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Climate Change Compounding Risks in North Africa

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Abstract

The impact of climate change on agriculture and poor groups' livelihoods are one of the greatest potential threats to development and a key challenge in climate change agenda. The North Africa region is particularly vulnerable to climate change due to geographic and ecological features. The situation is aggravated by the interaction of multiple economic and social sources of stress and further compounded by low adaptive capacity. This paper describes the interaction between climate change, economic development, and social stability in the North African region. An empirical-statistical crop climate model is used to measure the possible impact of climate change on agriculture sector.

Keywords: climate change, vulnerability, North Africa, economic development

JEL classification: Q54, Q56

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1 Introduction

Climate scientists now feel more confident that the scientific evidence supports the assertion that climate change is likely to occur (IPCC 1996a, b). They conclude that the current global warming is the result of emission of greenhouse gases through burning fossil fuel, deforestation, and growing population. The effects of climate change include rising temperatures, higher sea levels and more frequent extreme weather events like floods and droughts.

Because of climate change, droughts in many arid and semi-arid regions are likely to be more frequent and agriculture will be severely hit by global warming, climate disruption, and extreme weather events (IPCC 2007). The negative effects of climate change on agriculture include increased insect infections, crop damage from extreme heat, planning problems due to less reliable forecasts (uncertainty), increased soil erosion, increased weed growth and disease, decreased herbicide and pesticide efficacy, increased moisture stress, and severe storms and floods. Seasonal changes in rainfall and temperature could alter growing seasons, planting and harvesting calendars. In addition, water availability for irrigation and drinking will be less predictable because rainfall will be more variable. It is possible that salt from rising sea levels may contaminate the underground fresh water supplies in coastal areas. Therefore, agriculture in many countries will be under significant pressure to meet the demand from rising population, which exacerbates food security problem.

The IPCC assessment report 2007 states confidently that North Africa (Algeria, Morocco, Libya, and Tunisia) is extremely vulnerable to climate variations. The severity of climate change impacts on North African countries is related to the geographic and ecological particularity of the region.

Moreover, historical data confirm that the annual rainfall in the region has declined since the early twentieth century while annual mean temperature has increased. The frequency and severity of floods and heat waves in addition to years of recurring drought combined with the expansion of the Sahara desert into farmlands, confirm that climate change has already begun to affect the region.

However, despite the fact that the impacts of climate change on North Africa are likely to be more severe compared to other regions of the world (taking into account biophysical and socio-economic conditions of the region) there remains a considerable effort to understand the magnitude of the challenge facing the region and the region's capacity to cope.

> …. no concerted data gathering and research efforts could be traced regarding the impacts of climate change on health, infrastructure, biodiversity, tourism, water and food production. The economic impact seems to be totally ignored. Reliable records on climate patterns in the region barely exist. (AFED Report 2009).

Our objective is to provide a comprehensive analysis of the magnitude of the challenge facing the region, and the likely impacts of climate change. We make use of different indicators to assess the vulnerability of the region to climate change. We consider that the biophysical conditions, the socioeconomic conditions as well as the state of technology in the region are the main factors behind the extreme vulnerability of the region to climate change. In order to measure the likely economic impacts of global warming, we use a statistical crop model to test the sensitivity of agriculture production to higher temperature and lower rainfalls. Moreover, we discuss the potential impacts of climate change on the economies of the region.

We will, in section two, discuss the main manifestations of vulnerability to climate change. Section three will discuss climate change prospects for the region and analyze the potential impacts of climate change in North Africa. The fourth section concludes and offers policy recommendations.

2 Vulnerability of North Africa to climate change

In this section we will make use of different indicators to measure the sensitivity and the capacity of the region to cope with climate change and extreme climate events.

Following Scott (2008), we consider that region's vulnerability to climate change is directly related to: the biophysical conditions, the economic and social characteristics, and technology. The biophysical factors include: soil quality and groundwater availability. It is supposed that more productive soil and more groundwater available for agriculture and human use improve the capacity of the region to cope with climate change. Economic and social vulnerability depends, however, on agriculture dependency, in terms of contribution to GDP and employment. While technological vulnerability is related to development of infrastructure in rural area and vulnerability to rainfall variability.

2.1 Biophysical condition

North Africa belongs to the hydraulic poor regions located between tempered region of the Northern Hemisphere and the inter-tropical region, characterized by scarcity and spatial and temporal rainfall variability. With regards to climate change projections, the region will be threatened by desertification from the South and sea level rise from the North.

Figure 1: Physical map of North Africa

Source: http://printable-maps.blogspot.com.

North Africa has a total area of about 5 million km², of which more than 90 per cent is desert (Figure 1). The region relies on sparse winter rainfall and short rainy seasons to grow cereals, legumes and low-yield arboriculture as well as raises sheep and goats on fragile grazing land. The extremely arid areas in the south depend almost entirely on crop irrigation but are devoid of any major river systems. Instead, they utilize groundwater from wells, but this water layer is being depleted much faster than can be replenished by the limited rainfall. The region is one of the most water scarce regions in the world and annually exceeds its supply of water from rainfall and river flows, depleting groundwater resources.

Table 1: Potential of renewable water resources (billion m3/year)

	Algeria	Morocco	Tunisia
Surface water	10	18	2.7
Underground	7	4	2.1

Source: FAO.

As is shown in Table 1, among the three countries Tunisia is suffering the most from water scarcity. Moreover, according to many experts, the situation is very likely to worsen as fresh water availability is decreasing (Table 2).

Table 2: Water availability per capita and per year (m3)

	Algeria	Morocco	Tunisia
1955	1770	2763	1127
2025	332	590	324

Source: FAO.

Change in water quantity and quality due to climate change are expected to affect food availability and access. This will decrease food security and increase the vulnerability of poor rural farmers.

An additional problem that furthermore complicates the situation in the region is the relative fragility of soil. Soil in North Africa is subject to contrasting climate factors like drought and short duration torrential rainfall, and increasingly important anthropogenic factors along the coast, in addition to inadequate cultural practices (Mtimet 1999). All these factors make the soil relatively fragile. Longer periods of drought will accelerate desertification and shift the desert’s limit further north, and therefore decrease land areas suitable for agriculture.

Table 3: Soil Degradation[1]

	Degree of desertification in irrigated farmland (%)	Degree of desertification in rain-fed farmlands (%)
Algeria	15	93
Morocco	10	69
Tunisia	33	69

Source: Dregne and Chou (1992).

As is shown in Table 3, North Africa has a very high level of soil degradation due to high population increases and land use policies (Dregne and Chou 1992). Frequent droughts and soil fragility also play an important role in rainfed cropland degradation.

An important distinctive climatic feature of the region and one of the major factors that increase desertification is the Sirocco, a hot dry southerly wind that occurs around the year. The wind originates over the Sahara Desert and blows north across the region. It contains large amount of sand and dust and may cause a serious damage to crops. Sirocco is very likely to be exacerbated by low rainfall and higher temperature. Drying and warming trends as well as depletion of aquifer also contribute to desertification in the region.

2.2 Social and economic characteristics

In terms of risk exposure, the North African countries are highly vulnerable to extreme weather events. As is shown in Table 4 the region is particularly vulnerable to drought. Moreover, Algeria and Morocco seem to be relatively more vulnerable to drought and floods than Tunisia.

Table 4: Vulnerability to droughts and floods

	Algeria	Morocco	Tunisia
Drought (out of 184)	18th	10th	56th
Flood (out of 162)	58th	66th	116th

Source: www.preventionweb.net.

Higher variability of mean inter-annual precipitations associated with adverse effect of climate change makes an increasing number of people in the region, especially populations in rural areas, extremely vulnerable to extreme climate events. Modeled number of people present in hazard zones that are thereby subject to potential losses varies between about 800,000 in Tunisia to about 8,000,000 in Morocco (Table 5).

1 Aspects of desertification in rainfed farmlands include: soils subject to erosion damage, increase in crop losses by pathogen and parasitic pests.

Table 5: Number of people subject to potential losses

	Algeria	Morocco	Tunisia
Drought	3763800	7506710	782061
Flood	26738	23478	3748

Source: www.preventionweb.net.

It is assumed that higher GDP contribution from non-agriculture sectors, lower percentage employment in the agriculture sector and higher crop diversity will collectively lower a country's chances of developing socioeconomic drought when meteorological drought occurs (IWMI 2009).

Agriculture contributes to about 25 per cent to total labour force in the region and about 60 per cent of them are female (except from Libya). In Morocco and Tunisia, the sector sustains the livelihoods of an important share of the population. The share of agriculture in the GDP has, however, declined over the years.

Greater diversity in the range of crops is expected to help improve farmers' resilience to the adverse effects of climate change. Indeed, given the different levels of tolerance of crops to weeds, diseases and water stress associated with climate change, a more diverse crop plays a crucial role in adaptation to climate change.

Table 6: Crop diversity

	Cereals	Citrus fruit	Fibre crops primary	Fruit excl melons	Oilcakes equivalent	Oil crops primary	Pulses	Roots and tubers	Vegetables and melons
	Area harvested for 9 types of crops (Ha)								
Algeria	2438130	46389.56	100	391523.1	18691	248622	65575.11	84527.22	267388.3
Libya	350962.2	6740	57890	11944.44	152611.1	13895.56	12301.11	60521.11	
Morocco	5334256	79012.22	2702.222	293925.2	74951.44	612884.8	394938.9	61459	186653.9
Tunisia	1147319	26927.78	2000	204370.3	18844.44	2080993	95517.78	23323.33	131720.6
	Fractional cropped area out of total cropped area								
Algeria	68.47	1.30	0.00	10.99	0.52	6.98	1.84	2.37	7.51
Libya	52.63	1.01	8.68	1.79	22.88	2.08	1.84	9.08	
Morocco	75.76	1.12	0.04	4.17	1.06	8.70	5.61	0.87	2.65
Tunisia	30.75	0.72	0.05	5.48	0.51	55.78	2.56	0.63	3.53

Source: FAO.

As is shown in Table 6 for all the four countries of the region crops diversity is very low. Indeed, for Algeria and Morocco, cereals represent 68 per cent and 75 per cent of total cropped area, respectively. For Libya and Tunisia cereals and oil represent more than 80 per cent of total area harvested. Therefore, one strategy to improve the region's resilience to climate change is to diversify much more the range of crops, which may require rethinking dietary regime in the region.

To measure the socioeconomic vulnerability in the region we use the socioeconomic drought vulnerability index that includes the contribution of all the aspects mentioned previously (IWMI 2009). Three sub-indices make up the composite Socioeconomic Drought Vulnerability Index (SDI). We use the percentage contribution of agriculture to GDP, percentage of agricultural labour force, and the crops diversity index suggested by Jülich (2006) to determine the SDI.[2]

Table 7: Socioeconomic vulnerability

	Socioeconomic drought vulnerability index
Algeria	25.05
Libya	0.11
Morocco	80.13
Tunisia	53.71

Source: Author's calculation.

Compared to oil-exporting countries in the region (Algeria and Libya), Morocco and Tunisia have higher vulnerability to societal impacts of drought (Table 7). This is explained by the relative importance of agriculture sector in addition to low crops diversity. The apparent resilience of Libya to drought, however, is mainly explained by the dominance of mining and hydrocarbon industries sector (95 per cent of GDP) and the marginal economic role of agriculture sector.

Finally, the main economic and social activities in North Africa are concentrated along the coastal zones. Population within 100 km of coast is 68.8 per cent in Algeria, 78.7 per cent in Libya, 65.1 per cent in Morocco, and 84 per cent in Tunisia. Thus, sea level rise could result in major population movements and adversely affect many economic activities like tourism; a major source of employment and income in Morocco and Tunisia.

Technological vulnerability

Water scarcity is a main constraint to improve agricultural productivity. Irrigation facilities help to improve farmer's resilience to low and erratic rainfall. In North Africa over 90 per cent of agriculture is rainfed and there is no potential for additional development of irrigated agriculture because of water scarcity. Indeed, the region is among the most water-scarce region in the world and characterized by high spatial and temporal irregularity in water availability. The problem is more acute in view of the increasing urbanization, growing population and the already high rates of water uses. In addition, the high salt content in much of the available water further complicates irrigation efforts. In addition, traditional cultural practices are dominant and access to new technology by the majority of farmers is quite limited. Therefore, a small reduction in rainfall associated with climate change could cause a sharp decrease in agriculture production and shortage in food supply, particularly for smallholder in rural areas.

2 SDI has a score of 0-100 with 100 implying maximum vulnerability.

Given the increasing national water needs, the man-made reservoirs will play a crucial role in the region, as they store water during the wet periods to make it available during the dry periods.

Table 8: Storage capacity[3] and water use

	Storage capacity index	Water resources: total internal renewable (10^9 m3/yr)	Water use efficiency
Algeria	0.53	11.25	37
Libya	0.64	0.6	
Morocco	0.55	29	42
Tunisia	0.61	4.195	50

Source: FAO and author's calculations.

According to the storage capacity index (Table 8), the ability of the region to cope with water deficit cause by longer drought periods seems to be limited. Indeed, considering the hydrological regime in the region, the current storage facilities are still insufficient to face the challenge of more frequent and severe drought episodes. Moreover, water efficiency use in the region is low, which is a considerable limit for better management of existing water resources. The region needs to improve its storage capacity in order to cope with climate change adverse effects. However, among the crucial factors which will affect the magnitude of the shortfalls in water storage are identification and availability of sustainable reservoir sites (White 2005).

The natural availability of water resources in the region determines whether extreme climate event like drought are a serious threat or not. However, infrastructure development, like the availability of improved drinking water and general accessibility of rural areas, determines the capacity of the region to cope with extreme events. According to the 2009 Report of the Arab Forum for Environment and Development, 75 per cent of buildings and infrastructure in the region are at direct risk of climate change impacts.

Table 9: Infrastructure development

	Rural access index (1994-2004) (%)	% of Pop. with access to an improved water resource
Algeria		81
Libya		
Morocco	36	58
Tunisia	39	84

Source: World Bank and author's calculations.

3 The storage capacity as a proportion of total annual renewable freshwater resources within a country. It is an indicator of the extent of exploitation of national water resources.

As is shown in Table 9, the estimated proportion of the rural population who have adequate access to the transport system is relatively low; thus populations in the region seem to be vulnerable to floods and drought. Morocco, in particular, suffers from low access to improved water drinking in addition to underdeveloped infrastructure in rural areas. Therefore, longer and more frequent climate extreme events are likely to cause food shortage in rural areas.

3 Climate prospects and potential economic impacts

There is now very strong evidence that significant global warming cannot be explained by natural causes alone. Many scientists confirm that the actual temperature record does not fall in the envelope of the model results when only natural climate change is considered.

Therefore, scientists conclude that the current global warming is the result of anthropogenic emissions of greenhouse gases. Human activities are leading to an enhancement of the greenhouse effect by the emission of greenhouse gases through burning fossil fuel, deforestation, and the growing world population, which artificially warm the atmosphere of the earth. Indeed, since the industrial revolution the amount of CO_2 in the atmosphere has increased by 35 per cent and the average temperature on the planet has increased by 0.74.

North Africa countries contribute very little to global warming with low carbon dioxide emissions. Per capita carbon dioxide emissions from all sources in 2000 are 5.22 tonnes; compared to a world average level of 6.8 tonnes. Despite low greenhouse gas emission, the most recent assessments have concluded that North Africa will be adversely affected by climate change.

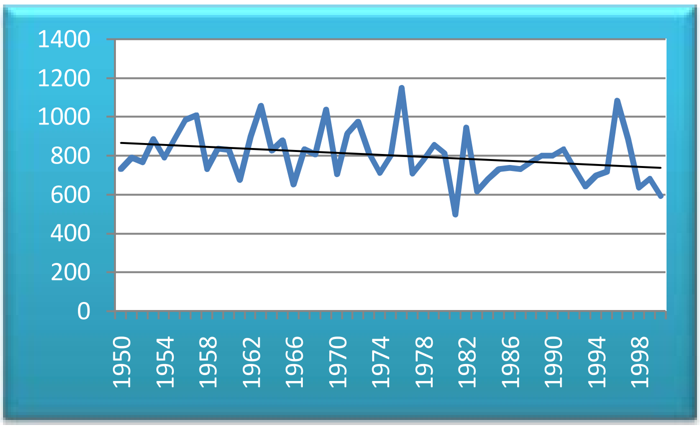
3.1 Climate change prospects for North Africa

The climate of North Africa varies substantially between coastal and inland areas. Along the coast, North Africa has a Mediterranean climate; which is characterized by mild, wet winters and warm dry summer (rainfall of 400 to 600 mm per year). Inland, the countries of North Africa have semi-arid and arid desert climates, which are marked by extremes in daily high and low temperature with hot summers and cold winters and little rainfall (100 to 400 mm per year).

Precipitations in North Africa are highly irregular and climate historical data show that rainfall amounts seem to be decreasing over time (Figure 1).

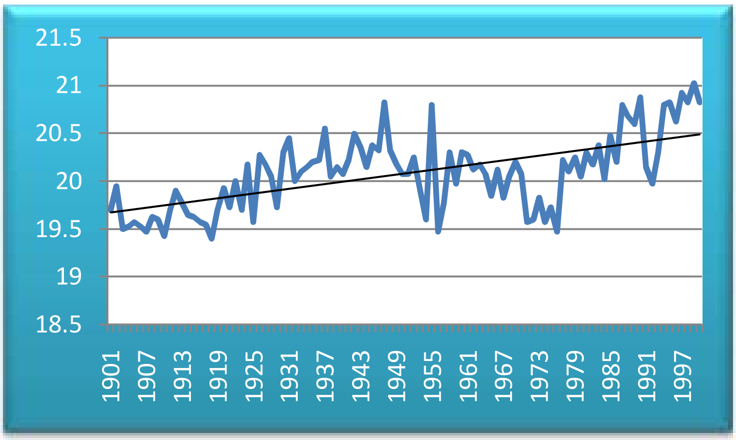
In addition, historical data show that annual average temperature has increased by more than 1°C since the beginning of the twentieth century (Figure 3). The highest increase was recorded in Tunisia by about 1.7°C.

Figure 2: Mean annual precipitation in the region



Source: data from www.cru.uea.as.uk.

Figure 3: Mean annual temperature in the region



Source: data from www.cru.uea.as.uk.

Droughts and floods are the most common extreme climatic events in North Africa and represent direct threats to lives, livelihoods and socio-economic aspects. There is observational evidence that the frequency and the intensity of extreme events have increased in the past 20 years. According to IPCC (2007) it is expected that the region will experience more frequent and severe meteorological and hydrological extremes like droughts, heat waves, sea level rise and floods.

A new reconstruction of the climate history of the Maghreb concluded that the twentieth century was the driest in North Africa since severe droughts in the thirteenth and sixteenth centuries (Touchan et al. 2010). Moreover, Agoumi (2003) points out that the region experienced one drought every 10 years at the beginning of the century, to a current state of five years of drought per ten years.

Table 10: Number of extreme events in the region

	1970-1989	1990-1999	2000-2009
Floods	23	20	57
Droughts	6	4	4
Heat waves		2	3
Total	29	26	64

Source: Compilation from the International Disaster Database.

Table 10 confirms the findings by Agoumi (2003), as climate extreme events seem to be more frequent in the region during the last ten years. The number of flood episodes, for example, increased from 26 in the 1990s to more than 60 in the 2000s.

Table 11: Floods by categories

	1990-1999			2000-2004		
	Algeria	Morocco	Tunisia	Algeria	Morocco	Tunisia
Flash[4]	2	3	1	3	3	1
General[5]	4	2	1	13	7	4
Unspecified	5	2	1	4		
Total	11	7	3	20	10	5

Source: Compilation from the International Disaster Database.

The frequency of reported disasters in terms of drought, flood and extreme temperature has more than doubled between 1990-1999 and 2000-2009. Moreover, the severity of the disasters is getting worse as the number of general floods has increase from 7 in the 1990s to 24 in 2000s (Table 11).

Knowledge of the likely climate change in the region requires that the region possess a General Climate Model (GCM).[6] This is the main tool used by scientists to project future climate change. These models simulate atmospheric and oceanic circulations, as well as processes that occur on land. According to the few existing studies on North Africa, climate change is going to result in raising mean annual temperatures by 3.5-3.6°C by 2030 (larger than the global annual mean of 2.8). Precipitations are expected to decrease by 5 per cent in the coastal areas of the region (Mediterranean area) and 10 per cent in the arid and semi-arid areas (inland areas). According to The Intergovernmental Panel on Climate Change (IPCC 2007), in southern Europe including

4 Rapid inland floods due to intense rainfall.

5 Gradually rising inland floods due to high total depth of rainfall.

6 GCMs tend to have low spatial resolutions on the order of 400 to 125 km. In addition, there is still uncertainty about the full magnitude of climate change in the region because the GCMs used for climate change projections cannot accurately resolve temperature and precipitation variations on such small spatial scale.

Mediterranean basin, extreme warm seasons are expected to increase by 100 per cent of 17 GCMs under A1B scenario. The temperature increase is projected to be higher in the inland areas. Moreover, IPCC has estimated future regional changes in sea level due to thermal expansion, including ocean density and circulation changes. Sea level is predicted to increase by 15 to 20 cm by 2099. Using a 1m sea level rise scenario, Dasgupta et al. (2007) finds that Tunisia is among the top 10 impacted countries in terms of population affected and GDP loses.

Climate change in the region will also result in a reduction of the growing period of crops, a reduction of crops cycle, and an increase in the risk of dry period during the course of crop cycles. The 2009 Report by the World Bank, the Food and Agriculture Organization of the United Nations (FAO) and the International Fund for Agriculture Development (IFAD) confirms the average yearly rainfall in the region could decrease by 10 per cent in the next 50 years. Moreover, because of more frequent drought and heat waves rain-fed crop yields are expected to fluctuate increasingly and decrease by almost 40 per cent in Algeria and Morocco.

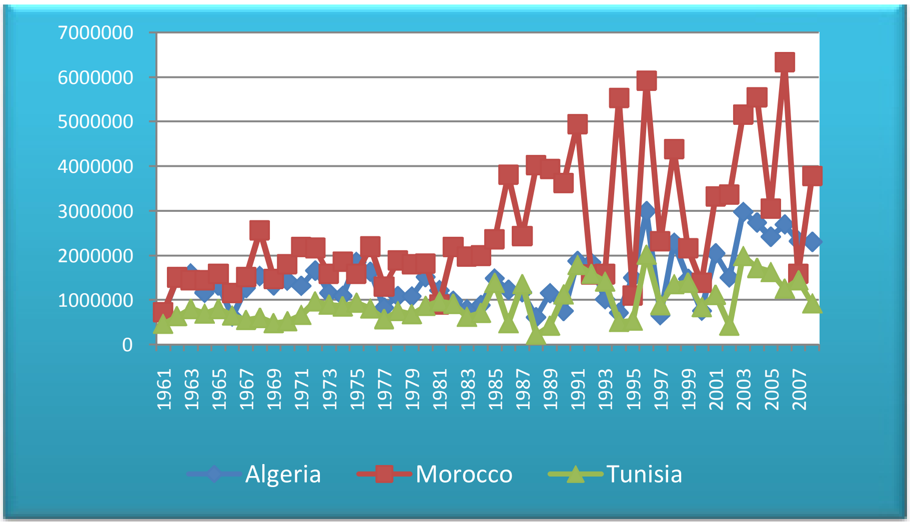
3.2 Potential effects of climate change

Only a few systematic modelling studies of the effects of climate change on agriculture in North Africa are available, possibly due to the fact that most of the region has an arid and semi-arid climate and they receive very low level of rainfall. Temporal and spatial irregularity in precipitation makes it difficult to predict the impacts of climate change on agriculture in particular and the economy in general.

However, as one of the world's most water-scarce regions with a high dependency on climate-sensitive agriculture, the economic and social conditions in North Africa are likely to deteriorate in the future. Higher temperature in the region will increase evaporation and cause the loss of surface water. In addition, in the quasi-totality of the aquifers ground water level reached alarming values and water quality is at the lower limit of standard. Changes in extremes including floods and droughts are also projected to affect water quality. Sea level rise is projected to extend areas of salinization of ground water resulting in a decrease of freshwater availability for human and ecosystem in coastal areas (IPCC 2007).

According to many experts because of more frequent drought periods, agriculture performance is projected to drop in the future. The adverse impacts of climate change include reduced crop yield due to drought and reduced water availability. Increasing temperature trend will make crops fail to reach mature due to lack of enough moisture in the soil. On the other side warmer climate will probably increase crop losses caused by weeds and diseases.

Figure 4: Wheat production (1961-2008)



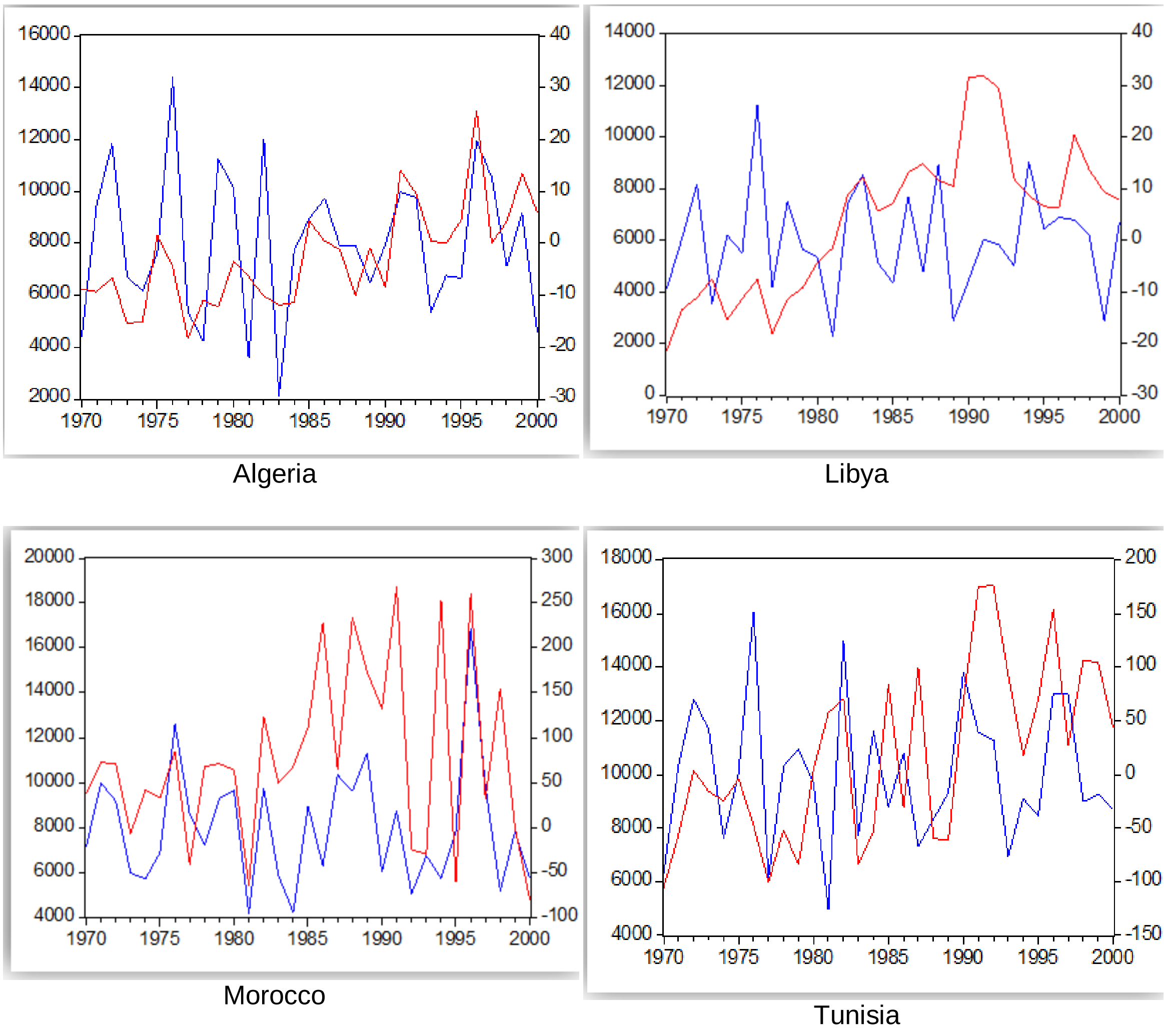
Source: data from FAO.

As the region has an arid and semi-arid climate, variability of precipitation and probability of drought occurrence tend to be higher (IWMI Research Report 2009). As shown in Figure 2, because temporal irregularity in precipitations, wheat production in the region is highly variable. For example, a dry season slashed grain crop production in Morocco by approximately 80 per cent in 2007 compared to 2006 level. For 2010, because of a dry season the production of wheat is expected to decrease by 44 per cent in Tunisia to 0.93 million tons, the World Bank confirms. Lower wheat production caused by erratic rains in 2010, is expected to result in increased wheat imports in Morocco by 2 million tons (or an increase by 130 per cent). Higher volumes of imports are also expected in Tunisia and Algeria (Food Outlook, FAO, June 2010).

For the region wheat production is vital. Figure 4 shows the variations of wheat yields and the cyclical variations of total precipitation over the period 1970-2000 for Algeria, Libya, Morocco, and Tunisia, respectively. We used the *Hodrick-Prescot* filter to decompose precipitation series into trend and cyclical components. The cyclical component is supposed to capture the wet and dry seasons.

As we can see in Figure 5, wheat yields are closely linked to fluctuations in rainfall, except for Libya, where the agricultural capacities are relatively very limited. The close relationship between wheat yields and fluctuations in precipitation confirms the high sensitivity of wheat production to climate variability.

Figure 5: Cyclical component of annual precipitations and wheat yields



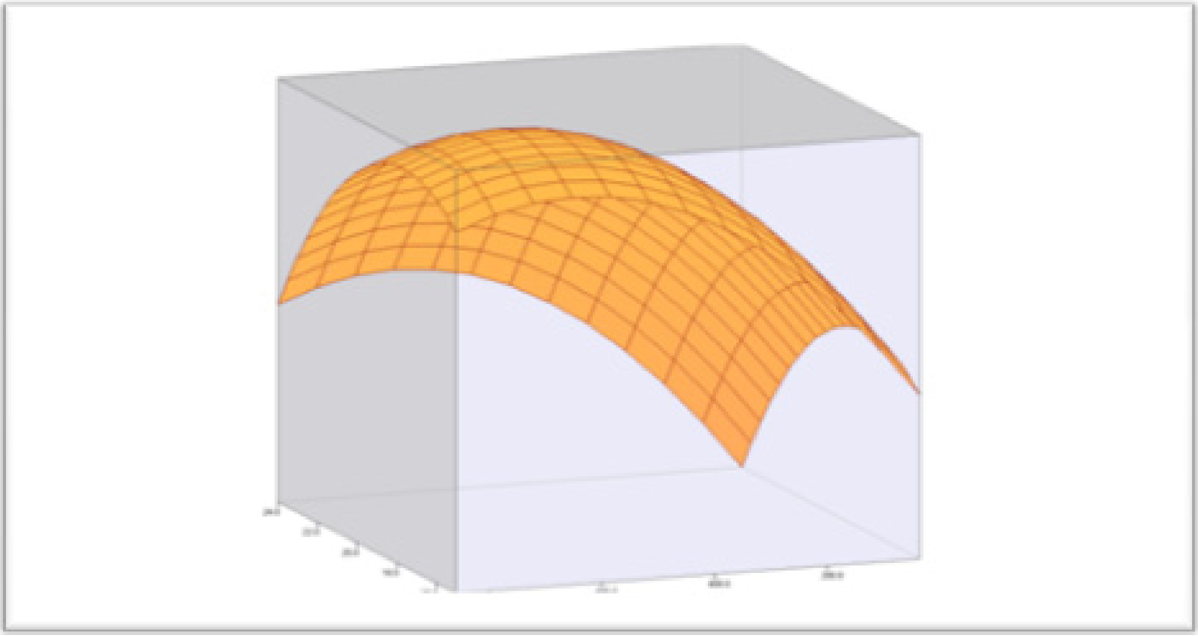
In order to test the potential effect on agriculture production of higher temperature and lower precipitation, we estimated a crop model for 9 MENA countries (Algeria, Iran, Jordan, Lebanon, Libya, Morocco, Syria, Tunisia and Yemen). The regression links log wheat yields to total annual precipitation (P) and annual mean temperature (T)[7] (see Lobell and Field 2007). We include a time trend to capture technological progress, as well as country specific effects. We use a quadratic function to test the impacts of climate change on wheat yield over the period 1970-2000.

$$log(yield) = 4.71 + 0.03\,trend + 0.002P - 1.5410^{-6}P^2 + 0.46T - 0.013T^2$$

As expected, the coefficient relative to the linear term is positive, while the coefficient relative to the squared term is negative, in agreement with several previous assessments (Lobell and Field 2007, Schlenker and Lobell 2010). All coefficients are significant at 1 per cent level and the model resulted in an R-squared of about 80 per cent. The optimum average temperature, where yield is maximized is about 18°C, with an optimum precipitation of about 650 mm.

7 Data are from FAO; for more details see appendix (Table A1).

Figure 6: Wheat yield variations with precipitations and temperature



In terms of precipitations, all the North African countries are located on the ascendant part of the curve with an average level less than the threshold (Figure 6). Therefore a decrease in rainfall is very likely to result in a decline of crop yield. However, all countries have an annual average temperature equal or higher than the optimum level, which means that higher temperature will have a negative impact on crop yield.

Table 12: Predicted yield changes (%)

	Algeria	Libya	Morocco	Tunisia
Average Predicted Yield Change for +2°C	-25.58	-22.09	-1.6	-8.99
Average Predicted Yield Change for -20% precipitation	-12.79	-11.04	-4.49	-0.8

Among the four countries, Algeria and Libya seem to be more sensitive to climate change. However, given the lack of financial resources, Morocco and Tunisia will suffer the most. The model indicates an average effect of +2°C of between about 26 per cent in Algeria and about 1.6 per cent in Morocco. The average effect of -20 per cent precipitations is also negative but smaller than for +2°C (Table 12). Cline (2007) finds more pessimistic results, the projected per cent changes in agricultural production capacity for 2070-99 with respect to 1961-90 baseline, are -26 per cent and -30 per cent in Algeria and Morocco, respectively. According to CIRCE Projections for the Mediterranean and Caribbean Areas, by the mid of the century, higher temperatures, lower water availability and desertification processes can decrease crop productivity up to 23 per cent in North Africa.

Climate change in the region is more than an issue of environment it is indeed a matter of development; 'unsustainable development is the underlying cause of climate change and development pathways will determine the degree to which social systems are vulnerable to climate change' (Huq et al. 2006: 4).

Table 13: Net cereal imports and food aid
(% total consumption) 1989-2000

Algeria	76
Libya	89
Morocco	54
Tunisia	57

Source: FAO and World Resources Institute.

The climate change will further exacerbate the situation in the region through reduced employment and higher food prices. Indeed, North Africa is one of the most disadvantaged regions of the world with regard to food self-sufficiency (Table 13); diminishing water resources for agriculture and inefficient management of water resources will limit the capacity to feed the region's own population and put more pressure on food prices. Food deficit is increasing and the reliance on external food sources has become a real constraint for development in most countries in the region. Consequently, any variations in agriculture production and food prices will have impact, with possible social ramifications.

Limited opportunities for financing and lending as well as misguided agricultural policies have limited adaptation in agriculture sector and resulted in declining farm output. Harsh living conditions in rural areas, due to the paucity of agricultural and rural development will trigger massive rural–urban migration.

Table 14: Share of agricultural labour force

	Share of agricultural labour force in total labour force (%)	Share of female in agriculture labour force (%)
Algeria	23	52
Libya	5	66
Morocco	34	85
Tunisia	23	42

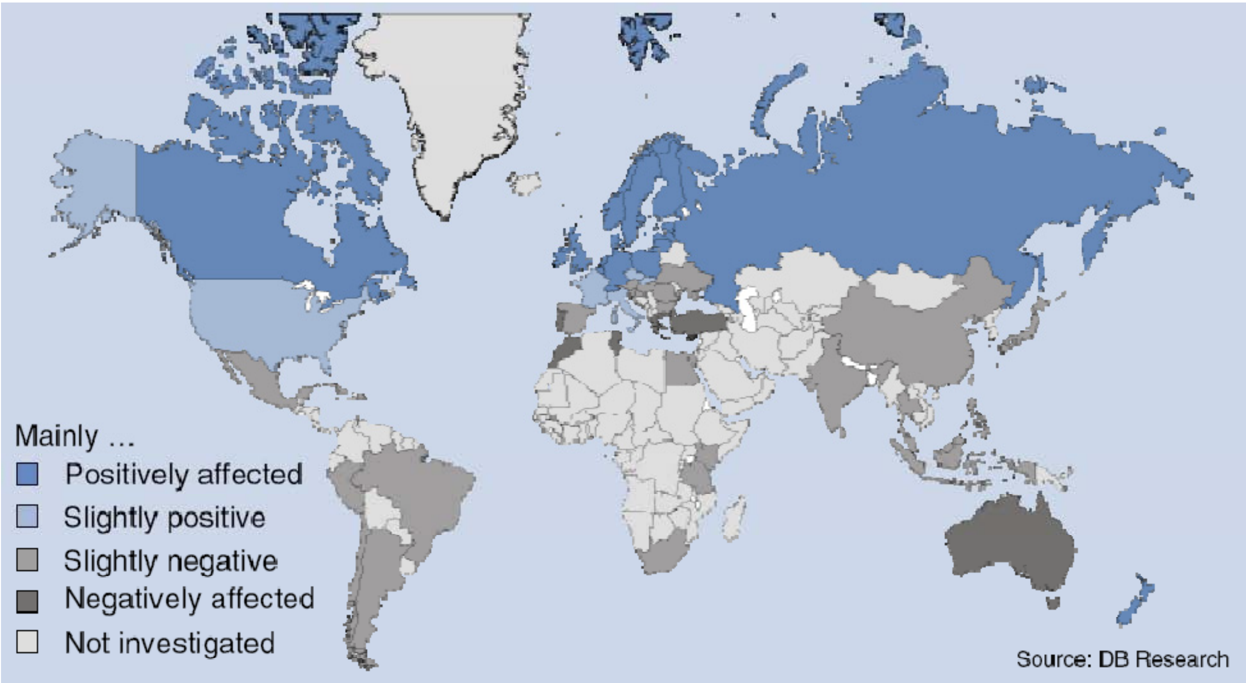
Source: FAO.

The degradation of agriculture is likely to increase unemployment in some countries where farm workers constitute about 30 per cent of the total labour force. Gender inequalities are likely to increase because the share of women in the agriculture labour force is relatively high (Table 14).

Droughts in rural areas associated with water scarcity will influence migration into cities, increasing urbanization and stressing the socio-economic conditions. Besides, the Sahara desert is continuously expanding to the north and according to UN conference on desertification held in Tunisia in 2006, by 2020 up to 60 million people could migrate from Sub-Saharan Africa to North Africa and Europe. Furthermore, some experts confirm that diseases from Central Africa like Malaria, yellow fever and dengue fever could extend their endemic areas to North Africa in response to climate change.

Finally, the Djerba Declaration on Tourism and Climate Change (2003) recognizes 'the existing and potentially worsening impact of climate change, combined with other anthropogenic factors on tourism development in sensitive ecosystems, such as the drylands, coastal and mountain areas as well as islands'.

Figure 7: How climate change will influence tourism



According to Deutsche Bank Research (2008), tourism in Morocco and Tunisia will be negatively impacted by climate change (Figure 7). Indeed, Morocco and Tunisia are heavily dependent on tourism, which accounts for about 16 per cent of GDP. Tourism is a strategic sector for development and an important source for employment and foreign exchange. The sector is extremely vulnerable to weather condition as it depends mainly on summer tourists and beach holidays. Hotter summer, sea level rise, and increased water scarcity will cause a drastic decline in the index of tourism comfort (AEFD Report 2009). Many experts confirm that given the expected impacts of climate change, the region may lose its attractiveness as tourist destination.

4 Conclusion

Over the centuries, people in North Africa have responded deftly to climate change, however, with modern life and economic progress their capacity to cope with climate variations has declined. The situation in the region is further compounded by the fact that North Africa has a low capacity to adopt, both technologically and financially. Transportation systems, water supply and waste water networks are generally vulnerable to projected increase in intensity and frequency of heat waves, storms and sea level rise. Huge floods in Alger in 2001 (751 people killed, US$300 million estimated damage), Morocco in 2002 and in Tunis in 2003, confirm that a lot of work needed to be carried out to make the infrastructure in the region more resilient to climate change. Moreover, over reliance on state and underdeveloped civil society are among the main bottlenecks handicapping the region's capacity to cope with the climate change.

Climate change now and for many years to come is foremost among the concerns of the North African countries, as these are extremely vulnerable to climate variations. Extreme events associated with climate change, like floods and droughts, will probably set economic development back many years. On the other hand, approaches to climate change adaptation are not usually aligned with development issues. Climate change mitigation will divert resources from programmes to address poverty, unemployment and poor-living conditions and threats the sustainability of development process. Therefore, conflicting interests between the development and climate change agendas need to be identified and addressed. Identifying a win-win strategy that succeeds to address climate change risks without jeopardizing economic development is top priority for the governments in the region.

Moreover, governments in the region need to shift from risk management to risk preparedness. In other words adaptation to climate change should be considered by countries of the region in development programmes. In addition, given that climate change will not be uniform across the country, a climate vulnerability map is needed to identify zones at risk and better targeting interventions. Governments in the region should take steps to reduce the vulnerability and enhance adaptive capacity of the most exposed populations.

Finally, limited resources hinder the ability of Morocco and Tunisia to mitigate the impacts of climate change; a regional and international support for the two countries will be more than necessary to cope with climate change challenges.

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Appendix

Table A1: Descriptive statistics

	Algeria	Iran	Jordan	Lebanon	Libya	Morocco	Syria	Tunisia	Yemen
					Wheat yields				
Mean	7480.94	11949.97	9838.61	16535.39	6844.16	11077.84	14783.45	10742.74	12721.55
Median	7297	10819	9929	15000	7450	10700	14000	10187	11770
Maximum	13090	19345	22632	27025	12380	18698	26181	17029	17344
Minimum	4336	7259	1663	8483	1734	4758	4021	5766	6990
Std. Dev.	1968.72	3312.76	5278.26	5644.30	2862.98	3940.29	6194.60	3252.33	3052.61
					Precipitations				
Mean	88.12	230.35	110.80	626.59	55.46	324.90	303.67	305.80	160.81
Median	88	228	106	650	55	321	310	312	160
Maximum	122	316	192	859	84	554	481	487	237
Minimum	59	145	54	361	36	193	178	190	99
Std. Dev.	14.78	40.90	33.42	133.80	10.79	75.87	68.37	70.51	39.58
					Temperature				
Mean	22.61	17.43	18.35	16.38	21.94	17.22	17.81	19.42	23.96
Median	22.70	17.50	18.30	16.40	21.90	17.20	17.90	19.50	24.00
Maximum	23.50	18.80	19.60	17.60	22.70	18.10	19.00	20.50	24.80
Minimum	21.60	15.80	17.20	15.20	21.40	15.90	16.50	18.40	23.30
Std. Dev.	0.52	0.67	0.56	0.60	0.34	0.55	0.60	0.58	0.32
No. of obs	31.00	31.00	31.00	31.00	31.00	31.00	31.00	31.00	31.00