PREFACE

Sustainable development in the already vulnerable MENA region faces serious challenges, among which is climate change. Though the MENA region is not a main contributor to Green House Gases' (GHG) emissions, the driver of climate change, it is projected that several vital sectors in the MENA region will be negatively impacted by climate change, which is a threat to the sustainability of its socio-economic development.

Water availability in the MENA region is predicted to be negatively impacted by climate change due to the projected reduction in rainfall and increased evapotranspiration as a consequence of temperature rise. In addition, domestic and agricultural demands will dramatically increase due to the projected temperature rise, which will enlarge the already existing gap between supply and demand in several MENA countries. It is important to note that the negative impacts on water resources will directly transfer to other sectors due to their strong mutual connectivity. These sectors are food security, health, ecology, environment, economy and social. Predicted sea level rise as a consequence of melting of the poles due to the forecasted temperature rise will result in land use change, which will in turn have severe social and economic consequences. Proper mitigation and adaptation options that take into consideration the multi-dimensional nature of the climate change impacts are a must to conserve these sectors and to sustain the socio-economic development in the MENA region.

This workshop in Amman, Jordan seeks to assemble professionals of multidisciplinary backgrounds and expertise over three days to present and to discuss their diverse experiences related to the possible climate change impacts, mitigation and adaptation options in the MENA region. This workshop is expected to strengthen the already existing professional connections among the EXCEED network partners in addition to establishing new professional connections with new participants from the region. The workshop intended to help the participants gain better understanding and share experiences related to climate change causes, impacts, mitigation measures and adaptation options. The newly gained knowledge and expertise will move downstream to the participants' students, research community and social community, which will help raise level of awareness about climate change and contribute to the adaptation efforts in the MENA region.

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WATER RESOURCES IN MOROCCO AS IMPACTED BY CLIMATE CHANGE

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Abstract

Global warming is currently well established. The average rate of warming over the last 50 years (0.13 ± 0.03 °C per decade) is nearly twofold higher than that recorded over the last 100 years. Changes in temperature and precipitations have impacted the hydrologic processes and water resources availability for agriculture, for water relying activities and for population. The change in intensity and frequency of precipitations is behind frequent floods observed in different regions. The potential of water resources that remain available in Morocco is estimated at 22 BCM (Billion m^3/yr.); 80% of it is provided by the north part of Morocco. The main part is provided as surface waters (16 BCM) regulated partly by 140 dams and 1,100 km pipes. In agriculture, the predicted increasing aridity will have negative effects on agricultural yields. Rain fed crops will be the most affected ones, such as cereals production accompanied by widespread land degradation, reduction of economic benefit, lower income of rural households, spread of poverty and increased rural to urban migration. The coastal zone in Morocco is also affected subsequent to accelerated sea level rise that leads to flooding, erosion of sandy beaches, and destruction of coastal wetlands. Water quality could be directly or indirectly affected through different biochemical processes. Furthermore, the specific effects will vary among different regions and types of water bodies. Different actions were taken at legislative and technical levels to cope with impact of climate change (CC). In agriculture, growers are encouraged to shift from traditional to drip by drip irrigation, to introduce resistant varieties of crops, to conduct direct seeding, to improve of storage capacity while building more big dams, protecting against flooding, transferring of raw water resources in the basins of the North to the South, desalinizing sea water. At institutional level, different national and international actions are taken.

1 Introduction

Global warming is currently well established. The average rate of warming over the last 50 years (0.13 ± 0.03 °C per decade) is nearly twofold higher than that recorded over the last 100 years. Changes observed include long-term changes in the surface temperature, precipitations, wind patterns, radiation, and other extreme weather events, such as droughts, floods, and heat waves.

Mediterranean and MENA region countries are among the most threatened ones by water stress [1], mainly areas, where water availability is a limiting factor for economic development as in the Mediterranean Basin, either for developed or for developing countries [2].

According to Intergovernmental Panel on Climate Change (IPCC), climate scenarios for Morocco reveals a trend towards an increase in average annual temperature (between 0.6 °C and 1.1 °C) as well as a decrease in average annual rainfall volume by about 4% in 2020 compared with 2000 levels [6]. Morocco is dominated by four types of climate: humid, sub-humid, semi-arid and arid. Indeed, studies using tree-ring analysis showed that from the 14^{th} to the 20^{th} century, 147 drought periods averaging 22 dry years per century [4-6]. Other studies reported that Morocco has experienced 49 major drought-related famines from 9^{th} century to early 1900s [7]. In the last 30 years, on average, drought occurs in Morocco every 3 years, representing the main constraint on expansion of the agriculture. The drought has considerable negative impacts on the crop production, reduction in GDP, and loss to livelihood. Table 1a and 1b show the number of occurrence of drought, the interval of the occurrences and the recent drought events

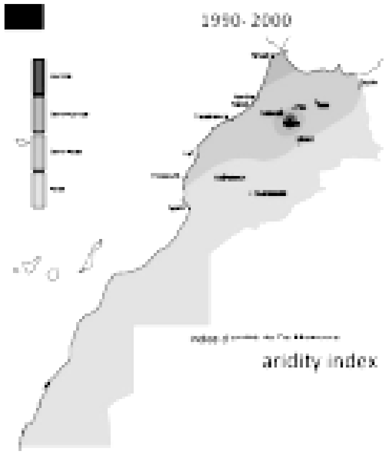
Table 1a: Drought occurring in north central Morocco Between 1000 and 1984 based on Col sad tree-ring series

Drought Length	Number of occurrences	Time interval, years
1 to 6 years	89	11.0
2 to 6 years	35	28.5
3 to 6 years	9	113.7
4 to 6 years	6	182.0
5 to 6 years	4	303.3
6 years	3	455.0

Table 1b: Recent droughts at the national level [9]

Drought Length	Period
1 year	1986-87
2 year	1991-93
2 year	1994-1996
4 year	1999-2003

As consequence of the successive waves of drought over the past decades, some regions have shifted from humid or sub-humid to semi-arid or arid climate regions (Figure 1).



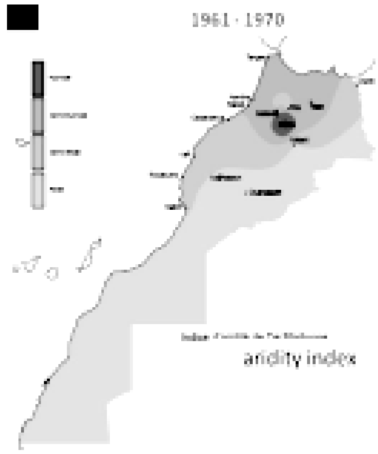


Figure 1: Increase of aridity in Morocco

In the 4 decades during 1961-2004, Morocco has been subject to the longest dry period with an average of 3 years, characterized by a decrease in precipitation and a clear trend of rising temperatures, and a prediction of decrease in surface runoff and precipitations, which are in good agreement with the conclusion of IPCC [10-12]. On another hand, changes in temperature and precipitations have impacted the hydrologic processes and water resources availability for agriculture and for water relying activities of the population. The change in intensity and frequency of precipitations is behind frequent floods observed in different regions.

Considering the growth of population, the expansion of agricultural, energy, and industrial activities as well as rapid urbanization, the demand for water in Morocco will increase at a time of growing contamination of water supplies and limited investment in water and sanitation services. Increasing water scarcity is unavoidable. In this paper, a survey of the climate change impact on different economic and social sectors is given.

2 Impact of CC on water on resources

Areas, where water availability is a limiting factor for economic development, are the most impacted ones by CC in the Mediterranean Zone. These countries rely on water resources in order to meet the needs of increasing populations and living standards, development of irrigated agriculture, increasing industry, tourism activities [13] and are considered to be a global “hot-spot” in terms of climate variability and change [14]. The magnitude of the impact is assessed by the vulnerability, generally based on three identified elements that are (i) exposure to climate change, (ii) sensitivity to climate change, and (iii) adaptive capacity [15-18], Morocco seems to be mainly affected by the sensitivity, which is directly linked to the agriculture [19]. Accordingly, the magnitude of the impact would be as follows: 87% of withdrawer water is used for agriculture, 95.2% of agricultural lands is rain fed, −39% of impact of climate change on productivity without carbon fertilizers by 2080 and −29.9% of impact of climate change on productivity with carbon fertilizers by 2080.

In terms of water availability, depending on the index used, Morocco as well as the other countries in North Africa are termed as stressed or scarce. Thus, according to hydrological water stress index (HWSI), Morocco is less scarce. This less dramatic conclusion is corroborated, if the human development is taken in consideration, Morocco would be stressed but not scarce according to social water stress scarcity index (SWSI) [20]. However, this vision is reversed, when other factors such quality of water access [21].

2.1 Potential of water in Morocco

The potential rainfall is estimated at 130 BCM/yr, of which 108 BCM are lost by evapotranspiration, and only 22 BCM/yr remain available; 80% of it is provided by the north part of Morocco. The main part is provided as surface waters (16 BCM), regulated partly by 140 dams and 110O km pipes (Table. 2).

Table 2: Repartition of water in the main rivers

Main basin	Surface water (%)	Groundwater (%)	Total
Loukous	23.1	11.2	25.9
Sebou	27.6	17.8	25.7
Oum Errabia	20.7	18.2	20.2
Bouregreg	4.70	5.10	4.70
Tensift	4.70	10.0	5.70
Sous massa	3.80	12.0	5.40

The uneven repartition is made works by decreasing tendency of rainfalls since 1970s. The ratio of water per capita is expected to drop below 500 m^3/cap.yr (Figure 3).

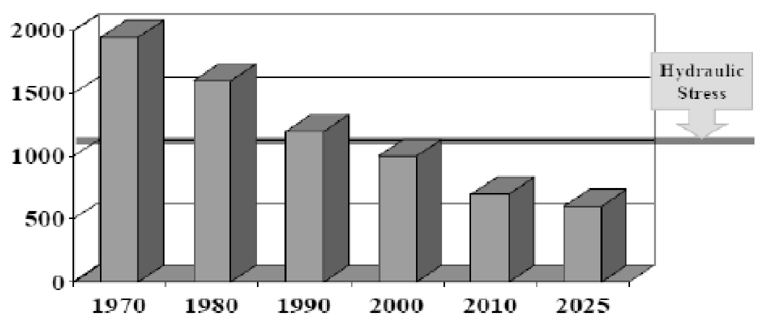


Figure 3: Water resources in Morocco (m^3/cap.yr) [22]

The impact of climate change is noticeable in various sectors and activities relaying on water usage. In the following, some of them are presented.

2.2 Impact of climate change on water resources.

Without climate change, increased urban demand will affect the amount of water dedicated to agriculture. A decrease by 2% is predicted by 2030, and 5% in 2050. Climate change will cause a larger decrease of water for agriculture: the decrease would achieve 16% by 2030 and 34% in 2050. The effect will vary from one basin to another; the basin of "Oum Rabia" being the most affected one. This situation requires an integrated approach that provides the water to main cities. The same decreasing tendency is observed for groundwater. According to an FAO study, current use of groundwater would be reduced by 28% to reach sustainable levels [23, 24].

2.3 Iimpact of climate change on agriculture

The agricultural sector accounts for roughly 15% of Morocco's gross domestic product (GDP), 23% of exported commodities, and close to 30% of total employment. During the last decade, this sector was the fastest growing sector in the country [25]. It is closely linked to Agro-industry sector that represents 27% of GDP. Agribusiness employs up to 143,000 people and is composed of 2,050 small and medium-sized industrial units.

Sensitivity plays a key role in the impact of CC on agriculture [19]. Accordingly, the magnitude of the impact would be as follows: 87% of withdrawer water is used for agriculture, 95.2% of agricultural lands is rain fed, −39% of impact of climate change on productivity without carbon fertilizers by 2080 and −29.9% of impact of climate change on productivity with carbon fertilizers by 2080. Dependency on precipitations determines the impact of CC. Prediction estimates to 30% the loss in productivity by 2080 [26]. Rain fed crops will be the most affected ones such as cereals production.

Citrus sector

Citrus and olive sectors are among the important agricultural sectors for their added value for the economy. In 2015–16 agricultural seasons, Morocco produced 918,000 t of oranges and 1,055,000 t of tangerines/mandarins, of which 79 and 64%, respectively, were consumed locally. Citrus sector has been affected by climate change. The production has declined on average of 10-55%. Some scenarios based on 30% decline of production with constant domestic consumption, the production would not be sufficient to satisfy domestic demand, and Morocco would need to import citrus fruit.

Survey conducted among grower of two main irrigated regions of citrus production in Morocco, namely Beni Mellal (BM, gravity system) and Souss Massa (SM, drip irrigation) revealed frustration of smaller farms (<10 ha) and those with older trees with deep roots using drip irrigation; the water seems not reaching into the soil. Growers expressed interest in changing irrigation systems. On another hand, climate change could impact the cost of water for irrigation that varies from MAD 0.80/m^3 to MAD 2.40/m^3 (MAD = Moroccan Dirham = 0,094 Euro). Climate change could have as effect the shifting of harvest timing. This would reduce reduces export competitiveness, since pack houses require reliable timing of crops in order to meet export market.

Olive oil sector

Water scarcity can affect olive sector by reducing oil production and oil quality. At least 693 mm/yr of water is required to maximize oil production. Olive oil yields are compromised at 396 mm/tree annually, while oil quality is affected at a level less than 297 mm/tree annually [27].

2.4 Floods and erosion

Most of the precipitations happen in the period of October to March, when the most significant climatic feature is rainfall. They are inversely related to the concurrent state of the North Atlantic Oscillation (NOA) mainly around the Atlantic coast. Rainfall period generally coincides with cereal production cycle that could be seriously impacted by climate change. Most models predict frequent and severe extreme-weather events, including both drought and flooding, as it was experienced by Morocco since 1980. This generally leads to widespread land degradation, reduction in returns from capital investments, lower income of rural households, spread of poverty and increased rural to urban migration.

The coastal zone of Morocco counts to 3500 km along the Mediterranean Sea and Atlantic Ocean. This zone is the most populated one in the country (more than 60% of the population, 90% of the industry) [2]. Many of the coastal zones are under diverse human pressures that make them experiencing acute environmental problems, such as coastal erosion, pollution, degradation of dunes, and salt-intrusion of coastal aquifers and rivers [10]. On another hand, accelerated sea level rise will enhance the impact on these areas, leading to flooding, erosion of sandy beaches, and destruction of coastal wetlands.

In their study on the vulnerability of Kenitra coast, Azidane et al. [28] indicated that the most vulnerable areas to inundation are the low-lying lands of Kenitra without natural coastal defenses, such as dunes have been destroyed in Mehdya Beach. Impact would affect also other economic sectors such as tourism, urban settlements, Mouth of the Sebou estuary, Sidi Boughaba Lake [28].

2.5 Water quality

Alteration of water quality could be directly or indirectly caused by different biochemical processes. Furthermore, the specific effects will vary among different regions and types of water bodies. It may include increased pollutant concentrations, enhanced nitrogen mineralization, and delayed recovery from acidification. During the drought period, lower flows can weaken the dilution effects of some pollutants

3 Adaptation to climate change

3.1. Adaptation capacity

IPCC divides the adaptive capacity of society into generic (GI) and impact specific indicators (ISI) [29]. The GI includes education, income, health, drought and floods, while ISI includes knowledge and technology [30]. Morocco showed the highest levels of income inequality and largest human development deficit. Thus, these indicators were low in Morocco compared with their respective indicators in North Africa. Thus, under five mortality was estimated to 36/1000 of living births and drinking water access in rural area to 60% (UNDP, 2009) among ISI factors corruption was estimated to 3.3, knowledge to 3.35 and technology to 3.9 over a score of 10; the lowest scores reflect the worst situation of the country [30, 31].

3.2 Adaptation measures adopted

In the water management issue, Morocco is improving his storage capacity by building more dams and headings toward reuse of treated wastewater. In this respect, the storage capacity has exceeded 17 BCM and the potential of wastewater 900 MCM (Million m^3) [33].

As adaptation measures in the agricultural sector, growers construct new wells, when the existing ones dry up, or forgoing irrigation altogether, even if they receive subsidies for irrigation for their young plants. The costs of pumping or water charges tend to be prohibitive to smallholders. In citrus and olive sector, growers with larger farms and using drip irrigation maintain large retention ponds to store water for each irrigation cycle [27].

At official level, a number of measures are taken to cope with frequency and severity of drought, including meteorological and agricultural monitoring and the use of multi-risk insurance for cereals. Though basic adaptive measures are already implemented, Morocco lacks of national drought strategy. Considering international experiences in this issue, Morocco needs to more fully adopt a proactive risk management and adaptation approach rather than the reactive crisis response. In this respect, some scientific drought indicators should be developed such as:

- Climatological drought onset indicators (data) to ensure coordination that could be used as starting point for initiating coordination and cooperation between various agencies and authorities to act rapidly and effectively;
- Providing an early warning system with structured mechanisms to initiate broad drought management coordination;
- Use of satellite images and model outputs to identify on the ground the signs of drought;
- Link of national and basin level efforts to anticipate and to respond to recurrent droughts to adapt to the broader effects of climate change.

The infrastructure will be reinforced by the construction of new dams (60 dams are planned), protection against flooding (PNI), transfer of raw water resources in the basins of the North to the South (800 MCM/yr., storage about 2 BCM of rainfall water, wastewater treatment.

Desalinization is also expected to improve, as Morocco is heading towards desalination solution mainly to the south in Agadir, where the largest plant is under construction. The expected capacity will be 22,000 m^3/d and will reach 400,000 m^3/d at it is full capacity. This technology is to be developed in conjunction with green energies such as wind power. Actually, some desalination plants are already functioning with wind energy.

In agriculture, the government encourages growers to shift from traditional to drip by drip irrigation; 550,000 ha are expected to shift to drip irrigation. Of this, 217,940 ha would be collective conversion in seven irrigated zones and 332,060 ha through individual conversion, introduction of resistant varieties of crops, and encouraging direct seeding, Rural energy supply is also considered. The development of renewable energy is another axis towards adaptation to climate change. In rural areas, the majority of energy is provided by firewood placing significant pressure on vegetation.

At institutional and legislation level, Morocco has adhered to the main international conventions, created provincial committees of the national Plan for Water, basin agencies, plan on Integrated Management of Water Resources, protection against pollution , principle sampler-pays and polluter-pays principles [33].

4 Conclusions

As all the Mediterranean countries, Morocco is subject to warming trend due to climate change. Expert scenarios expect a trend towards an increase in average annual temperature (between 0.6 and 1.1 °C) as well as a decrease in average annual rainfall volume by about 4% in 2020. Potential of water resources is mainly constituted by surface water and mainly confined in the northern part of the country. Under the prevailing climate change and increasing water relying activities, the ratio per capita is decreasing and has reached the alarming level of 550 m^3/yr. Agriculture is the main consumer of water resources and, therefore, the main affected sector. Other derived phenomena are recorded such as increasing floods, pollution. As adaptation measures, technical, legislative and administrative measures are taken, including increasing storage capacity of water that could exceed 17 BCM, encouraging growers to shift from traditional to drip irrigation system, usage of resistant varieties of crops, heading toward usage of treated wastewater and desalinized sea water in agriculture, flooding, zones from launching a national plan to protect vulnerable ones. At administrative level, the authorities tend to improve coordination between the different departments for better management of water resources.

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