

# Climate change impacts on North African countries and on some Tunisian economic sectors

LEILA RADHOUANE

*National Tunisian Institute for Agriculture Research (INRAT), Ariana, Tunisia*  
*E-mail : radhouane.leila@iresa.agrinet.tn*

*Submitted on 2013, 14 January; accepted on 2013, 20 February. Section: Reviews*

**Abstract.** Global temperature is increasing and that the main cause is the accumulation of carbon dioxide and other greenhouse gases in the atmosphere as a result of human activities. The economic costs alone will be very large: as extreme weather events such as droughts and floods become more destructive and frequent; communities, cities, and island nations are damaged or inundated as sea level rises; and agricultural output is disrupted. Impacts on ecosystems and biodiversity are also likely to be devastating. But what about Climate change impacts on water resources and agriculture in North African regions and especially on Tunisia country?

North Africa is vulnerable to climate change impacts. Scenarios predict an average rise in annual temperatures, higher than the average expected for the planet. Heat waves would then be more numerous, longer and more intense. North Africa would be particularly affected by droughts that would be more frequent, more intense and longer-lasting. The projections also announce a drop of 4 to 27% in annual rainfall. The water deficit will be worsened by increased evaporation and coastal aquifers will become more salty. The sea level could rise by 23-47 cm. by the end of the 21st century. Many Mediterranean regions would then run a major risk of being submerged and eroded.

In North Africa, rising temperatures associated with climate change are expected to decrease the land areas suitable for agriculture, shorten the length of growing seasons and reduce crop yields. In these countries, we estimate that a 1°C rise in temperature in a given year reduces economic growth in that year by about 1.1 points. The decrease in annual precipitation that is predicted for Northern Africa in the 21st century will exacerbate these effects, particularly in semiarid and arid regions that rely on irrigation for crop growth. These effects of climate change are more dramatic for Tunisia country especially for water resources and arable cropland.

The African countries face numerous environmental challenges and have to reconcile many conflicting priorities, from promoting economic diversification, ensuring water supply and food security, and furthering environmental

protection and conservation to adapting to the impacts of global warming.

*Key words: Climate changes, North Africa, Tunisia, Temperature, Drought*

## **Introduction**

Climate change represents one of the most serious and far-reaching challenges facing humankind in the twenty-first Century. The international consensus of scientific opinion, led by the Intergovernmental Panel on Climate Change (IPCC, 2007), is agreed that global temperature is increasing and that the main cause is the accumulation of carbon dioxide and other greenhouse gases in the atmosphere as a result of human activities (Stott *et al.*, 2000). Scientific opinion is also agreed that the threat posed will become more severe over coming decades (Mann *et al.*, 1998).

The cost of failing to mobilise in the face of this threat is likely to be extremely high. The economic costs alone will be very large (Sala *et al.*, 2000): as extreme weather events such as droughts and floods become more destructive and frequent; communities, cities, and island nations are damaged or inundated as sea level rises; and agricultural output is disrupted (Huntingford *et al.*, 2005).

The social and human costs are likely to be even greater (Carraro 2002; Kaul *et al.*, 2003), encompassing mass loss of life, the spread or exacerbation of diseases, dislocation of populations, geopolitical instability, and a pronounced decrease in the quality of life (USNRC. 2002). Impacts on ecosystems and biodiversity are also likely to be devastating (Cox *et al.*, 1998).

## **What about Climate change in North Africa?**

Climate change in North Africa, which emits low levels of greenhouse gases (between 1.5 and 3.5 emission tonnes of CO<sub>2</sub>/inhabitant/year), represent a veritable threat to the region's socio-economic development and to its population (Agouni, 2003).

The severity of climate change impacts on North African countries is related to the geographic and ecological particularity of the region. 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. (Scott, 2008)

North Africa's major economic sectors are vulnerable to current climate sensitivity, with huge economic impacts, and this vulnerability is exacerbated by existing developmental challenges such as endemic poverty, complex governance and institutional dimensions; limited access to capital, including markets, infrastructure and technology; ecosystem degradation; and complex disasters and conflicts. These

in turn have contributed to Africa's weak adaptive capacity, increasing the continent's vulnerability to projected climate change.

North Africa has a total area of about 5 million km<sup>2</sup>, of which more than 90% is desert. The climate of North Africa varies substantially between coastal and inland areas of the region. Along the coast, North Africa has a Mediterranean climate, which is characterized by mild, wet winters and warm, dry summers, with ample rainfall of approximately 400 to 600 mm per year. Inland, the countries of North Africa have semiarid and arid desert climates, which are marked by extremes in daily high and low temperatures, with hot summers and cold winters, and little rainfall approximately 200 to 400 mm per year for semiarid regions and less than 100 mm per year for desert regions (CIA, 2009). In Egypt, for example, precipitation is only significant in the northern Mediterranean coast (about 180 mm/year) and it is extremely low in the rest of the country's desert territory.

North Africa is vulnerable to climate change impacts, particularly the Mediterranean regions has been qualified as the « hot spot for climate change» (Giorgi, 2006).

Climate change and its effects on the marine and coastal domain are already perceptible for natural reasons, life styles and the development concentrated on the coastal area (Elrafy, 2009).

Model projections available for North Africa indicate a clear increase in temperature over the next 20 years that is expected to continue throughout the 21st century, probably at a rate higher than the estimated global average (Agoumi, 2003). A new reconstruction of the climate history of the Maghreb concluded that 20<sup>th</sup> century was the driest in North Africa since severe droughts in the 13<sup>th</sup> and 16<sup>th</sup> centuries (Touchan et al., 2010).

The models associated with the A1B scenario predict an average rise in annual temperatures that could reach 2.2 to 5.1°C by the end of the century, higher than the average expected for the planet. The rise should be greater in the interior than on the coasts (Adger, 1999), at sea or in islands, and more noticeable in the summer (2.7 to 6.5°C) than in winter (1.7 to 4.6°C).

Heat waves would then be more numerous, longer and more intense, with frequent days of scorching heat, with all the repercussions that these events could have on human health and the risk of fires (Agrawala et al., 2003). Model simulations also suggest a drying trend in the region, particularly along the Mediterranean coast, driven by large decreases expected in summertime precipitation.

North Africa would be particularly affected by droughts that would be more frequent, more intense and longer-lasting. Drought would be more marked in summer than in winter (Elrafy, 2009).

The projections also announce a drop of 4 to 27% in annual rainfall (PNUE, 2008). Torrential rain will be more frequent.

The water deficit, that represents a major stake for the countries concerned, will be worsened by increased evaporation, the fact that resources will become scarcer and will be over-exploited, and that coastal aquifers will become more salty (Magano *et al.*, 2007). Because coastal areas historically receive by far the largest amount of rainfall in North Africa, future decreases will likely have a significant and noticeable impact. Precipitation trends in the interior semiarid and arid regions of North Africa are more difficult to predict due to the very small amount of natural precipitation that characterizes these areas. Climate change will induce some variations in precipitation patterns, but the trend is not clear, as some models predict slight increases and others predict slight decreases in annual precipitation amounts.

The rise in the sea level is still hard to predict at world level, and more particularly in the Mediterranean basin. According to 2007 projections (IPCC), which are considered to be optimistic, it could rise by 23-47 cm. by the end of the 21st century. Many Mediterranean regions would then run a major risk of being submerged and eroded; among these we can cite the extreme cases of the Kerkennah and Kneiss archipelagos in Tunisia (Ministère de l'environnement, 2001) and Alexandria and the Nile delta in Egypt. In fact, El-Raey *et al.* (1999) assessed losses and socio-economic impacts over the Port Said Governorate in Egypt and found some industries may be seriously affected.

Given the ecological and socioeconomic characteristics of the southern Mediterranean countries, the impact of climate change may be more marked than in other regions of the world. Still, most of the predicted impacts in the region are already occurring regardless of climate change (e.g., water stress and desertification). Climate change is expected to exacerbate these trends.

Based on global climate projections and given inherent uncertainties, the most significant impacts of climate change in North Africa (Morocco, Algeria, Tunisia, Libya, and Egypt) will likely include the especially Water Resource Stress and Agriculture. (Abou-Hadid, 2009).

As one expert stated: "There are two major and immediate consequences. First, rising sea levels will affect coastlines and marine life severely and could impact on desalination plants that are the source of water for the region. Second, rising temperatures mean increasing water demand and with falling freshwater levels and increasing salinity in sea water (which affects the efficiency of desalination plants), water scarcity is a fearsome prospect."

### ***Water Resource Stress***

Water is at the heart of the main expected impacts of climate change on the natural environment in the Mediterranean (El-Quosy, 2009). For the Mediterranean, more than 40 percent reduction in freshwater availability is suggested by the end of this

century along the coastal areas (Abdulla et al., 2009). This may have significant implications for future availability of freshwater resources. Water scarcity, even in the absence of climate change, will be one of the most critical problems facing North African countries in the next few decades (Ashton, 2002).

Model simulations show a general decrease in rainfall across North Africa, with median decreases in average annual precipitation of 12% and 6% projected for the Mediterranean and Saharan regions, respectively (NIC, 2009). This general drying trend for North Africa is punctuated by seasonal variations in projected precipitation that differ by region. It is estimated that Morocco and Algeria's water resources will be reduced by 10-15% by 2020, Tunisia's water resources will decline by 28% by 2030, and 74.8% of Egyptians will have less than adequate fresh water by the same year (Paeth et al, 2009).

Predicted decreases in average annual rainfall, accompanied by projected increases in the population of the region, may impede access to water for millions of inhabitants (Giorgi, 2006). North Africa are particularly exposed to water shortages. An additional 155–600 million people may suffer an increase in water stress in North Africa with a 3 °C rise in temperature. Competition for water within the Region and across its borders may grow, carrying the risk of conflict (FAO, 2008).

Conflicts over water, as have been observed in the past, are likely to surface between African countries. In addition, low-efficiency surface irrigation practices may produce higher water losses, decreases in land productivity, and increased salination.

Soil salination, is particularly pronounced in countries south of the Mediterranean, such as in large parts of Algeria, Libya, and Egypt and a few regions in Morocco and Tunisia. For example, in Tunisia water quality is often a concern, as more than 30% of available water contains more than 3g /l of salt (Abou-Hadid, 2006).

### *Agriculture*

All dimensions of food security (availability, stability, utilization and access) will be affected by climate change. 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. In the other side warmer climate will probably increase crop losses caused by weeds and diseases.

A number of countries in North Africa already face semi-arid conditions that make agriculture challenging, and climate change will be likely to reduce the length of growing season as well as force large regions of marginal agriculture out of production. Projected reductions in yield in some countries could be as much as 50% by 2020, and crop net revenues could fall by as much as 90% by 2100, with small-scale farmers

being the most affected (Boko *et al.*, 2012).

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.

Irrigation plays the most crucial role in the arid regions, which are characterized by low rainfall or evapotranspiration exceeding precipitation most of the year and high interannual rainfall variability.

Accordingly, water scarcity related to climate change is expected to have negative consequences on North Africa's agriculture (El-Shaer *et al.*, 1997). Water and land resources in North Africa are primarily used for agriculture. North Africa accounts for more than 41% (about 6 million hectares) of total irrigated lands in Africa. (Abou Hadid, 2006) Consequently, the Northern region represents more than half of the agricultural water withdrawal of the continent. (Ragab and Prudhomme, 2002) In North Africa, rising temperatures associated with climate change are expected to decrease the land areas suitable for agriculture, shorten the length of growing seasons, and reduce crop yields (Ringius *et al.*, 1996).

The decrease in annual precipitation that is predicted for Northern Africa in the 21<sup>st</sup> century will exacerbate these effects, particularly in semiarid and arid regions that rely on irrigation for crop growth (Hulme *et al.*, 2001).

IPCC (2007) reported that agricultural production in many African countries is projected to be severely compromised by climate variability and change. Yields from rained agriculture in Africa could be reduced by up to 50% by 2020, and the projected sea-level rise will affect low-lying coastal areas with large populations, which will require a total cost of adaptation that could amount to at least 5-10% of GDP.

Model results are inconsistent regarding future changes in crop yields and agricultural growing seasons in North Africa, and we do not know whether variations in temperature, precipitation, or atmospheric CO<sub>2</sub> will be the dominant factor.

Increases in air temperature are also predicted to cause a decrease in the land area suitable for growing wheat, from approximately 106,000 ha of land in Lower Egypt in 2005 to 6,500 ha in 2075.

The 2009 Report by the world Bank, the FAO and the IFAD confirms the average yearly rainfall in the region could decrease by 10% 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% in Algeria and Morocco.

In poorer countries, we estimate that a 1°C rise in temperature in a given year reduces economic growth in that year by about 1.1 points. In rich countries, changes in temperature have no discernable effect on growth.

Accordingly, the study predicts that by 2050, climate change could reduce agricultural yields of several Egyptian crops—from an 11% reduction in rice to 28%

for soybeans when compared to production under current climate conditions. However, the same study suggests that reductions of farm net revenue could be less severe if farmers opt to use heavy machinery on farms, and revenue could even increase if farmers use irrigation (Helmy *et al.*, 2007).

Adaptation to climate change in North Africa is a major issue from the perspectives of food production, rural population stabilization, and distribution of water resources. Previous studies have addressed adaptation in a top-down approach, evaluating theoretical options with little relation to current agricultural management (Abdel Hafez *et al.*, 2003)

Additional anthropogenic disturbances such as deforestation, overgrazing in rangelands, non sustainable irrigation practices, and extractive farming practices, which produce fertility reductions and depletion of carbon stored in the soil, may be contributing to desertification in North Africa.

Continued investment in agriculture research and development is key to sustainable food production as technology may well offset negative impacts of climate change on agricultural production.

### **What about Climate change in Tunisia?**

With opening on the Mediterranean Sea on the North and East, and a long coastline of 1300 km, Tunisia undoubtedly benefits from important economic and ecological assets. It shall be noted that the key position of Tunisia between the tempered regions of the Northern Hemisphere and the inter-tropical regions grant its climate a special variability. Such a characteristic makes Tunisia a country particularly vulnerable to Climate Change (Vicente-Serrano, 2006).

According to the simulations made by climate specialists on the basis of the IPCC (2007) scenarios, it is foreseeable that at the 2100 horizon, a potential increase of the temperature from 1.3 to 2.5 °C, and an elevation of the sea levels from 38 cm to 55 cm will occur. Transposed on an equal scale to the Mediterranean scale, these same assumptions of climate warming and sea level elevations could deeply affect the natural and fitted systems.

In addition, faced with the threats caused by the accelerated sea level rise (ASLR), Tunisia is at risk to be more exposed and thus more vulnerable. In fact, the ASLR can have important harmful consequences on various economic sectors related to the sea or the coast line, as well as on the physical and biological coastal environment and on human settlements. Dasgupta *et al.* (2007) finds that Tunisia is among the top 10 impacted countries in terms of population affected and GDP losses.

The finding, which were presented in a report published in February 2007 (GTZ (2007)), illustrate the dramatic effects of climate change in Tunisia. However, they also show that the impacts for the different regions were widely:

1. Increase in annual average temperature by 1.1°C by 2030. The south of the country will be affected to a far greater extent than the north (1.6°C and 0.9 respectively).
2. The number and intensity of droughts will increase.
3. A 28% decline in Tunisia's water resources by 2030. The loss of groundwater reserves in particular will become a problem.
4. 20% loss in arable cropland by 2030.
5. 50% loss of non-irrigated forested areas in southern Tunisia.
6. Drastically increased risk of forest fires.
7. Substantial increase in the vulnerability of ecosystems. Many of Tunisia's ecosystems are not managed sustainably and therefore have little resilience and are extremely vulnerable. For example, a drought which lasted from 1999 to 2001 caused substantial losses in the agricultural sector, with macroeconomic development falling to the lowest level in the last 20 years in 2002.
8. Many regions would run a major risk of being submerged and eroded

The main risks are erosion, increased salinity and submersion; the whole Tunisian coast is exposed to these risks. The rocky coast and cliffs are the least vulnerable (Dasgupta *et al.*, 2007).

Changes will be noticed in the productivity of fisheries and fishing areas, with an increase in exotic species in sea catch and an increase in the productivity of the lagoon areas and *sebkhas*.

The most exposed sites: the Bizerta lagoon, Garaet Ichkeul, the Ghar el Melh lagoon, the Kalaat el Andalous *sebkhas*, the wetlands and lagoons in the Gulf of Gabès, the archipelagos and islands of Kuriat, Kneiss, Kerkennah and Jerba and all the sandy beach.

This situation clearly demonstrates the major potential impact of climate change in a country such as Tunisia. Far-reaching consequences are anticipated, especially in relation to Tunisia's water supply and therefore also its agricultural sector. The expected sea level rise will put not only agriculture but also tourism – a major economic sector in Tunisia – at risk. The tourism sector is highly sensitive to climate, since climate is the principal driver of global seasonality in tourism demand (Becken and Hay, 2007). Approximately 10% of global GDP is spent on recreation and tourism, constituting a major source of income and foreign currency in many developing countries (Berrittella *et al.*, 2006). In Tunisia, around 80% of the tourism infrastructure is located directly along the coast. In fact, seaside tourism seems likely to suffer damage from most of the effects of climate change, notably beach erosion, higher sea levels, greater damage from sea surges and storms, and reduced water supply. These situations will concern several regions and a diminution of demand from the leisure traveller may be seen (WTO, 2003).

Whatever the environmental outcome, tourism cannot be seen in isolation. Major



changes in the pattern of demand will lead to wider impacts on many areas of economic and social policy - such as, for example, in employment and labour demand and in regional policy issues such as housing, transport and social infrastructure. Knock-on effects could influence other sectors, such as agriculture supplying tourism demand, handicraft industries, local small business networks and so on.

In order to mitigate the impacts of global warming in Tunisia, the adaptation strategy provides for the following measures:

1. Appointment of an interministerial National Climate Council to improve the coordination of measures for adaptation to climate change.
2. Promotion of interdisciplinary climate research and development of appropriate training programmes.
3. Broader-based collection of climate and water resource data to improve the quality of forecasting.
4. Better enforcement of existing water and agricultural ordinances.
5. Introduction of insurance services for climate-related damage in agriculture, with a particular focus in small farmers.
6. Assistance with a restructuring of farms that are affected by climate change.
7. Development of a climate label for agricultural products which are particularly resilient to the impacts of climate change.

## Conclusion

The vast majority of international scientists and peer-reviewed reports affirm that climate change is a serious and growing threat, leaving no country, however wealthy, immune from the extreme weather events and rising sea levels that scientists predict will occur, unless action is taken.

The African countries face numerous environmental challenges and have to reconcile many conflicting priorities, from promoting economic diversification, ensuring water supply and food security, and furthering environmental protection and conservation to adapting to the impacts of global warming.

Future climate change may substantially widen income gaps between rich and poor countries, with many poor countries driven toward greater poverty, other things equal.

The focus is centred largely upon enhancing the capacity of developing countries and the poorest to adapt to the impacts of climate change. As a result, interventions to facilitate adaptation need to identify and address key barriers to ensure that societies are resilient in the face of a changing climate and foster successful adaptation.

The development of clean, climate-friendly energy technologies will provide new business opportunities and new avenues of prosperity for both developed and developing countries alike.

As the causes of climate change are global, however, the challenge can only be met

with all the countries of the world working together. The politics involved are difficult, but we believe progress can be made.

## References

- Abdel Hafez, S. A., Ainer, N. G. and Eid, H. M., 2003. Climate Change Impacts on Delta Crop Productivity, water and agricultural land. *J. Agric.Sci. Mansoura Univ. Special Issue, Scientific Symposium on "Problems of Soils and Water in Dakahlia and Damietta Governorates"*. ISSN 1110-0346 Pp. 15-26 March 18, 2003.
- Abdulla, F., Eshtawi, T. & Assaf, H. 2009. Assessment of the impact of potential climate change on the water balance of a semi-arid watershed. *Water Resour. Manage.*, 23: 2051-2068.
- Abou-Hadid, A.F., 2006. Assessment of impacts, adaptation and vulnerability to climate change in North Africa: food production and water resources. A Final Report Submitted to Assessments of Impacts and Adaptations to Climate Change (AIACC), Project No. AF 90 (Washington, D.C.: International START Secretariat, 2006).
- Abou-Hadid, A.F., 2009. Arab Environment. Climate Change. Impact of Climate change on Arab countries. Report of Arab Forum for Environment and Development. 2009. Eds Mostafa K.Tolba and Najib W. Saab.
- Adger, W. N. 1999. 'Social vulnerability to climate change and extremes in coastal Vietnam' *World Development*, 27: 249-269.
- Agoumi, A. 2003. "Vulnerability of North African Countries to Climatic Changes: Adaptation and Implementation. Strategies for Climate Change," *Climate Change Knowledge Network*, 2003, [http://www.cckn.net/compendium/north\\_africa.asp](http://www.cckn.net/compendium/north_africa.asp).
- Agrawala, S., Moehner, A., Hemp, A., van Aalst, M. Hitz, S., Smith, J., Meena, H., Mwakifwamba, S.M., Hyera, T. and Mwaipopo, O.U. 2003. Development and climate change in Tanzania: focus on Mount Kilimanjaro. Environment Directorate and Development Co-operation Directorate, Organisation for Economic Co-operation and Development, Paris, 72 pp.
- Ashton, P.J. 2002. "Avoiding conflicts over Africa's water resources," *Ambio*, 31: 236-239
- Becken, S. and J.E. Hay, 2007. *Tourism and climate change: risks and opportunities*. Climate Change, Economics and Society Series, Channel View Publications, Clevedon, UK, 352 pp.
- Berrittella M., A. Bigano, and R.S.J. Tol, 2006. A general equilibrium analysis of climate change impacts on tourism. *Tourism Management*, 27(5): 913-924.
- Boko, M., I. Niang, A. Nyong, C. Vogel, A. Githeko, M. Medany, B. Osman-Elasha, R. Tabo and P. Yanda, 2012: IPCC, 2012: *Managing the Risks of Extreme Events*

- and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY, USA, 582 pp.
- Carraro, C. 2002 Climate change policy: models, controversies and strategies. In *The International Yearbook of Environmental and Resource Economics 2002/2003* (ed. T. Tietenberg & H. Folmer), pp. 1-65.
- Central Intelligence Agency (CIA), 2009. *The 2008 World Factbook*, <https://www.cia.gov/library/publications/the-world-factbook/index.html> (accessed May 15, 2009).
- Conway, D. 2005. From headwater tributaries to international river: observing and adapting to climate variability and change in the Nile basin. *Global Environ. Chang.*, 15: 99–114.
- Cox, P. M., Huntingford, C. & Harding, R. J. 1998 A canopy conductance and photosynthesis model for use in a GCM land surface scheme. *J. Hydrol.*, 213: 79-94.
- Dasgupta, S., Laplante, B., Meisner, C., Wheeler, D. and Jianping Yan, J. 2007. “The Impact of Sea Level Rise on Developing Countries: A Comparative Analysis,” World Bank Policy Research Paper 4136 (World Bank, February 2007). <http://www.wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/2007/02/09/000016420070209161430/Rendered/PDF/wps4136.pdf> (assessed May 6, 2009).
- El-Quosy, D. 2009. Impact of Climate Change: Vulnerability and Adaptation. Fresh Water pp 75-86 Report of the Arab forum for Environment and Development. Mostafa K.Tolba and Najib W.Saab Eds.
- El-Raey, M., Dewidar, K.R. & El-Hattab, M. 1999. Adaptation to the impacts of sea level rise in Egypt. *Mitig. Adapt. Strat. Glob. Change*, 4: 343–361.
- Elrafy, M. 2009. Impact of Climate Change: Vulnerability and Adaptation of Coastal Areas. Report of the Arab forum for Environment and Development. Mostafa K.Tolba and Najib W.Saab Eds.
- El-Shaer, M. H., Rosenzweig, C., Iglesias, A. H.M. Eid, H.M. and Hellil, D. 1997. ‘Impact of climate change on possible scenarios for Egyptian agriculture in the future.’ *Mitigation and Adaptation Strategies for Global Change*, 1: 233-250.
- FAO 2008. Newsroom of the United Nations Food and Agriculture Organization, “Agriculture in the Near East likely to suffer from climate change: The hungry and poor will be most affected – FAO meeting debates impact on the region,” (March 3, 2008), <http://www.fao.org/newsroom/en/news/2008/1000800/index.html>.

- Giorgi, F. 2006. 'Climate change hot-spots'; *geophysical Resources Letters*, 33: 707-715.
- GTZ. 2007. *Adaptation to climate change: development of a national strategy for agriculture, ecosystems and water resources in Tunisia 2005 to December 2007*. 3p
- Helmy M., El-Marsafawy, E.S.M. and Ouda, S.A. 2007. "Assessing the Economic Impacts of Climate Change on Agriculture in Egypt: A Ricardian Approach" Policy Research Working Paper (Development Research Group of The World Bank, July 2007),  
[http://www.wds.worldbank.org/external/default/WDSContentServer/IW3P/IB/2007/07/31/000158349\\_20070731143402/Render ed/PDF/wps4293.pdf](http://www.wds.worldbank.org/external/default/WDSContentServer/IW3P/IB/2007/07/31/000158349_20070731143402/Rendered/PDF/wps4293.pdf) (accessed April 6, 2009).
- Hulme, M., Doherty, R., Ngara, T., New, M. and D. Lister, D. 2001. "African Climate Change: 1900-2100." *Climate Research*, 17(2): 145-68.
- Huntingford, C., Lambert, F.H., Gash, J. H. C., Taylor, C. M. & Challinor, A. J. 2005. Aspects of Climate Change Prediction Relevant to Crop Productivity. *Philosophical Transactions: Biological Sciences*, Vol. 360 (1463): 1999-2009.
- IPCC. 2007. Summary for Policymakers', in M. L. Parry et al. (eds.), *Climate Change 2007: Impacts, Adaptation and Vulnerability – Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, University Press Cambridge, Cambridge and New York
- Kaul, I., Conceicao, P., le Goulven, K. & Mendoza, R. U. 2003 *Providing global public goods*. Oxford University Press. (eds)
- Magano, T., Hoshikawa, K., Donma, S., Kume, T., Onder, S., Ozekici, B, Kanber, R. and Watanabe, T. 2007. Assessing adaptive capacity of large irrigation districts towards climate change and social change with irrigation management performance model. In: N. Lamaddalena, C. Bogliotti, M. Todorovic and A. Scardigno (eds.). *Water Saving in Mediterranean Agriculture and Future Research Needs* (Proc. of the International Conf. of WASAMED project, 14-17 February 2007, Valenzano, Italy). *Option Mediterranean Series, CIHAM, B*, 56 (1): 293-302.
- Mann, M. E., Bradley, R. S. & Hughes, M. K. 1998. Global-scale temperature patterns and climate forcing over the past six centuries. *Nature*, 392: 779-787.
- Ministère De L'Environnement et de L'Amenagement du Territoir, 2001. (Ministry of Environment and Land Planning), "Communication Initiale De La Tunisie À La Convention Cadre Des Nations Unies Sur Les Changements Climatiques (Initial Communication of Tunisia to the United Nations Framework Convention on Climate Change)," Republic of Tunisia, 2001,  
<http://unfccc.int/resource/docs/natc/tunnc1esum.pdf>.
- N.I.C. 2009. (NIC 2009-05, August 2009). *Geopolitical Implications*. pp 42.
- P.N.U. 2008. *Climate change and energy in the Mediterranean. Plan Bleu*. Centre d'Activités Régionales. Sophia Antipolis. Juillet 2008

- Paeth, H., Born, K., Girmes, R., Podzun, R. and D. Jacob, D. 2009. "Regional Climate Change in Tropical and Northern Africa Due to Greenhouse Forcing and Land Use Changes." *Journal of Climate*, 22(1) : 114-32
- Ragab, R. and Christel Prudhomme, C. 2002. "Climate change and water resources management in arid and semi-arid regions: prospective and challenges for the 21st century." *Biosyst. Eng.*, 81: 3–34,
- Ringius, L., Downing, T.E., Hulme, M., Waughray, D., Selrod, R. 1996. "Climate Change in Africa - Issues and Challenges in Agriculture and Water for Sustainable Development," ISSN: 0804-4562, Center for International Climate and Environmental Research – Oslo (CICERO) (Oslo: University of Oslo, November 1996).
- Sala, O.E., Chapin, F.S., Armesto, J.J., Berlow, E., Bloomfield, J., Dirzo, R, Huber-Sanwald, E. , Huenneke L F., Jackson, R. B., Kinzig, A. , Leemans, R. , Lodge, D.M., Mooney, H.A., Oesterheld, M., Poff, N.L., Sykes, M.T., Walker, B.H., Walker, M. & Wall, D.H.. 2000. Global biodiversity scenarios for the year 2100. *Science*, 287: 1770-1774.
- Scott L. 2008. Climate variability and climate change: implications for chronic poverty, Chronic Poverty Research Centre Working Paper, N 108.
- Stott, P. A., Tett, S. F. B., Jones, G. S., Allen, M. R., Mitchell, J. F. B. & Jenkins, G. J. 2000. External control of 20th century temperature by natural anthropogenic forcing. *Science*, 290: 2133-2137.
- Touchan, R., Kevin, J., Anchukaitis, D., Meko, M., Sabir, M., Said, A., Aloui, A. 2010. Spatiotemporal drought variability in northwestern Africa over the last nine centuries. *Climate Dynamics*, 2010; DOI: 10.1007/s00382-0100804-4.
- USNRC 2002. US National Research Council. *Abrupt climate change: inevitable surprises*. Washington, DC: National Academies Press.
- Vicente-Serrano, S. M. 2006. Spatial and temporal analysis of droughts in the Iberian Peninsula (1910-2000). *Hydrol. Sci. J.*, 51(1): 83-97.
- World Bank, 2009. *World Development Indicators*. The International Bank for Reconstruction and Development, The World Bank, Washington, District of Columbia, 242 pp.  
<http://devdata.worldbank.org/wdi2006/>.
- W.T.O. 2003. *Climate Change and Tourism*. Proceedings of the 1st International Conference on Climate Change and Tourism. Djerba, Tunisia, 9-11 April 2003.