within interior drainage basins and (iii) Marine tides which are of limited importance within the sub-region and which occur along the Gulf of Gabès at the eastern coast of Tunisia.

In spite of various common factors with the Mediterranean countries, the sub-region shows many specific characteristics that are of a huge importance for the sustainability of wetlands, of which:

Local variability of the climate:

Water resources: Freshwater resources are scarce as their availability don't exceed $1000m^3$/inhabitant in the North Africa. The off take index of freshwater resources is very high for most of the southern countries where more than 80% of freshwater off take are used for agriculture production.

Demography, which is a major dominant factor of the socio-economic and environmental development within the sub-region. It is expected that it will be of a major concern for further development during the 21st century, in particular with regard to water resources scarcity.

Socio-economic development: The prevailing constraints to development process will be further exacerbated by the demographic increase and the scarcity of freshwater resources and desertification.

Desertification, which affects livelihood of rural population in arid and dry sub-humid areas of the sub-region is opposing a major constraint to development efforts. Thus, climate change might exacerbate desertification and, conversely, desertification aggravates carbon dioxide emission from cleared land and reduces their carbon sequestration potential.

North African wetlands show two main groups according to their functions: The first one includes wetlands having various functions, including the productive function, while the second includes wetlands having other functions than the productive one, mainly ecological and or scientific functions.

Very few national works have been done on wetlands. There is no systematic updated inventories as most of the available information are out of date. Presently, North African wetlands are experiencing either intensive anthropoid interventions or simply the lack or absence of interventions; most of wetland are not protected nor managed and valuable wetlands have been almost drained for agriculture or impacted by national water management schemes.

Because of the characteristics of water resources within the sub-region, **wetlands are very prone to climate change effects** and consequences. Indeed, Biophysical effects will appear as a result of Climate change impact on water balances and their variability over time as well as on hydrological drought frequency. It is also expected that climate change will impact coastal wetlands as a result of the interactive effects of sea level rise, warming, and decrease in precipitation.

Then, climate change impacts on water resources and coastal/marine ecosystems will in turn induce effects biophysical effects on wetlands, mainly:

Loss of the specific biodiversity within various coastal wetlands leading to the decrease of their productivity which could be balanced, into some extent, by the formation of new wetlands on salt marshes and sebkhets.

Disturbance of flora distribution and habitat for fauna together with a decrease of the carrying capacity of wetlands; which effect is likely to be balanced by a limited development of aquatic biodiversity.

Given the specific problems characterising the Maghreb countries in particular with regard to water resources scarcity, the reliance of rural livelihood on natural resources, desertification hazards, demography pressure, climate change, etc., will likely have various adverse socio-economic impacts which, in turn, would affect wetlands. Socio-economic impacts of climate change will be generated by biophysical effects on freshwater resources as well as by the biophysical impacts of sea level rise. These impacts are likely to affect indirectly wetlands through: (i) Increased anthropoid pressure on major productive coastal wetlands; (ii) Increased freshwater demand for domestic use and agriculture, which will exacerbate water resources problems leading to more pressure on freshwater and its diversion from natural systems and wetlands; (iii) The magnitude of sea level rise impacts on coastal infrastructures, together with desertification processes, will be a major concern with regard to social costs involved to cope with such impacts that will burden socio-economic development efforts placing environmental issues, such as wetlands, on a second hand priority .

In order to cope with such effects, adaptations should involve integrated adjusting measures primary, on the institutional framework at national levels in order to adjust the relationship between the human element and the regarded ecosystem and Secondly, on the international environment in order to help within the preparation and the implementation of adjusting measures at national levels through financial co-operation, technology transfer, capacity building, monitoring and evaluation, etc.. these adaptations should address :

Biophysical effects through: (i) The improvement of the knowledge of wetlands; ((ii) The review of national strategies in connection with water resources management in the context of climate change; (iii) The review of national land use planning and management strategies as to integrate climate change and sea level rise issues.

Social adaptations through the development of an enabling environment which should: (i) Allow the development of ways and means as to reduce sensitivity of the rural production systems to climate stimuli; (ii) Enhance the development of alternative livelihood opportunities for rural population, which involve the strengthening of infrastructures, diversification of the economic settings, human resources development, etc. (iii) Reduce social an economic vulnerability to extreme events such as drought, floods, storm waves, and other natural disaster;

With regard to climate change mitigation, North African wetlands don’t bear interesting potential mitigation options. Mitigation potential options should be sought in connexion with energy and transportation sectors as they reflect opportunities for energy efficiency improvements and evenly in the rural sector where forests, agricultural lands, and other terrestrial ecosystems offer significant carbon mitigation potential, mainly through land use change and, into some extent, through afforestation and forest integrated management schemes.

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BIOPHYSICAL AND SOCIO-ECONOMIC IMPACTS
OF CLIMATE CHANGE ON WETLANDS.

1. INTRODUCTION

Wetlands evokes generally water and water resources or water systems which evokes water cycle which evokes ultimately climate. They provide globally significant social, economic and environmental benefits. Important wetland functions include water storage, groundwater recharge, storm protection, flood mitigation, shoreline stabilisation, erosion control, and retention of carbon, nutrients, sediments and pollutants[1]. Wetlands also produce goods that have a significant economic value such as clean water, fisheries, timber, peat, wildlife resources and tourism opportunities.

Humankind history showed that wetlands have been subject to increasing human pressure leading to loss and degradation of valuable resources, which are obviously driven by:

Increased demand for agricultural land associated with population growth which continues to be a significant cause of wetland loss in some parts of the world;

Infrastructure development and river flow regulation which constitutes another major cause of wetland degradation and loss, as well as the invasion of non-native species and pollution.

Climate change has been also identified as a notable factor contributing to loss and degradation of wetlands, but there has been little attention given so far by policy-makers to the relationship between climate change and the conservation and wise use of wetlands. However, the projected changes in climate are likely to affect wetlands significantly, in their spatial extent, distribution and function.

According to the Third Assessment Report, the projected effects of climate change on natural systems could globally lead to :

Water resources :

Increases of annual mean streamflow in high latitudes and southeast Asia, and decreases in central Asia, the area around the Mediterranean, southern Africa and Australia;

Decreases of streamflow and groundwater recharge in many countries that are water-stressed such as those in central Asia, southern Africa and countries around the Mediterranean sea.

Terrestrial and freshwater ecosystems:

Poleward movement of boundaries of freshwater fish distributions along with loss of habitat for cold and cool water fishes and gain in habitat of warm-water fishes; shifts in the geographical distribution of wetlands; fragmenting habitats and raising obstacles to species migration pursuant to land use change;

Coastal and marine ecosystems:

increases in sea surface temperature and mean global sea level , change in salinity, wave condition, etc.. Many coastal areas will experience increased levels of flooding, accelerated erosion, loss of wetlands and mangroves, and sea water intrusion into fresh water sources.

The IPCC Third Assessment Report, which made substantial advances since the previous IPCC assessments in the detection of change in biotic and physical systems, pointed out that the greatest vulnerabilities are likely to be in unmanaged water systems and systems that are currently stressed or poorly and unsustainably managed due to policies that discourage efficient water use and protection of water quality, inadequate watershed management, failure

[1] Dugan 1990 quoted in "Wetlands and Climate Change": Exploring collaboration between the Convention on Wetlands (Ramsar, Iran 1971) and the UNFCCC, October 1999 - G. Bergkamp & B. Orlando

to manage variable water supply and demand, etc.. and stressed the need for initiatives to begin designing adaptation strategies and building adaptive capacities, and identified high priorities for narrowing gaps between current knowledge and policy making needs, of which:

Quantitative assessment of sensitivity, adaptive capacity, and vulnerability of natural and human systems to climate change, with particular emphasis on changes in the range of climatic variation and the frequency and severity of climate extreme events;

Understanding dynamic response of ecosystems to multiple stresses, including climate change, at global, regional and finer scales;

Assessment of potential impact of the full range of the projected climate changes, particularly for non-market goods and services ..;

Improving tools for integrated assessment, including risk assessment to investigate interactions between components of natural and human systems and the consequences of policy decisions;

Assessment of opportunities to include scientific information on impacts, vulnerability and adaptation in decision making processes, risk management and sustainable development initiatives;

Improvement of long term monitoring systems and methods and understanding the consequences of climate change on and other stresses on human and naturals systems.

It is against this background, that this paper has been prepared in view of identifying anticipated biophysical and socio-economic impacts/effects of climate change on wetlands within the Maghreb countries, and assessing adaptation strategies and mitigation options as to prevent and/or mitigate such effects.

This paper is structured into five main parts: (i) a review of climate change scenarios for the Mediterranean with special reference to the Maghreb sub-region; (ii) an overview of water and wetlands in the sub-region and their specificity; (iii) the identification of anticipated biophysical and socio-economic effects of climate under the adopted scenarios; (iv) the assessment of adaptation strategies and (v) mitigation options.

2. CLIMATE CHANGE

The climate of a region at any given time can be defined by the values of variables that characterise the weather (climatic variables). The main variables are temperature, precipitation, and wind, plus atmospheric pressure, atmospheric humidity and sunshine.

Climate is considered as a norm that takes into account not only the mean values of climatic variables, but also their fluctuations over time. Nevertheless the mean values of climatic variables (temperature, rainfall, etc.) are the main characteristics of the climate in a given region, the seasonal and multiyear variability of these variables also play an important role in defining climate.

Climatic characteristics vary also as a function of latitude from the equatorial zone to the polar regions, but significant differences can also be observed at the same latitude. These are linked to the geography of the region such as : proximity of ocean, relief, altitude, exposure to prevailing winds, etc.

Within a given location on earth, climatic variables/characteristics are determined by the interaction between the atmosphere, the oceans/seas, the sun energy which form the climatic system. Thus, the climate system appears as thermal machine that converts and redistributes energy from the sun via the movements of the atmosphere and the oceans and exchanges between the different "compartments" of the system, of which the main vector is the water cycle[2].

Climate change could be attributed to natural climate variability observed over comparable time periods an/or , directly or indirectly, to human activity that alters the composition of the global atmosphere.

Within this paper, climate change is used in the meaning of IPCC definition which refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the Framework Convention on Climate Change, where *climate change* refers to a change of climate that is attributed directly or indirectly to human activity and that is in addition to natural climate variability.

2.1. GLOBAL SCENARIO

The Third Assessment Report (TAR) of Working Group I of the Intergovernmental Panel on Climate Change (IPCC) builds upon past assessments and incorporates new results from the past five years of research on climate change. Indeed, since the release of the Second Assessment Report (SAR), additional data from new studies of current and palaeo-climates, improved analysis of data sets, more rigorous evaluation of their quality, and comparisons among data from different sources, have led to greater understanding of climate change. The report pointed out that:

An increasing body of observations gives a collective picture of a warming world and other changes in the climate system. In this regard the TAR underlines the following established facts among others :

The global average surface temperature has increased over the 20th century by about 0.6°C.

Temperatures have risen during the past four decades in the lowest 8 kilometres of the atmosphere ;

Snow cover and ice extent have decreased ;

Global average sea level has risen and ocean heat content has increased ;

Emissions of greenhouse gases and aerosols due to human activities continue to alter the atmosphere in ways that are expected to affect the climate;

Confidence in the ability of models to project future climate has increased;

There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities.

The report concludes that:

Global average temperature and sea level are projected to rise under all IPCC Special Report Emission Scenarios. In this respect:

- ***Temperature*** increases are projected to be greater than those in the SAR, which were about 1.0 to 3.5°C based on the six IS92 scenarios. The globally averaged surface temperature is projected to increase by 1.4 to 5.8°C over the period 1990 to 2100. On time scales of a few decades, the developed approach suggests that anthropogenic warming is likely to lie in the range of 0.1 to 0.2°C per decade over the next few decades under the IS92a scenario.

Sea level rise: as a basic result of thermal expansion and loss of mass from glaciers and ice caps, the globally mean sea level is projected to rise by 0.09 to 0.88 metres between 1990 and 2100, for the full range of SRES scenarios.

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[2] Marc Morell - Climate changes 3, 2001

- These projections indicate that warming would vary by region, and be accompanied by increases and decreases of precipitation. In addition, there would be changes in the variability of climate, and changes in the frequency and intensity of extreme climate phenomena and events such as droughts and floods.

Human influences will continue to change atmospheric composition throughout the 21st century and anthropogenic climate change will persist for many centuries.

Further action is required to address remaining gaps in information and understanding.

2.2. MEDITERRANEAN SCENARIOS

2.2.1. Regional simulation scenarios

The Mediterranean sub-region is formed by the Mediterranean coast of Europe (Southern end), Asia (Middle East end) and Africa (Northern end). Its climate is determined by the interaction of forcings and circulations that occur at the planetary, regional and local spatial scales, and at a wide range of temporal scales.

From a geographical, historical and, into some extent, climatic point of view, it could be defined as a relatively homogeneous region. However when considering political or climate change issues, such a definition is difficult to apply.

As a matter of fact, the TAR WGI reported that, while analysis of transient climate simulations indicates that average climatic features are generally well simulated at the planetary and continental scale, at the regional scale, area-average biases in the simulation of present day climate are highly variable from region to region and across models. Seasonal temperature biases are typically within the range of ±4°C but exceed ±5°C in some regions, particularly in DJF months. Precipitation biases are mostly between -40 and +80%, but exceed 100% in some regions. The TAR reported also that these regional biases are, in general terms, smaller than those of a similar analysis presented in the SAR.

As far the Mediterranean region is concerned, sub-regional climate change scenarios have been derived from the global and regional ones constructed under different emission scenarios using various models and leading methodologies.

Results on regional climate change are based on data for 2071 to 2100 and 1961 to 1990 that have been directly analysed and assessed by the lead authors. They were obtained from a set of simulations models based on either SRES preliminary marker emission scenarios A2 and B2, or IS92a using GHG forcing/climate sensibility. The results which were then assessed for inter-model consistency could be summarised as following:

Warming:

For the Mediterranean basin, the results showed that under both SRES and IS92a emissions scenarios, the warming is in excess of 40% above the global average.

Tables n°1: Results of climate change simulations for the Mediterranean region: warming.

Emission scenarios	Scenarios	Global annual average warming	Regional 40% amplification
SERES	A2	1.2 to 4.5°C	1.7 to 6.3°C
	B2	0.9 to 3.4°C	3.5 to 5.3°C

IS92a	GG	3.0 to 4.9°C	4.2 to 6.9°C
	GS	2.5 to 3.8°C	3.5 to 5.3°C

Precipitation: For precipitation, results were much less consistent (see table 2).

Tables n°2: Results of climate change simulations for the Mediterranean region: Precipitation.

Emission scenarios	Scenarios	DJF months	JJA months
SERES	A2	No change	Large decrease <20%
	B2	No change	No agreement
IS92a	GG	No agreement	Small decrease : between –5 and –20%
	GS	No change	Small decrease : between –5 and –20%

Sea level change:

important to recognise that in all models and scenarios the rate of local sea level rise in the 21st century is projected to be greater than in the 20th century at the great majority of coastal locations.

reveal significant uncertainty in the analysis of 20th century sea level change. Also, we have little knowledge of the regional pattern of sea level change. Observational determination of such a pattern would be a powerful test of the coupled models required for projections of globally averaged and regional sea level rise. Requirements for reducing uncertainties include:

2.2.2. National scale simulation scenarios

Within the framework of the implementation of the UNFCCC, the Maghreb countries undertook various activities, of which vulnerability studies to climate change: In Tunisia the vulnerability study focused on sea level rise and its implications on coastal ecosystems, in Algeria the vulnerability study focused on agriculture, while in Morocco, the vulnerability study focused on water resources.

The climate change projections adopted within these studies for the horizon 2020 were based on SERES and/ or IS92a global warming scenarios using various models and are summarised below.

Table n°3: Climate projections adopted by the Maghreb countries for the horizon 2020.

	Tunisia	Algeria	Morocco
Warming	0.2°C per decade	0,8 à 1,3°C	0.6°C et 1.1°C
Precipitation	?	-5 à –13%	-4%

Regarding sea level rise, the Tunisian study worked out three scenarios constructed on the basis of combined IPCC warming scenarios together with different development levels of anthropoid coastal activities in Tunisia. These scenarios are summarised in table 4

Table n°4: Mean projected sea level rise on Tunisian coasts relatively to the present

Regions	Present situation	Projected situation: 2100		
		Minimum of risk Warming: 0,13°C	Reference scenario Warming: 0,2°C	Maximum risk Warming: 0,25°C
Extreme North	0,16	0,54	0,66	0,71
Gulf of Tunis	0,16	0,38	0,66	0,71
Gulf of Hammamet	0,00	0,38	0,5	0,55
Sfax	0,00	0,38	0,5	0,55
Kerkenna island	0,00	0,38	0,5	0,55
Gabès	-0,13	0,25	0,37	0,42
Jerba Island	0,00	0,38	0,5	0,55
Extreme South	0,00	0,38	0,5	0,55

(Unit: meter).

3. WATER AND WETLANDS IN THE MEDITERRANEAN

3.1. OVERVIEW OF WATER AND WETLANDS IN THE MEDITERRANEAN

3.1.1. Water resources in the Mediterranean

Water either as a resource, or as an environment, is at the heart of interactions and tenseness, even conflicts, between the environment and the development, particularly within the Mediterranean region.

Water as a resource:

As a resource, water refers to total freshwater renewable resources, which include flows of rivers and groundwater from rainfall in the country, and river flows from other countries. Within the Mediterranean basin water as a resource is rare and it is more and more solicited and submitted to anthropogenic pressures, while forthcoming water shortages will be a huge threat for development. Indeed, outside few river valleys which are coming from more humid areas such as the Nile, the Rhône, etc., the Mediterranean basin is among regions where water is relatively rare because of its dry summer, the irregularity of its precipitation, its relief and the limited extend of its river basins. In spite of various common factors, the variability of local conditions is such that natural water resources are unequally distributed within the Mediterranean basin between the North and the South, with respectively 86% and 14%[3]. Such

[3] Jen Margat. L'au dansle bassin Mediterranéen in Revue Aménagement et nature n°121.p 59.

a distribution is well illustrated through the real annual flows from each country to the Mediterranean sea (See table 5).

Table 5: Real annual water flows from Mediterranean countries to the sea[4]

	Real annual flows from each country to the Mediterranean sea (Km^3)
Northern Mediterranean counties	
Italy	159
France	60
Spain	19,5
Tukey	63,5
Greece	53
Yugoslavia	29
Southern Mediterranean counties	
Algeria	8,5
Morocco	3
Tunisia	1,1
Libya	0,7
Egypt	6

In addition, during the 21st century, the projected differences between demographic increase within the Northern countries – which will be low to near zero increase – and the southern ones which is still to be high, will sharpen water shortage within the less provided/supplied countries such as Algeria, Morocco and Tunisia.

Water as an environment :

Water as an environment refers to all marine/coastal and terrestrial natural wetlands, as well as to artificial water reservoirs, where water is a major component for habitat as for the maintenance of the food chain.

Within the Mediterranean basin, water is a valuable, but fragile environment which has been taped/valorised for various purposes for centuries. First there is the Mediterranean sea itself which, covering 2.3 millions Km_ and which is a common patrimony for most of the surrounding countries (Fishing, transportation, Salinas, tourism and recreation, etc.). Beside its proper biological characters linked to its paleo-ecological history, the Mediterranean sea determine largely the climatic characteristics of terrestrial and coastal biotopes and ecosystems (coastal wetlands). In addition specificity of Mediterranean coasts is the result of the physical characteristics of the sea it self : warm water, low tide, high salinity, narrow continental plateau, etc.

Thus, the Mediterranean ecosystems have several proper characteristics which are resolved by the existence of a more or less lasting dry season. In addition, the existence of narrow coastal plains backed to Est-West oriented mountainous chains oriented or hilly inland, create various ecological niches (mountain wetlands, humid forests, endorheic drainage basins) which are favourable to the settlement of a great variety of vegetal and animal populations as well as a large number of species, leading to the development of the specific or exceptional biodiversity of the region.

[4] Source of information: Plan Bleu, 1996.

Water resources and climate change :

Water resources within the Mediterranean region are prone to climate change effects and consequences, which may be induced by the GHG emissions. The amplitudes and time lines of such a change remain affected by uncertainties, difficult to quantify and could not be estimated under a defined probability. However, there is a consensus about the presumption of a greater contrast of the climate. In the South, the risk of a more arid climate may not be excluded and it could have a double effect during the XXIst century: decrease of the resources and increase of the requirements/needs through increase of evaporation, aggravating droughts. In the North, climate will be more contrasted, more rainy in winter and dryer and more irregular in summer, which would have consequences on water regimes and emphasise water requirements in summer.

3.1.2. Wetlands :Factors responsible for the distribution of wetlands in Mediterranean

According to Britton and Crivelli[5], three main environmental factors are responsible for the distribution of wetlands in the Mediterranean. These factors are: climate, topography and geology, and marine tides.

A. The Mediterranean climate and its implications:

The fundamental characteristics of the Mediterranean climate are that it is "a non-tropical climate with seasonal variation in photoperiod, with the rainfall concentrated in the cold or cooler part of the year; the summer, the hottest season, being dry"[6].

Evaporation greatly exceeds rainfall during the summer months, and generally on an annual basis as well. Typically the winters are mild, prolonged freezing is rare, and plant growth can continue throughout the year.

Regional and sub-regional climate variations:

The sub-region is located at the north of the 30th parallel and could be considered to have a subtropical Mediterranean climate, characterised by the regular alternation of a more or less winter rainy cool season and a summer dry season. Indeed the sub-region is submitted to the influences of three main climatic processes: The Mediterranean sea, the Sahara and the Atlantic ocean. Although most of the area covered can be considered to have a Mediterranean type climate, there are strong regional variations:

During the northern summer the Azores anticyclone produces a northerly air stream over almost the entire North Africa region. It is a dry stream which brings virtually no rain. This dry wind blows across Algeria to the tropic of cancer;

During the northern winter the general orientation of the main relief (East-West) of the northern part of the sub-region, which presents numerous corridors, allows the penetration of N-W and W streams of humid westerly air from the Atlantic and bring rains on the northern fringe;

In the south, high pressures prevails from the Sahara during the northern winter and winds then blow off the desert towards the south-west and north-east. They are hot, dry and dusty;

Such variations led to the consideration of three main climatic zones:

The northern fringe located at the north of the main relief, where Mediterranean climatic conditions are predominant (sub-humid to humid);

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[5] Wetlands of the word I – DF wingham et al. 1993

[6] Emberger 1954 quoted by Britton and Crivelli, 1993 in Wetlands of the word I – DF wingham et al.

The southern zone north of the Sahara where Saharan climatic conditions are dominant and where aridity is quite a constant (semi-arid to arid);

The central zone where the Mediterranean and the Saharan climatic conditions are perpetually opposed, leading to a great annual variability of climatic conditions depending on the predominance of Mediterranean or Saharan climatic conditions. In addition, this variability is amplified by the prevalent local conditions such as topography, continentality, influence of the sea, etc.(arid to hyper-arid).

Consequently, rainfall varies mainly on a north to south gradient, but there are strong local variations due to topography. Highest rainfall (>1000 mm) occurs on high mountains high Atlas, Morocco) and where mountain ranges approach the coast (Kroumirie-Mogods mountains/Tunisia, Tellien Atlas, Algeria). Lowest rainfall occurs in areas bordering the Sahara. In areas bordering the Atlantic, rainfall is more evenly spread over the year and the annual range of temperature is small.

There is also a marked west to east and north to south decrease in winter temperature across the Mediterranean basin. However, in North Africa sub-region, temperatures rarely fall below zero at sea level but lakes in the High Atlas mountains at altitudes of over 1,000 m regularly freeze for short periods in winter. Freezing also regularly occurs in high inland areas (hauts plateaux of the Saharan Atlas, high plains), which have a steppe climate.

As well as being highly seasonal, the climate is characterised by great year to year variation, particularly in the timing and quantity of rainfall. Year to year variation in the quantity of precipitation increases as the mean annual rainfall decreases. As one progresses towards the driest region (Sahara), rainfall ceases to be an annual event, and only intermittent heavy rains occur at intervals of several years. In mountainous areas mean annual rainfall is higher and there is less year to year variation than in lowland areas.

A final feature of the Mediterranean climate is that locally strong winds occur. These greatly increase evaporation from open water, have direct effects on some wetland plants and animals.

Implications for wetlands:

Since annual evaporation greatly exceeds annual rainfall except in humid mountainous areas, wetlands only occur in topographic depressions which collect and retain water from a surrounding catchment. Moreover, since rainfall and evaporation show great seasonal variability, wetlands which do not have a connection to a permanent source of water, show regularly pronounced draw-down in water level in the summer months, however, the timing and duration of the draw-down within any wetland system is not fixed.

In the sub-region, many wetlands are normally dry and only flood after exceptionally wet winters, which may only occur at intervals of several years.

The excess of evaporation over rainfall allows the build up of dissolved salts even in inland wetlands, and in the more arid parts of the region most wetlands are saline. The seasonality of the rainfall/evaporation deficit also causes variation in salinity in non-freshwater wetlands. Many isolated coastal lagoons regularly evaporate to dryness and to saturation with sodium chlorine. Salinity may show both seasonal and long-term year to year variation.

Summer drought and high summer salinity make this season unfavourable for many wetland organisms. However, winter temperatures are sufficiently high in most parts of the region to allow for plant and animal growth. Some wetland organisms, which grow and reproduce in the summer in northern Europe, perform these functions in winter and early spring in the Mediterranean region, and pass the summer months in quiescent stages.[7]

B. Topography, geology and their implications:

The Mediterranean region, being at the point of contact between the African and Eurasian tectonic plates, is very mountainous. Around most of the basin, mountains descend to the coast and a coastal plain, if it exists at all, is very narrow and discontinuous.

In North Africa an extensive, but discontinuous, coastal plain exists along the Atlantic coast of Morocco, but the Mediterranean coasts of Morocco, Algeria, and northern Tunisia are mountainous. The eastern coast of Tunisia has a continuous coastal plain of varying width: In the north it is the flood plain of the River Medjerda facing the Gulf of Tunis, while in centre the coastal plain extends inland to include the Sahel region and the eastern part of the low steppe. In the south, facing the Gulf of Gabès, the coastal plain extends inland to include the huge interior drainage basin of the Chott Djerid (Tunisia) and Chott Melghir (Algeria) which lie below present-day sea level; it also extends to the south-east to include Jeffara plain which continue to the Tripolitan region in Libya.

Endorheic drainage basins also occur further west into Algeria on altitudes (the high plateaux) between the mean Atlas (Tellien Atlas) and the Saharan Atlas mountains. A few such basins, of small size, also occur in Tunisia between the Sahel and the low steppe.

Implications for wetlands :

Most of wetlands occur on these coastal plains and within interior drainage basins, and wetlands consequently have a patchy and discontinuous distribution. Riverine wetlands are associated to the presence of a river system like the delta of Medjerda facing the Gulf of Tunis, while non-riverine wetlands are associated to the extend of high sea bottoms and/or sea intrusion into lowlands (sea lagoons), and to topographic depressions which collect and retain water from a surrounding catchment under the semi-arid and arid conditions (sebkhats and shotts).

The uplands of the Mediterranean are mainly composed of porous limestone in which the water table lies many meters below the surface. Rivers are generally short and steep and most of them cease flowing out of the rainy season.

Fresh water lakes are rather scarce out of the humid and sub-humid mountains area and the largest examples have been drained[8].

C. Marine tides

Throughout most of the Mediterranean the vertical tidal amplitude is less than 50 cm per cycle. Variations in sea level tidal amplitude are caused by wind surges, changes in barometric pressure, or seasonal variation in evaporation and rainfall are generally greater than this. Inter-tidal wetlands are therefore mostly absent from the coasts of the Mediterranean.

However, two areas within the western basin of the Mediterranean have a greater than average tidal amplitude and show limited development of inter-tidal flats and salt marsh. These are at the northern end of the Adriatic (near Trieste), and along the Gulf of Gabès at the eastern coast of Tunisia, between Sfax and the island of Djerba. Although there is a moderate tidal range along the Atlantic coast Morocco, inter-tidal wetlands are restricted in occurrence by the generally steep coastlines. Tidal wetlands which occur along these coastlines are mostly

[7] Nourrisson and Aguesse 1961, Champeau 1971 quoted by Britton and Crivelli, 1993 in Wetlands of the word I – DF wingham et al.

[8] Britton and Crivelli, 1993 in Wetlands of the word I – DF wingham et al.

associated with existing river estuaries or with relict estuaries (e.g. Merja Zerga, Morocco), and are mostly of rather limited extent.

Implications for wetlands:

For the region as a whole, therefore, inter-tidal wetlands are of limited importance as compared to other coastal regions of the world.

3.2. SPECIFIC ANALYSIS OF SUB-REGIONS MOST LIKELY AFFECTED

3.2.1. Main characteristics of the sub-region

The area covered-by this study comprises those parts of North Africa which lie within the basin of the Mediterranean Sea and which have a Mediterranean climate type, excluding Libya and Egypt. In spite of various common factors with the Mediterranean countries, this area shows many specific characteristics which are of a huge importance for the sustainability of wetlands. In this regard five main characteristics are considered to be of a high risk for wetlands even without climate change. These factors are : the variability of climate, water resources, demography, socio-economic development and desertification.

A. Local variability of the climate:

See § 3.1.2. A.

In the remaining countries, which constitute the Maghreb (Tunisia, Algeria, and Morocco), the southern limit of the area is formed by the Sahara, where rainfall is no longer a regular annual event, and where wetlands are virtually absent.

Indeed, about 60% of the area is formed by the Sahara which is hyper arid and encounters the influence of the Mediterranean Sea limiting its effects to a narrow strip formed by the coastal plains and the surrounding hills and mountains. The middle areas are submitted to the antagonist influence of the Mediterranean Sea and the Sahara leading to a very erratic climatic conditions.

B. Water resources

The variability of local climate conditions within the Mediterranean region is such that natural water resources are unequally distributed within the Mediterranean basin between the Northern countries and the Southern ones, with respectively 86% and 14%[9]. Such a distribution is well illustrated through the real annual flows from each country to the Mediterranean sea (See table 6).

Table 6: Real annual water flows from Mediterranean countries to the sea[10]

	Real annual flows from each country to the Mediterranean sea (Km^3)
Northern Mediterranean counties	
Italy	159
France	60
Spain	19,5
Turkey	63,5
Greece	53

[9] Jen Margat. L'au dansle bassin Mediterranéen in Revue Aménagement et nature n°121.p 59.

[10] Source of information: Plan Bleu, 1996.

Yugoslavia	29
Southern Mediterranean counties	
Algeria	8,5
Morocco	3
Tunisia	1,1
Libya	0,7
Egypt	6

More specifically, the off take index[11] of freshwater resources is very high for most of the southern countries, exceeding 100% in some cases. This means that the available resource margins are very limited. According to the Plan Bleu the 2025 projections showed that these indexes will likely reach 60% for Algeria, 70% for Morocco and will near 100% for Tunisia[12].

Such a problem should reach its real significance when we know that within these countries, more than 80% of freshwater resources off take are used for agriculture production (See table …). In other words, food production is largely depending on freshwater availability and quality.

Table n° ..: Freshwater[13] resources use balance in some Mediterranean countries[14]

	Freshwater resources	**Annual freshwater withdrawals**					**Access to safe water**			
							Urban		Rural	
	Cubic meters per capita 1998	Billion cubic.m[a]	% of total resources[a]	% for agriculture[b]	% for industry[b]	% for dometic[b]	1982 - 1985[c]	1990 - 1996[c]	1982 - 1985[c]	1990 - 1996[c]
Northern Countries										
Albania	12,758[d]	1.4	3.3 [d]	71	0	29	100	97	88	70
Greece	6,562[d]	7.0	10.2 [d]	81	3	16	91	..	73	..
Italy	2,909 [d]	7.5	34.4 [d]	45	37	18	100	..	96	..
Spain	2,847 [d]	35.5	31.7 [d]	62	26	12	100	..	95	..
Southern countries										

[11] Or the share of natural renewable water resources wich is off taken by all users (Agriculture, industry and domestic uses).

[12] Mohames Ben Blida : Problèmes de la gestion de l'eau en Mediterranée in Aménagement et nature, N°121. P53.

[13] Freshwater resources refer to total renewable resources, which include flows of rivers and groundwater from rainfall in the country, and river flows from other countries.

[14] Source of information: 2000 World Development indicators. p 13 -133.

Algeria	478 [d]	4.5	31.5 [d]	60[e]	15 [e]	25 [e]	..	..	..	..
Morocco	1,08	11.1	36.8	92 [e]	3e	5 [e]	63	98	2	14
Tunisia	439 [d]	2.8	69.0 [d]	86 [e]	2 [e]	13 [e]	98	..	79	..

a. Data refer to any year from 1980 to 1998, unless otherwise noted.
b. Unless otherwise noted, sectoral withdrawal shares are estimated for 1987.
c. Data refer to the most recent year available in the period.
d. Total water resources include river flows from other countries.
e. Data refer to years other than 1987 .

In addition, the availability of freshwater is a key factor for human settlements and, subsequently for land use and management and has various implications on natural resources management, including wetlands. During the 21[st] century, the projected differences between demographic increase within the Northern countries – which will be low to near zero increase – and the southern ones which is still to be high, will sharpen water shortage within the less provided/supplied countries such as Algeria, Morocco and Tunisia (See §. 3.2.1.C below).

C. Demography

Demography is a major dominant factor of the socio-economic and environmental development within the sub-region, and it is expected that it will be of a major concern for further development. According to the United Nations projections, the total population of the Mediterranean region will increase from 420 millions in 1995 to 446 millions in 2000 and between 508 and 579 millions in 2025 according to the projection hypothesis/scenarios. Such an increase will be mostly the fact of the countries lying on the southern and eastern coast of the Mediterranean, among which the Maghreb ones.

In fact, during the 21[st] century, the projected differences between demographic increase within the Northern countries – where the increment will be low to near zero increase – and the southern ones where the increment is still to be relatively high, will exacerbate socio-economic and environmental issues, in particular with regard to water resources within the less provided/supplied countries such as Algeria, Morocco and Tunisia.

So, within the Mediterranean region, there are two different demographic dynamics: a young population with relatively high increment rates in the southern countries and a aging population with low increment rates, and even a stagnation or a certain decrease, in the northern countries. Such dynamics have major implications on employment, food production and nutrition, land use management, environment pressure and on water demand.

This situation is exacerbated by urbanisation which continue on a accelerated basis, emphasising demographic and activities concentration within coastal plains.

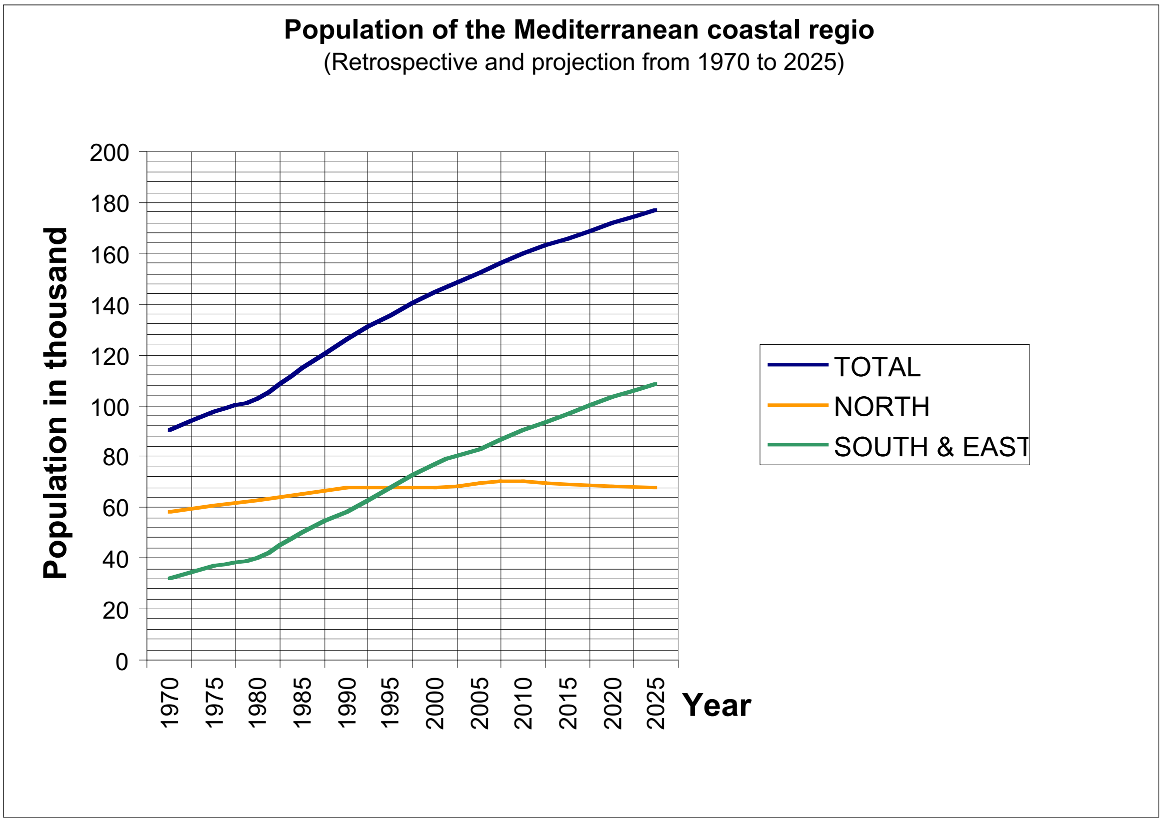
Tableau n°7: Population density within the Mediterranean coast of the Maghreb sub-region

	Last year available	POPULATION (Thousand inhabitant)			Density (inhab./km2)		
TUNISIA	1994	8 785	6164	70	57	135	2.37

TOTAL[15]		392636	135391	34	45	132	2.93

Source of information: Plan Bleu.

Indeed, the geographic distribution of the population of the sub-region is largely driven, among other factors such as accessibility and infrastructures, by the local climatic conditions in such a way that the population is mostly concentrated in coastal plains and/or in the northern fringes which are, from a climatic point of view, under the influence of the Mediterranean Sea. According to the Plan Bleu, the population density of the Mediterranean areas of the sub-region is very much higher than the national mean density. Such a phenomena is illustrated in Table which shows a density index varying between 2.35 for Morocco and 21.5 for Algeria (See table 7). In addition, the retrospective studies and projection of the population of the Mediterranean coastal region from 1970 to 2025 confirmed very closely the United projections and showed that the Mediterranean coastal population of the southern countries will near to double while the it will practically stagnate (See figure n°1).



South: *Turkey, Syria, Lebanon, Israel, Egypt, Libya, Tunisia, Algeria, Morocco, Cyprus.*

North: *Spain, France, Monaco, Italy, Malta, Slovenia, Greece, Croatia, Bosnia, Yugoslavia.*

D. Socio-economic development

As far as socio-economic development is concerned, inequity between the Northern and the southern countries is very important. According to the "Plan Bleu[16]", over a global GDP

[15] The total, calculated using data corresponding to different years, is only shown as an indicative information

[16] Plan Bleu: Vision Mediterranéenne sur l'eau, la population et l'environnement au XXIème siècle. Janvier 2000.

nearing $ billion 4000 in 1995 for the whole Mediterranean countries, 90% is provided by the 5 countries of the European community.

Such a situation reflects the very contrasted national investment capacities which make the poorest countries dependant from external donors. In addition, the behaviours of national investors are very different: In the southern and eastern countries private investments are very often oriented to shelters and construction industry or to foreign investment, while in the northern countries private investment are much more diversified and driven by market forces and economic opportunities.

To be completed

E. Desertification[17]

Desertification is opposing a major constraint to development efforts within the considered countries, in particular when natural resources are concerned. Indeed, within the sub-region, the primary economic activities consist of the exploitation of terrestrial natural resources accessible to rural populations (soil, water, vegetation, fauna) through the practice of agriculture and livestock activities, fishing, etc.. These activities are run within a range of production systems which are more or less complex.

As all systems, a production system can be defined as a totality of linked elements that compete to a common goal which is, in the present case, rural production. These elements are:

The ecosystem or the natural milieu which is characterised by factors that do not change, **unless at human life scale**, that could be qualified as "non evolving factors" like climate factors, geology, pedology, etc.., and which govern natural milieu production and energy potential as well as its stability.

The human element that exploits the ecosystem resources to meet his basic needs, and who is characterised by factors tending to change such as demography, consumption pattern, know-how and technology, etc.., that could be qualified as "evolving factors".

The institutional framework which comprises policies, development strategies, rules and institutions, pricing policies, etc.., that govern the behaviour of the human component within his milieu, while competing to the production process.

To these elements could be added a fourth one, that is the international environment which, under some conditions, could have an opposing or a synergyzing effect on the production process.

That being, a given production system that enable one community to meet its basic needs and which is in balance with its environment at a given period, will be inevitably in contradiction with this environment at a later period if some adaptations are not undertaken. This could be explained by the unavoidable imbalance that develops between the non **evolving factors** of the milieu and the **evolving ones** of the human element. Indeed, in **the absence of**

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[17] The United Nations Convention to Combat Desertification (UNCCD) defines desertification as "land degradation in arid, semi-arid, and dry subhumid areas resulting from various factors, including climatic variations and human activities" (United Nations, 1994). Furthermore, UNCCD defines land degradation as a "reduction or loss, in arid, semi-arid, and dry subhumid areas, of the biological or economic productivity and complexity of rain-fed cropland, irrigated cropland, or range, pasture, forest, and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns, such as: (i) soil erosion caused by wind and/or water; (ii) deterioration of the physical, chemical, and biological or economic properties of soil; and (iii) long-term loss of natural vegetation."

adjustments the production system reaches a lower energy balance than the initial one, leading to a loss of bio-mass productivity.

In such a case desertification occurs and affects livelihood of rural population in arid and dry sub humid areas of the sub-region. It appears as the expression of an imbalance between factors at stake within the agro-ecosystem i.e the natural milieu factors, human factors (socio-economic) and institutional ones. It is therefore a dynamic process where, from a given degradation threshold, causes feed effects and effects develop into causes to worsen and amplify desertification process.

In the sub-region, local climate variability and irregularity, which is the corollary of drought like conditions or even drought, is a major factor contributing to desertification process beside anthropogenic factors such as inappropriate natural resources use/management, etc.. However, generally this two factors are in synergy to produce the most adverse effects.

Presently such a situation is and will be more aggravated because it is established, not without certain uncertainty, that climate is changing, which will increase the weight of climate variability within the "equation". Indeed, climate change and desertification remain inextricably linked through feedback between land degradation and precipitation. Climate change might exacerbate desertification through alteration of spatial and temporal patterns in temperature, rainfall, winds, etc.. Conversely, desertification aggravates carbon dioxide emission through the release of CO_2 from cleared and dead vegetation and reduction of the carbon sequestration potential of decertified land. Although the relative importance of climatic and anthropogenic factors in causing desertification remains unresolved, evidence shows that certain arid, semi-arid, and dry sub-humid areas have experienced declines in rainfall, resulting in decreases in soil fertility and agricultural, livestock, forest, and rangeland production. Ultimately, these adverse impacts lead to socio-economic and political instability.

3.2.1. Wetland types and their main characteristics[18] and functions

Wetlands within this sub-region extend from Tunisia to Morocco. The main environmental factors explaining the distribution of the wetlands are: climate, topography and geology and, into some extent, tides.

The main geomorphologic formations containing wetlands are: endorheic drainage basins, coastal lagoons and, into some extend, riverine floodplains. The sub-region contains many other wetlands of lesser importance which are determined by particular geomorphologic formations and, in some rare cases, by inter-tidal systems.

As mentioned above, wetlands are considered within this paper according to their geo-morphological distribution which, in our view, reflect likely the biophysical and socio-economic factors of the sub-region. In this regard four main wetlands groups or types are defined beside all the other various wetlands.

It is to be noted that the main feature of North African wetlands is that:

i) There is very few national works done on wetlands, except for a limited number of wetlands of international which have been placed under international conventions;

ii) There is no systematic updated inventories of wetlands which take into account all anthropoid interventions during the last decades.

F. Coastal wetlands

[18] This chapter is largely based on the compilation of information provided within four main publications which are: (a) Wetlands of the word I – DF wingham et al. by Britton and Crivelli, 1993. - (b) A directory of African wetlands by R.H Hughes and J.S. Hughes , IUCN/UNEP/WCMC, 1992. – (c) Biological conservation nr. 83 and161 Ed. by Eric Duffey. 1982.

Coastal wetlands in the sub-region comprises a large varieties of wetlands of more or less importance which includes coastal lagoons, river deltas, vegetated sebkhets and many other wetland types of much lesser importance such as seasonal mesohaline wetlands, permanent mixohaline wetlands, etc.. The general common feature of the coastal wetlands is that they are located in heavily populated regions where the average demographic densities are higher than the national averages.

Coastal lagoons:

These occur all around the Mediterranean and along the Atlantic coast of Morocco wherever there are extensive coastal plains.

Lagoons were formed by the processes of coastal sedimentation and dune formation and some occur on former marine terraces now lying above sea level. All of them have open connections to the sea and have a salinity similar to that of seawater. Brackish water lagoons occur where there is only limited communication with the open sea, and where there is some input of freshwater. The salinity of these lagoons varies seasonally according to the relative inputs of sea water and freshwater (Halk el Menzel in Tunisia, Merga Zerga in Morocco).

Natural hypersaline lagoons are now rare as most of them have been converted to salinas, but seasonally flooded lagoons (Sebkhets), which become highly saline before drying out are frequent along the coasts of Tunisia and Morocco Commercial salines are a characteristic and widespread form of man-modified coastal lagoon are frequent within Tunisian Eastern coast.

River deltas:

No large examples of river delta occur in the Maghreb sub-region, where most rivers are short, highly seasonal, and do not provide sufficient sediment for delta formation. The delta of Oued Medjerda in Tunisia remain the unique example worth to mention.

Regarding its main functions, there are multiple including:

Fish production within the lagoon (4,500 ha);

Provision of habitat for rodents, snakes, wintering and migrating waterfowl, supporting large number of ducks and sandpipers;

Vegetated sebkhets:

These comprise a group of shallow mixohaline waterbodies in which the salinity mar range higher for shorter periods in summer prior to seasonally drying out.They have clay/silt or sandy bottom and the salinity is low enough to allow several macrophyte species. This type of site is found only in Morocco and is represented by the Wetland complex of Sidi Moussa comprising 3 sites grades of international importance[19], and Sebkhet Zima.

G. Endorheic wetlands

Endorheic wetlands in the sub-region comprises chotts and sebkhets which are also designated by the terme “Athalassic salt lakes”[20] to describe saline waters which are isolated from the sea, or which were once connected to the sea, but which have dried out before being re-flooded by water of nonmarine origin. As a wetland type, they are restricted to more arid areas, particularly to the Maghreb, where the annual rainfall is less than 400 mm.

Most of the North African chotts and sebkhets are natural and occupy endorheic drainage basins of tectonic origin but some have periodic outflow at times of extreme high water level.

[19] According to Morgan & Boy (1982) Quoted in Biological conservation nr. 161 Ed. by Eric Duffey. 1982.

[20] Williams, 1981 Quoted by Britton and Crivelli, 1993 in Wetlands of the word I – DF wingham et al.

They vary from sites lying below present sea level (Chott Melrir, Algeria at -30 m and Chott Djerid, Tunisia at -28 m) to upland basins at over 1,000 m (e.g. Plain of Chotts, Algeria in the High plateaux of the Saharian Atlas). There is evidence that many of the basins now occupied by salt lakes in North Africa were once extensive freshwater lakes when the climate was much more humid than at present[21].

However, some of these salt lakes appear to result from anthropoid activities. Indeed they seem to be used as irrigated land during the Roman period and had been abandoned following soil degradation subsequent to excess of salinity resulting from water quality, lack of drainage and the rise of saline water table in particular in coastal plains (Example of Garaât Oued Maleh in Monastir, Tunisia). Other salt lakes seem to result from the unbalance between the charge and the discharge of the local water table following to deforestation and cropping of large surrounding hills during the ancient periods (likely the Roman period), which led to water table rise and drainage to the lowest land.

All of the chotts and sebkhets are shallow and at least occasionally dry out completely. The periodicity of flooding depends both on the climate and on the ratio of the area of the catchment to the area of the lake. In general, there is a north to south gradient in flooding regime. In the extreme north of Tunisia and Algeria salt lakes are typically seasonal and dry out in summer and reflood in most winters. Further south in North Africa, salt lakes are mostly irregularly flooded and may remain dry for several years. Following rainfalls, they may hold water for weeks, months or even years[22].

Tree main types of wetlands could distinguished:

Chotts:

They consist of a series of large swallow depressions stretching east-west along the northern extremity of the Sahara were lakes during the Pleistocene [23] and in some cases are below the sea level. They are characterized by a uniform clay/silt or sand substrate, irregular water supply both in space and time, frequently being without water for several years, a high ration evaporation/rainfall (>8) and a high salinity reaching saturation during dry out.

Unvegetated sebkets:

The unvegetated sebkhet lie to the north of the arid zone of the chotts. They are concentrated in the central part of Tunisia and in the plateau to the south of Constantine in Algeria. They form a shallow pans with clay/silt bottom and are seasonal with eu-hyperhaline water conditions. They mostly dry out in June to October but the estern sebkhets may hold water for periods up to two years.

Vegetated sebkhets:

Their distribution is similar to vegetated sebkhets and they have similar physical characteristics to the chotts and unvegetated sebkhets, being shallow, seldom exceeding 1 m in water depth and clay/silt or sandy substrate. They are much smaller in area and seasonal with the easterly sites holding water for longer periods and may dry for up two months between January and March with maximum frequency of dryness between July and September.

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[21] Hutchinson 1957 Quoted by Britton and Crivelli, 1993 in Wetlands of the word I – DF wingham et al.

[22] Amat 1982, Morgan and Boy 1982 Quoted by Britton and Crivelli, 1993 in Wetlands of the word I – DF wingham et al.

[23] Hutchinson, 1957 Quoted in Biological concervation Nr. 83.

H. Riverine floodplains

Because of the highly seasonal nature of North African rivers plains and the narrowness of coastal plains, riverine flood plains are very rare. This type of wetlands is represented only by the :

The flood plain of river Lokkos in Morocco (Marais Bas Lokkos);

The Garaet Ichkeul wetland in northern Tunisia which is of international importance and which is also considered as freshwater or a oligohaline lake. It drains several small rivers which have been dammed.

I. Tidal wetlands

These wetlands have a very restricted distribution because of the low tidal range. They are rather localized along the Atlantic coasts and occur in river estuaries, or in sheltered bays. Tidal systems occurring within the sub-region are of two classes :

Permanently flooded estuaries of variable salinity which occur in Morocco on the Ocean coast. In these wetlands, freshwater input is seasonal, the rivers dry in summer, and there is only a limited development of salt marsh vegetation. In extreme cases, (e.g. in the extreme south of the Morocco), the estuary is a relict from a period of more humid climate, and the river now flows only irregularly. At this site the upper marsh is replaced by an unvegetated salt pan (sebkhet). Because of the seasonality of rivers in Morocco there is a tendency for tidal inlets to become blocked by a sand bar at times of low discharge. Such systems then develop into seasonally flooded saline coastal lagoons until another river flood once more makes a breach in the sand bar.

Unvegetated sand and mud flats, exposed at low tide: The unique example of such wetland is the Gulf Gabès in Tunisia where Tidal wetland occurs at the head of shallow, gently shelving bays. The extent of salt marsh is rather limited, and it appears that Spartina dominated salt marsh is absent.

J. Fresh water lakes

In North Africa, permanent freshwater lakes have always been scarce outside of the sub-humid mountainous areas, and the largest examples have now been drained (e.g. Lake Fetzara, Algeria). Indeed, freshwater lakes are all in high altitude above 1000 m and are located mostly on the high Atlas mountains in Morocco and to some extend in the Kabylie district of Algeria.

The only large lowland freshwater lakes that remain, either dry out periodically or are in coastal areas and receive some inflow of saline water in periods of drought. Garaet Ichkeul in Tunisia receives water from the marine Gulf of Bizerte when freshwater inflow ceases in the summer, and it then becomes oligo to mesohaline. A similar situation was found in the complex of Lakes Oubeira, Melah, and Tonga in Algeria[24] but return flow of saline water is now prevented by sluices.

Lac Kelbia in Tunisia use to be a freshwater lake few decades ago before incoming freshwater flows from 3 important Oueds have been dammed for flood protection of Kairouan plain. Presently it is reduced to a permanent meso to hypersaline lake of no more than 2 Km_ area because of very limited and controlled periodic flows from the dams.

[24] Skinner and Smart 1984, Stevenson et al. 1988, Guelorget et al. 1989. Quoted in by Britton and Crivelli, 1993 in Wetlands of the word I – DF wingham et al.

K. Other wetlands

Man-made reservoirs

The insatiable demand for freshwater in the semi-arid climate of the Mediterranean countries has led to the building of so many water storage reservoirs and dams that their number and area far exceeds all the remaining natural freshwater wetlands. Moreover, construction of new reservoirs is continuing, particularly in the Maghreb. For instance, in Tunisia, most of the feasible dam sites on the major rivers have been constructed or are under way. In addition, the present freshwater mobilization strategy is moving towards the implementation of a large programme for the creation of more than one thousand water small hilly lakes behind dikes of a storage capacity not exceeding 50.000 cubic meters, as well as the construction of small dams (< 300.000 cubic meters).

Reservoirs, in general, have deleterious effects on downstream wetlands, as a result of flow regulation with reduced flooding and sediment deposition which is required for the development of coastal wetland systems. On the other hand, some reservoirs have themselves developed into wetland systems of considerable wildlife value or have been developed into fisheries. Reservoir has introduced permanent standing water into arid landscapes where none existed before and some such man-made lakes are much used by migratory waterfowl. To some extent reservoirs have replaced natural freshwater wetlands, as feeding and roosting sites for these birds. In North Africa, The Boughzoud lake in Algeria is of international importance for waterfowl, thus compensating in part for the loss of most of natural permanent freshwater lakes in the Maghreb[25]. In general, however, most reservoirs in the Mediterranean have been constructed in upland areas and have steep shorelines, are subject to severe draw down on a seasonal or even diurnal basis, and of very little wildlife value.

3.2.2. Wetland use and management problems in North Africa

As underlined above, very few national works have been done on wetlands, except for a limited number of them of international importance which have been placed under international conventions (Ramsar Convention, etc.), and there is no systematic updated inventories of wetlands as most of the available information are out of date. However, one could find out that :

Most of wetland are not protected, nor managed;.

Most valuable wetlands have been managed/drained for agriculture development or are very much impacted by national water management schemes and programmes.

Short and medium term socio-economic development concerns were and still prevailing on sustainability and environment issues, leading to an increasing anthropoid pressure on freshwater resources as well as on coastal ecosystems and wetlands.

3.2.3. Conclusion

A quick checking of north African wetlands shows that two main families of wetlands could be distinguished according their functions:

The first family is the one including wetlands having various functions and particularly the productive function (mainly fishing). This family includes most of coastal wetlands such as coastal lagoons and sebkhets, freshwater wetlands and human made reservoirs;

The second family is the one having other functions than the productive one, mainly ecological and or scientific functions. This family include all endorheic wetlands i.e chotts and sebkhets.

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[25] Chalibi 1990 - Quoted by Britton and Crivelli, 1993 in Wetlands of the word I – DF wingham et al.

Such a classification is very helpful fir the assessment of climate change effects as well as for the understanding of environmental policies within the considered countries, in particular with regard to wetlands issues.

4. EFFECTS OF CLIMATE CHANGE ON WETLANDS

Because of their dependence from water resources, wetlands are very prone to climate change effects and consequences which may be induced by the GHG forcing, in particular within the Mediterranean region where water resources are posing a major problem in many countries. According to the IPCC TAR, the amplitudes and time frames of such a change remain affected by uncertainties, there are still difficult to quantify and could not be estimated under a defined probability. However, for the Mediterranean region, there is a consensus about the presumption of a greater contrast of the climate:

In the South, the risk of a more arid climate may not be excluded, which could have a double effect during the XXI century : Decrease of water resources and increase of water requirements/needs through increase of evaporation, aggravating droughts, which could lead to increasing pressure on water, both as a resource and as an environment, and to feeding various degradation processes and desertification;

In the North, climate will be more contrasted, more rainy in winter and dryer and more irregular in summer, which would have consequences on water regimes and emphasises water requirements in summer.

In both cases climate change will affect wetlands. Thus, on the basis of the climate change scenarios summarised above and the existing literature, the following paragraphs will give a tentative assessment of biophysical and socio-economic effects of climate change on North African wetlands.

4.1. BIOPHYSICAL EFFECTS

North African wetlands experienced and are still experiencing either intensive anthropoid interventions and pressure or simply the lack or absence of interventions. Depending on the wetland type, biophysical effects will result from :

Combined or interactive impacts of various anthropoid pressures on water resources and climate change: This is the case of most valuable wetlands providing goods and services for population such as coastal lagoons, deltaic wetlands, freshwater lakes, etc.;

The climate change itself which is partly induced by anthropoid pressures and activities: This is the case of wetlands of limited functions such as chotts and sebkhets.

Thus, in any case the biophysical effects on wetlands will be the result from the (i) effects on hydrology and water resources, and (ii) the effects on coastal zones and marine ecosystems. , which will have various implication on wetlands.

4.1.1. Effects on Hydrology and water resources

Potential effects of climate change on the components of water balance and their variability over time will result from the interactive effects of the rise of surface temperature and the decrease in precipitation. In fact, the projected increase in surface temperature and the decrease in precipitation mean:

A general increase in evaporation from the land surface including evaporation from open water, soil, shallow groundwater, and water stored on vegetation, along with transpiration through plants;

An increased biological activity within natural and humanised ecosystems (agro-systems) which will likely induce an increase in water resources demand, in particular in arid and dry sub-humid areas of the sub-region, leading to more frequent stress of natural vegetation and crops;

That a smaller proportion of precipitation may fall as snow. In the sub-region where snowfall are currently confined to limited areas, snow may cease to occur, with consequent, very significant, implications for hydrological regimes of tributary rivers leading to more frequent or more violent floods.

River flows will be significantly reduced : In fact, River flows in arid and dry sub-humid semi-arid areas of the sub-region are very sensitive to changes in rainfall: A given percentage change in rainfall can produce a considerably larger percentage change in runoff and probably in groundwater recharge and resources. There have been relatively no studies in the sub-region but, according to the TAR[26], change in average annual runoff by 2050 will range between 0 and –25 mm y^{-1} in semi-arid areas and between –50 and -150 mm y^{-1} in dry sub-humid areas.

Changes in hydrological drought frequency which may occur consequently to rainfall deficits, soil moisture deficits, lack of flow in rivers, low groundwater levels, or low reservoir levels.

Indeed, the national communications to the UNFCCC stressed clearly such effects, in particular in Morocco and Algeria. The Morocco communication stated that in the year 2020:

Surface and groundwater resources will experience an average decrease comprised between 10 and 15% on the whole national territory relative to 1998-2000 figures;

Freshwater requirements estimated at 15,4 billion cubic meters will be increased by 0,8 billion cubic meters due to warming, of which 75% are for agriculture at 20% for other uses (industrial and domestic).

Seasonal precipitation's will be more disturbed, leading to the decrease of freshwater potential that could mobilised through dams.

The decrease of the number of snowing days in high altitude which will significantly affect rivers regimes and flows.

4.1.2. Effects on coastal and marine ecosystems

Potential effects of climate change on coastal wetlands over time will result from the interactive effects of sea level rise, warming, and decrease in precipitation. The magnitude of these effects will depend on local conditions such as geomorphology as well as on anthropoid activities and the degree of humanisation of wetlands. According to the TAR, an estimate by Nicholls et al. (1999) suggests that by the 2080s, sea-level rise could cause the loss of as much as 22% of the world's coastal wetlands.

Given the nature of the North African Mediterranean coast and the geographical extend/distribution of coastal plains, most wetlands which are likely to be potentially affected or impacted are those of the eastern coast which is located in Tunisia. Indeed, the Tunisian national communication to the UNFCC devoted a special study on the vulnerability to sea level rise resulting from climate change. This study find out that most of coastal wetlands will be significantly impacted. Effects of sea level rise will appear through:

- Increased shoreline erosion on several locations i.e the Gulf of Tunis, the Gulf of Gabès;

[26] Work has been done in southern Africa (Schulze, 1997), Australia (Bates et al., 1996), northern China (Ying and Huang, 1996), and southern Russia (Georgiyevsky et al., 1996; Shiklomanov, 1998).

- Seawater intrusion to the main freshwater lake within the sub-region, the Garaet of Ichkeul, leading to the extending of the lake on freshwater marshes and the migration of freshwater marshes upland on agricultural land;
- Reduction of islands areas and the eventual disappearance of the smallest ones ;
- The formation of new lagoons on former salt marshes and coastal sebkhets such as sebkhet Ariana, Sebkhet El Maleh, etc.;
- The annexation of several lagoons to the sea domain, in particular within the Medjerda delta;
- The reduction of agricultural land within coastal plains around the Mejerda delta.

The magnitude and severity of such effects will depend on the considered climate change scenario.

4.1.3. Implications of climate change impacts on water resources and coastal/marine ecosystems for wetlands

Biophysical implications of climate change for wetlands are be summarised in the following tables.

Table n°8: Summary of the Biophysical impacts of climate change in North Africa and their implications for wetlands

<table>
<tr><th colspan="2" rowspan="2">Wetland type</th><th colspan="3">Climate change</th></tr>
<tr><th>Rise of surface temperature</th><th>Decrease in precipitation</th><th>Rise of sea level</th></tr>
<tr><td rowspan="2">River delta</td><td>Socio-economic Impacts</td><td colspan="2">▪ Decrease in fresh water inflows leading to the unbalance of the discharge between freshwater and seawater and the intrusion of sea water into the delta which means :
- Partial or total drying of freshwater marshes;
- Enlargement of existing salt marshes;
- Change in water quality as water will be more saline in the wetlands;
- Decrease of sediments inflows in the delta which could feed coastal dune erosion;</td><td>▪ Increased coastal erosion;
▪ Rise of saline shallow groundwater table and increase of water logging in the neighbouring cultivated areas;
▪ Seawater intrusion into freshwater aquifers;
▪ Inhibition of primary production processes on areas flooded by seawater;
▪ Extending of grassland and scrub ;
▪ Lagoons becomes an integral part of the sea;</td></tr>
<tr><td>Effects wetlands</td><td colspan="3">▪ Disturbance of biodiversity within the lagoons leading to the loss of their specific biodiversity as decrease of their productivity (fishing);
▪ Disturbance of flora distribution and habitat for fauna (Rodents, birds and reptiles) together with a decrease of the carrying capacity of the wetlands.</td></tr>
<tr><td rowspan="2">Coastal lagoons and sebkhets</td><td>Socio-economic</td><td colspan="2">▪ Decrease in fresh water inflows;
▪ Increase of evaporation;
▪ Change of water quality : increase of salinity;
▪ Decrease of salt marshes;
▪ Increase of biological activity and biodoversity as a consequence of warming.</td><td>▪ Extending of salt marshes; Lagoons will be integrated part of the sea;
▪ Increase of flood frequency in sebkhets and some sebkhets will become lagoons;
▪ Disturbance of the habitat;</td></tr>
<tr><td>Effects wetlands</td><td colspan="3">▪ Loss of specific biodiversity of lagoons leading to a decrease of their productivity (fishing) which could be balanced by the formation of new lagoons on salt marshes and sebkhets.
▪ Barren areas in vegetated sebkhets will extend and most of their vegetal cover will disappear leading to a disturbance of habitat for mammals and reptiles. This effect is likely to be balanced by a limited development of aquatic biodiversity.</td></tr>
<tr><td>Tidal wetlands</td><td>Socio-economic</td><td colspan="2">▪ Increase of biological activity and biodoversity as a consequence of warming.</td><td>▪ Mud flats will be affected by organic and inorganic sediments;
▪ Salt marshes will tend to became lagoons;
▪ Increased vulnerability of landward side to storm waves;</td></tr>
</table>

	Effects wetlands	▪ **Decrease of productivity of wetlands subsequent to increase of biodiversity;**	
Endorheic wetlands: Chotts and sebkhets	Socio-economic	▪ Increase of evaporation as well as soil salinity at wetland shores; ▪ More frequent dry out; ▪ Change of water quality as salinity will increase; ▪ Going down of shallow water table;	
	Effects wetlands	▪ **Change in water quality of wetlands;** ▪ **Extending of mesohaline vegetation on wetland shores ;** ▪ **Increase of habitat for mammals and terrestrial fauna;** ▪ **Decrease of the carrying capacity of wetlands for migrating and wintering birds;**	
Riverine flood plans	Socio-economic	▪ Increase of evaporation and decrease in fresh water inflows; ▪ Reduction of flood periods as well as flooded areas; ▪ Partial or total drying of freshwater marshes on elevated areas and shores ; ▪ Disturbance of habitat for migrating and wintering birds together with a limitation of the carrying capacity of the wetlands.	
	Effects wetlands	▪ **Disturbance of flora distribution and habitat for fauna (Rodents, birds and reptiles) together with a decrease of the carrying capacity of the wetlands.**	
Fresh water lakes	Socio-economic	▪ Increase of evaporation; ▪ Potential increase of biological activity and biodoversity as a consequence of warming. ▪ Decrease in fresh water inflows in lowlands and disappearance of small lakes; ▪ Increase of in fresh water inflows in highlands.	
	Effects wetlands	▪ **No significant impact.**	

Man-made water reservoirs	Socio-economic	▪ Increase of evaporation; ▪ Increase of biological activity and biodoversity as a consequence of warming.	▪ Decrease in fresh water inflows;	
	Effects wetlands	**▪ Possible change in water quality which will become more saline;** **▪ Potential development of such reservoir into valuable wetlands.**		

4.2. SOCIO-ECONOMIC EFFECTS

Given the specific problems characterising the Maghreb countries in particular with regard to aridity and water resources scarcity, the relative reliance of livelihood on natural resources and subsequent desertification hazards, the weight of demography pressure and the subsequent relative precariousness of their socio-economic settings, climate change will likely have various adverse socio-economic impacts which, in turn, would affect wetlands.

In order to appreciate the effects of socio-economic impacts of climate change on wetlands, one should first attempt to figure out "what are the socio-economic impacts of climate change" and then identify their possible implications for wetlands.

4.2.1. Socio-economic impacts of climate change

According to the IPCC WGII TAR, numerous Earth systems that sustain human societies are sensitive to climate and will be impacted by changes in climate.

Impacts can be expected in sea level, the water cycle, the productivity and structure of natural ecosystems, the productivity of agricultural, grazing, and timber lands, and the geographic distribution, behaviour, abundance, and survival of plant and animal species, including vectors and hosts of human disease. Changes in these systems in response to climate change, as well as direct effects of climate change on humans, will appear in biophysical effects (See § 4.2.) which would impact socio-economic welfare, positively and negatively through:

Changes in supplies of and demands for water, food, energy, and other tangible goods that are derived from these systems;

Changes in opportunities for non consumptive uses of the environment for recreation and tourism;

Changes in non-use values of the environment such as cultural and preservation values;

Changes in incomes;

Changes in loss of property and lives from extreme climate phenomena; and changes in human health.

On the other hand, potential impacts of climate change on socio-economic welfare are also depending on non climatic changes driven by the socio-economic factors (demography, land use, etc.) and environmental/institutional context within which climate forcing will operate, as the latter's could influence :

The ***sensitivity*** of the system or the degree to which it is affected;

Its *adaptive capacity* to adjust to climate change, and

Its vulnerability or its ability to cope with adverse effects of climate change, including climate variability and extremes.

Natural and human systems are expected to be exposed to climatic variations such as changes in the average, range, and variability of temperature and precipitation, etc., and would be also exposed to indirect effects from climate change such as sea-level rise, soil moisture changes, changes in land and water condition, etc.. The sensitivity of a system to these exposures depends on its characteristics and includes the potential for adverse and beneficial effects. The potential for a system to sustain adverse impacts is moderated by adaptive capacity. The capacity to adapt human management of systems is determined by access to resources, information and technology, the skill and knowledge to use them, and the stability and effectiveness of cultural, economic, social, and governance institutions that facilitate or constrain how human systems respond.

Thus, the evaluation of socio-economic impacts of climate change don't make sense unless it is done a coherent, internally consistent, and plausible description of a possible future situation, or a scenario. In addition, while it is recognised that some progress has been made in evaluating potential socio-economic impacts of climate change, this progress, however, has not been as substantial as that relating to biophysical impacts, in particular with regard to sea level rise due to climate change on coastal and marine systems.

Given the complexity of the situation, the lack of specific references on the subject within the sub-region, socio-economic impacts of climate change are to be roughly appreciated on the basis of the scenarios constructed for the 21st century[27] (SRES, stabilisation) scenarios) to assess the global impact of climate change on five sectors i.e Socio-economic/technological, land cover and land use change, environmental, climate and sea level.

4.2.2. Implications of socio-economic impacts of climate change for wetlands

Socio-economic impacts of climate change are likely to impact indirectly wetlands mainly through:

An increased pressure on freshwater available resources which is induced by an increased social demand of water for domestic use and food production leading to an increase in freshwater withdrawals at the expense of natural systems. Such an effect is almost unavoidable within the context of the sub-region where water resources is a major stake;

The burden put by socio-economic impacts of sea level rise the alleviation/mitigation of which will generate a major social cost within a context of a limited socio-economic development and resources, in particular in the case of Tunisia, which may lead to a low ranking priority for some environmental issues.

Table 9 summarise the major socio-economic impacts of climate change and their implications for wetlands.

[27] Climate change 2001. IPCC WG II, TAR – § 3.8 Developping and applying scenarios, p. 175.

Table n°9: Summary of the socio-economic impacts of climate change in North Africa and their effects on wetlands

Sector		Climate change		
		Rise of surface temperature	Decrease in precipitation	Rise of sea level[28]
Socio-economic / technological	Socio-economic Impacts	1. Population: 2. GDP/GDP/per capita: 3. Water use: ▪ Decrease of rangland productivity (Algeria)[29]; ▪ General decrease of freshwater water resources (10-15%) by 2020 (Morocco)[30]; ▪ Decrease of crop yields (wheat) between 10 to 50% according to the climatic conditions of the year by 2020 leading to a food deficit of 6 millions Tonnes in 2020 (Morocco); ▪ 5-30% decrease of areas equipped for irrigation[31] by 2025. ▪ Decrease of freshwater availability from an average of 1000 m^3/inhabitant in 1995 to less than 500 m^3 after 2025 (Tunisia)[32]. ▪ Increase of drought hazards leading to the aggravation of the desertification processes. 4. Trade and liberalisation: 5. Yield technology: 6. Flood protection:		▪ Severe negative impact on tourism as 90% of tourism infrastructures are located on the coast; ▪ Disturbance of sewage water discharge systems for the city of Tunis; ▪ Potential negative impact on fishing infrastructures i.e. small harbours; ▪ Negative impact on traditional coastal fisheries in Kerkenna islands;; ▪ Loss of agricultural land in the coastal plains around the Mejerda delta as well as upland of Garaet Ichkeul (1160 ha); ▪ Negative impact on freshwater supply in the coastal areas because of seawater intrusion into freshwater aquifers; ▪ Loss of agricultural land pursuant to flood;

[28] The impacts listed under this heading refer to the Tunisian initial national communication to UNFCCC – 2001.
[29] Algeria initial National Communication to the UNFCC. 2001
[30] Morocco initial National Communication to the UNFCCC. 2001
[31] Climate change 2001; IPCC WGII – TAR. § 4. Hydrology and water resources p. 212.
[32] Tunisia initial National Communication to the UNFCCC; 2001.

	Effects on wetlands	▪ **Increased anthropoid pressure on major productive coastal wetlands (lagoons) and fisheries subsequent to the change in biodiversity composition (due to warming and sea level rise) will lead to a decrease of wetland productivity. These effects would be partially balanced by the formation of new productive lagoons on coastal sebkhets;** ▪ **Increased freshwater demand for domestic use and agriculture will aggravate water resources problems leading to more pressure on freshwater and its diversion through dams at the expense of natural systems and wetlands. Nevertheless, there is a potential to develop artificial water reservoir into valuable wetlands which could balance partially the assumed degradation of natural wetlands.** ▪ **The magnitude of sea level rise impacts on various coastal infrastructures, in particular in Tunisia, will be a major concern with regard to social costs involved as to cope with such impacts and will burden socio-economic development efforts putting some environmental issues, such as wetlands, on second priority in terms of development policy.** ▪ **The magnitude of Desertification processes in all North African counties will be a major concern with regard to social costs involved as to cope with drought and desertification effects and will burden socio-economic development efforts putting some environmental issues, such as wetlands, on second priority in terms of development policy.**

5. ADAPTATION STRATEGIES

5.1. GENERAL

Within the sub-region, Wetlands, just like any other natural systems or ecosystems, have been more or less humanised depending on their productivity, even those protected under international conventions or erected into national parks and/or reserves, which have been deeply disturbed in the past before such a protection, and most of them have an energy balance very much lower than the natural or climax one. In addition, the geographical extend of these natural ecosystems is generally very limited to allow autonomous natural development/evolving in order to reach a sustainable balance.

On the other hand, the anthpogenic pressure on natural resources and the increasing social needs subsequent to population increase, are such that there are serious constraints as to set apart natural systems and/or to maintain the existing/remaining "natural" ecosystems on a sustainable basis.

Lastly, we are presently living within an organised and more or less institutionalised environment at various levels (international, regional, sub-regional, national, etc..) where almost all activities and issues (such as natural resources, land use, human settlements, health, trade, etc..) are erected/run by an arsenal of "tools" including rules, laws/regulations, policies/strategies and institutions, which are provided to cope with the prevailing environment as well as with particular circumstances and to insure equity, durability, etc., through a continuous or a dynamic process of learning and adaptation of the said "tools".

Now regarding natural systems conservation, including wetlands, the brief analysis presented in § 3.2.1. E regarding desertification remains valid, meaning some minor adaptations. Indeed, similarly to other ecosystems, wetlands are more or less taped for their goods and services to meet social needs. There are an integral part of a global system including:

i) Natural and humanised ecosystems;

The human element;

The institutional framework at national, regional and local levels;

The international environment including international conventions, regional conventions (Barcelone 1995) and international co-operation.

However wetlands, more than other natural ecosystems and agro-sytems, have the particularity to be more integrated to world ecosystem or the Biosphere because of their common base as for coastal wetlands, their utility for migrating birds and, of course, for their contribution to world biodiversity.

Thus, a given wetland which is in balance with its environment at a given period, will be inevitably in contradiction with this environment at a later period if some **adaptations** are not undertaken. This is due to the unavoidable imbalance that develops between the non **evolving factors** of the milieu and the **evolving ones** of the human element. And, in **the absence of adaptations and adjustments** the wetland reaches a lower energy balance than the initial one, leading to a loss or a decrease of goods and services (bio-mass productivity, biodiversity, carbon sink, etc.,).

Adaptations mean primary all integrated adjusting measures on the institutional framework at national levels in order to adjust the relationship between the human element and the regarded ecosystem/agro-system towards:

The maintenance of an appropriate/comprehensive ecological balance of the system which take into account immediate human needs and the need to preserve natural resources productive base for future generations.

The restoration/safeguarding of degraded natural systems and the search for ways and means in position to increase their productivity without altering their integrity;

The provision of alternative livelihood opportunities for the human element as to alleviate anthropogenic pressure and avoid overtapping of natural resources ;

The provision of a bearing or an enabling environment in position to reduce social vulnerability to – and to cope with - extreme events such as drought, floods, storm waves, and other natural disaster which are known to be as a part of the considered environment;

Secondly, adaptations mean all integrated adjusting measures on the international environment in order to help within the preparation and the implementation of adjusting measures at national levels through financial co-operation, technology and know-how transfer, capacity building, monitoring and evaluation, etc..

In addition, adaptations are to be regarded as a global and perpetual "mechanism" provided to cope with all environment and development issues and not specifically for wetlands or desertification, etc. In this respect such a mechanism should be institutionalised. Finally, given the international/global character of environment issues, in particular wetlands issue, there is a tremendous need for an effective integration between the two sets of adaptations measures.

As far as the north African countries as concerned, very few progress have been done towards such adaptations since the ratification of the UNFCCC as most of actions undertaken to date didn't go above adaptation studies which have been implemented under specific projects.

5.2. BIOPHYSICAL ADAPTATION

Biophysical adaptations evoke all adjusting measures provided to allow alleviating, preventing or correcting the biophysical impacts of climate change on wetlands. While such adaptations shouldn't be considered separately from other adaptations, there is a need to point out the following fields of adaptations:

The improvement of the knowledge of wetlands in particular with respect to their functioning, functions, productivity and economic values, sensitivity/adaptive capacity/vulnerability to climate change;

The review of national strategies in connection with water resources mobilisation and management in the context of climate change. In this regard all water consuming sectors and activities are to be considered in particular agriculture which is using more than 80% of freshwater resources. In addition strategies should consider various aspects of water use : ecological, technological, economic/managerial, socio-cultural, health , etc.

The improvement or the review of national land use planning and management strategies as to integrate climate change considerations as well as sea level rise.

The implementation of such adaptation should involve co-operative programmes in the between national and regional scientific and research institutions, technological transfer programmes and exchange of experience between the Mediterranean countries.

In addition, these adaptations will not lead to the expected results if they aren't prepared and implemented within a global development policy which put climate change into the frame.

5.3. SOCIAL ADAPTATION

Social adaptations mean all adjusting measures that could to allow alleviating, preventing or correcting the socio-economic impacts of climate change that could impact negatively wetlands.

If we refer to the north African countries, the main socio-economic impacts of climate change that could impact wetlands (Cf. § 4.2.2.) are those affecting water resources and the social cost of sea level rise and desertification. In this respect, the required adaptations should be oriented to the development of an enabling environment which is in position to :

Allow the development of ways and means as to reduce sensitivity of the rural production systems to climate stimuli through the development of drought resistant crops/variety, improved irrigation techniques and appropriate cropping systems, etc.. This involve the development of various activities in the field of fundamental and applied research;

Allow the development of alternative livelihood opportunities for rural population which involve the strengthening of infrastructures, diversification of the economic settings, human resources development, etc.

Reduce social an economic vulnerability to extreme events such as drought, floods, storm waves, and other natural disaster;

As for biophysical adaptations, these adaptations will not lead to the expected results if they aren't prepared and implemented within a global development policy which put climate change as a full part of the frame.

6. MITIGATION OPTIONS

Climate change is a global and long-term problem, which involves complex interactions between climatic, environmental, economic, political, institutional, social and technological processes.

The assessment of the IPCC WG II (TAR) stated that climate change will produce adverse socio-economic impacts in Africa Region, while national communications of the considered countries on the subject stated more drastic impacts. At the same time, the IPCC WG III (TAR) pointed out that climate change mitigation will both be affected by, and have impacts on, broader socio-economic policies and trends, such as those relating to development, sustainability and equity[33].

Regarding climate change mitigation options, given the important weight of energy and transportation sectors GHG emissions in the considered countries, mitigation options have been based mostly on such activities as they reflect opportunities for energy efficiency improvements.

Nevertheless, within the sub-region, forests, agricultural lands, and other terrestrial ecosystem offer significant carbon mitigation potential, mainly through land use change and, into some extent, through afforestation and forest integrated management schemes. Indeed, the Tunisian national communication stressed such options which put into action Biological mitigation through :

Upgrading of the ecological or energetic balance of degraded agro-systems (land use change) which involves the change of cropping systems and patters (perennial ligneous crops instead of annual crops combined with livestock;

Sequestration by increasing the size of carbon pools and the development/improvement of management schemes.

Estimates of cost and benefits of these mitigation options revealed that they could be implemented at no or negative costs.

[33] Climate change 2001 - IPCC WG III – TAR. Spm.