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Review Article

WHY DON'T ADAPT TUNISIAN AGRICULTURE TO CLIMATE CHANGE?
1. CLIMATE CHANGE AND AGRICULTURE IN TUNISIA

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Abstract: Agriculture is a major activity in Tunisia at the economic and social levels. Until now, not all efforts have been enough to cope with ever-increasing food demand. This situation will become more critical in the current context of climate change that is already starting to impact agricultural production. In fact, agriculture is at a crossroad due to water scarcity, climate change, population pressure and environmental degradation. Both predicting the impact of climate change on agriculture, and finding ways to mitigate these changes, requires diverse skills, expertise and experience.
Extensive agriculture represents 75% of agriculture farms but productivity of this type of agriculture has been continuously very low. This situation will become more acute with the adverse impacts of climate change, which will have a profound impact on human and eco-systems during the coming decades through variations in global average temperature and rainfall. Agriculture performance is projected to drop in the future. In fact, with an increase in temperature at a rate higher than the estimated global average and a larger precipitation decreases, yields of many primary crops will be reduced. In addition, pressures from pests, weeds, and diseases are also expected to increase. Climate change will also affect livestock production in multiple ways, both directly and indirectly.
Sea level rise will cause temporary or permanent submersion of low coastal areas, accelerated erosion and increasing saltwater intrusions. These impacts will significantly affect water resources, natural ecosystems, coastal infrastructure, agriculture and tourism.
Keywords: Agriculture, climate change, desertification, Tunisia.

Introduction

Agriculture is a major activity in Tunisia at the economic and social levels. Until now, these efforts have not been enough to cope with ever-increasing food demand. Indeed, Tunisia is highly dependent on imports of basic agricultural products such as cereals, meat…. Agricultural trade balance of the region is negative because trade coverage reached 61% in Tunisia [1].

The absence of a good rural transport infrastructure, the dry climatic, and soil conditions of this region can partially explain this deficiency in agricultural production [2]. Despite the significant development of irrigated areas due to the building of various categories of dams, production of several crops, particularly grain yields are still very low. This situation will

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become more critical in the current context of climate change that is already starting to impact agricultural production around the globe. In this context, [3] had reported that agriculture is at a crossroad due to water scarcity, climate change, population pressure and environmental degradation.

In fact, without productivity growth commensurate with demand growth, pressures to increase the amount of land under cultivation for the production of food will increase. But, there is a potentially vicious spiral of increased land use, increased global climate change risk, and decreasing availability of land cultivatable at high levels of productivity.

Climatic constraints, especially the scarcity of water and land resources have always been characteristic of Mediterranean agricultural systems. In fact, drought, which is the main factor influencing crop production in semi arid and arid areas (like Tunisia) is already impacting on natural systems and crop productivity and researchers need to act now to mitigate climate change and to prepare for the future.

The question is how can improve crops management, enhance resilience to climate change and contribute to adaptation strategies?

Both predicting the impact of climate change on agriculture, and finding ways to mitigate these changes, requires diverse skills, expertise and experience.

What about agriculture in Tunisia?

Agriculture is a major activity in Tunisia at the economic and social levels. It represents 6% of GDP, 10% of total investments, 11% of total exports and employs 16% of active population [4].

In Tunisia, we have two kinds of agriculture: an extensive agriculture and an intensive one. The first represents 75% of agriculture farms. It is executed by families and takes place in very small lands (less than 10 hectares). The majority of farmers have, on average, more than 60 years. These farmers suffer from the weakness of infrastructure, a very low instruction level, a tricky access to markets and transformation units as well as an absence of financial subsidies. Combined with irregular rainfall and lack of access to equipment (average 159 tractors per 100 km^2 of arable land), seeds and fertilizers, productivity of this type of agriculture has been continuously very low [4].Even if it represents a small fraction of national production, the extensive agriculture is important for many reasons. Indeed, paying attention to this kind of agriculture allows government to reduce poverty and inequality, guarantees equilibrium between rural and urban population as well as improve town planning and economic growth.

The second type that is intensive is led by capitalists with much tied link to local agribusiness industry [2]. Despite these two types of agriculture, the trade balance of Tunisian agriculture is still negative [1]. This situation will become more acute with the adverse impacts of climate change, which will have a profound impact on human and eco-systems during the coming decades through variations in global average temperature and rainfall [5]. Agriculture performance is projected to drop in the future because of more frequent drought periods [6]. So, all dimensions of food security (availability, stability, utilization and access) will be affected.

In Tunisia, 51% of the water resources are surface waters and 49% are underground waters [7]. Water exploitation ranges from dams (20.5%) and groundwater resources (33.2%) to deep water resources (46.3%).

Agriculture is the main user of land and the number one water consumer with a proportion of 83% of total available resources of the total national water consumption. As noted by Horchani [8], 2100 million m^3 of water are used for irrigation with an average consumption per ha of approximately 5500 m^3/year.

Irrigated area (8% of total cultivated land) constitutes an important pillar of the agricultural economy because it provides 40% of the production, 10% of the exports (of the sector), and 27% of the workforce [4]. However, if the irrigation so far to increase and diversify agricultural production and initiate a process of consolidation and promotion of family farms in a natural environment binding, a multitude of constraints makes the extension of irrigation increasingly problematic. The increase in irrigated areas has led to a rapid increase in consumption of water for irrigation, so that the prospects of development of the sector remain fundamentally linked to water availability. As such, it should be noted that, with a rate of mobilization that exceeds 95%, Tunisia approaching the physical limits of water it can mobilize. The limit is already reached for ground water that is subject to over-exploitation in recent years. Besides water scarcity, its quality constitutes an additional problem because the salinity of most water resources exceeds the international threshold for health and agricultural uses [9]. Salinity would be increase in next decade as a result of overexploitation of groundwater and intrusion of the seawater.

In Tunisia, the area of agricultural land is estimated at 10 million ha, divided between 5 million ha of arable land, 4 million ha of rangeland and 1 million ha of forest and scrubland [4]. Tunisian agriculture remains focused in the crop sector, providing more than 80% of the total value of the sector, the remaining 20% coming from the animal sector.

Agricultural production in Tunisia is extensive and the main products are olive oil, citrus fruit, cereals, dates, and several horticultural products.

The main rain-fed crops grown are cereals (mainly wheat and barley) that represent about two-thirds of cultivated areas and 16% of agricultural production, followed by tree crops (mainly olives) covering circa 40% of cultivated areas and representing 28% of agricultural production and 60% of exported foods. The remaining is divided between forage crops, vegetable crops, legumes and others [4].

Annual agricultural production and yield of mainly crops, especially cereals, can vary significantly from year to year due to Tunisia's unpredictable and largely irregular rainfall patterns [10].

Grain yields are still very low in Tunisia (1-2 t h^{-1}) and are under the average yields in other Euro-Mediterranean countries [11] and for MENA countries [4].

For the last two decades, Tunisia has been a net importer of agricultural products [12]. Leading agricultural imports in 2016 were wheat ($474 million), soybeans ($204 million), corn ($110 million), vegetable oils ($185 million), sugar ($177 million), and barley ($110 million). The leading agricultural exports were olive oil ($407 million), dates ($227million), fish ($126 million), and citrus (($11million).

Organic agriculture is relatively new in Tunisia. However, in the last ten years, organic land area, number of farmers, and crop diversification increased rapidly. With 155,323 hectares under organic management, that represent 1.59 % of total agricultural area, Tunisia has now one of the most developed organic sectors in Africa [13]. Since there is not yet a strong domestic demand market for organic products, most of the production is directed to the export market. Some of the farmers are producers and exporters at the same time.

About three quarters of organic land in Tunisia is dedicated to growing olives, many of which are processed into oil. Organic olive farmers receive a price premium ranging from 10 to 20 % relative to non-organic products [14]. Other crops include dates, jojoba, almonds, fruits and vegetables, honey and aromatic plants [15]. In recent years, organic livestock husbandry in Tunisia has expanded significantly.

What about climate change in North Africa, especially in Tunisia?

North Africa is vulnerable to climate change impacts; particularly the south Mediterranean regions have been qualified as the « hot spot » for climate change [16, 17]. Model projections 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 [5]. In

fact, 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 [18]. The rise should be greater in the interior than on the coasts [19] 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 [20,21].

Paeth et al. [22] estimate that by 2050 surface temperatures in North Africa will increase by approximately 1.5 to 2 °C and precipitation will decrease by 10 to 30% across many of the desert areas of the region, with larger precipitation decreases along the coasts of Morocco, Algeria and Tunisia.

North Africa would be particularly affected by droughts that would be more frequent, more intense and longer-lasting [23]. Drought would be more marked in summer than in winter [24]. Recent transient model runs for the 2020s suggest an overall decrease of between 1.5 and 7.3% [25,26] projections announce a drop of 4 to 27% in annual rainfall.

Severe drought is common in North Africa [27]. Prolonged droughts were reported in Morocco and in Tunisia [28]. During the 20thcentury, Tunisiahas experienced severalsevere droughts [29]. These droughts have not affected the different decades with the same frequency. For example, the years 1950 and 1970 are distinguished by the appearance of low dry years. In the years 1920, 1940,1960 and 1980 multi-years droughts was recorded with a large spatial extension and a high rainfall deficit [30].

Over the last few decades the northern regions of North Africa (north of the Atlas Mountains and along the Mediterranean coast of Algeria and Tunisia) have experienced a strong decrease in the amount of precipitation received in winter and early spring [31]. The observed record also indicates greater than 330 dry days (with less than 1 mm day rainfall) per year over the 1997–2008 time period [32].

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 [33].

In addition, the rate of desertification would increase due to increases in erosion, salinization and fire hazard and reductions in soil quality. As a result, the process of desertification is likely to become irreversible. The economic and human costs of an increase in desertification would be tremendous - even today, the annual costs of desertification in Tunisia is US$100 million [34].

While desertification is in part a product of climate change, there are also important feedbacks on local climate. In fact, land degradation tends to reduce soil moisture and this in turn reduces evaporation resulting in increased maximum temperatures and lower rainfall [35].

Reductions in vegetation have a similar effect as this reduces the amount of water captured and then recycled through evapotranspiration to create rain. Analysis of temperature data for this century shows that warming was nearly 0.2°C greater over dryland areas than over land areas as a whole [36].

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)[37] 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 [38].

According to the GIEC [39] an elevation of the sea levels from 38 cm to 55 cm will occur in Tunisia that could deeply affect the natural and fitted systems. Rising sea levels would bring the risk of inundation, higher rates of erosion and increased saline intrusion. As a consequence, some low-lying coastal areas would be lost through flooding or erosion, while rivers and coastal aquifers would become more salty [40]. The ASLR can have important harmful consequences on various economic sectors related to the sea or the coastline, as well as on the physical and biological coastal environment and on human settlements [41]. A sea level rise of 1 m would affect 5% of the population in Tunisia [42].

Several recent studies reported evidence of climate change in the last decades over the Mediterranean and tried to foresee the expected trend and its impact on Mediterranean agriculture in the future [43, 44, 45, 46].

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 [47]. In this context, [48] showed that increasing temperatures and declining precipitation over semi-arid regions are likely to reduce yields of many primary crops in the next two decades. These changes could have a substantial negative impact on global food security.

The effects of climate change could influence the viability and relevance of water development policies, given that economic growth and development of the majority of

Maghreb countries are closely related to water resources that contribute strongly to the socioeconomic balance and gross domestic product.

Water is at the heart of the main expected impacts of climate change on the natural environment in the Mediterranean [49]. In fact, all climate change scenarios in the Mediterranean region reported that available water resources will decrease while irrigation demand increases [50].

Water scarcity is endemic in North African regions, making these countries particularly vulnerable to any reduction in supplies. For these regions, more than 40 percent reduction in freshwater availability is suggested by the end of this century along the coastal areas [51].

In this context, The World Bank warned in 2004 [52] that Tunisia is one of 17 countries where water resources will be an "absolute rarity" by 2025 and [53] estimated that 80% of Tunisian available water resources would lost by 2040. 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 [54, 55].

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 [56]. 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 [22].

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 [16, 57].North Africa is particularly exposed to water shortages, particularly Tunisia as a whole suffers from high water scarcity [58, 59].

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 [60].

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 salinization. Soil salinization, 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 [61].

The impact of the climate change on the Mediterranean agriculture is already evident in many areas and especially in arid and semi-arid regions. The available evidence suggests that climate change will have a deleterious impact on food production throughout the region, increase prices and add to food insecurity in the southern basin. Tunisia is among countries threatened by these phenomena and among the top 10 impacted countries in terms of population affected and GDP loses [62]. The overall assessment of the costs of environmental damage for water, air, soils and forests, coastlines and wastes amounts to an average of 2.5% of GDP [63]. 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 [64].

In many developing countries, a central pillar of the economy is agriculture, which is largely dependent on the climate [65, 66]. Several recent studies reported evidence of climate change in the last decades over the Mediterranean and tried to foresee the expected trend and its impact on Mediterranean agriculture in the future [45,46,67]. Adaptation measures suited to local circumstances and productive systems must be identified; such measures included, inter alia, the development of improved seed varieties adapted to new agro-climatic conditions, heat and/or water stress and exposure to different pests [68].

References

[1] Alvarez-Coque, J.M.G. ; 2012. Agriculture in North Africa: A Chance for Development. The German Marshall Fund of the United States. Mediterranean Policy Program- Series on the Region and the Economic Crisis, Washing-ton, Accessed at: http://www.gmfus.org/publications/agriculture-north-Africa-chance-development.

[2] Ben Jebli, M. and Ben Youssef, S.; 2017. The role of renewable energy and agriculture in reducing CO2 emissions: Evidence for North Africa countries. Ecological Indicators, 74: 295-301.

[3] Agbicodo, E.; Fatokun, C.; Muranaka, S.; Visser, R.; Linden, C.; 2009. Breeding drought tolerant cowpea: constraints, accomplishments, and future prospects. Euphytica, 167: 353-370.

[4] I.T.E.S. (Institut Tunisien des Etudes Stratégique) ; 2017. La sécurité alimentaire et nutritionnelle en Tunisie. 216 pp

[5] Radhouane, L.; 2013a.Climate change impacts on North African countries and on some Tunisian economic sectors. Journal of Agriculture and Environment for International Development (JAEID), 107 (1): 101–113.

[6] Palmer, M.A.; Lettenmaier, D.P.; LeRoyPoff, N.; Postel, S.L.; Richter, B.; Warner, R.; 2009.Climate Change and River Ecosystems: Protection and Adaptation Options. Environmental Management, 44(6):1053-1068.

[7] Ministry for Agriculture and Water Resources (MARH) (Tunisia) and Gesellschaftfür Internationale Zusammenarbeit (GIZ); 2007.Stratégie Nationale d'Adaptation de l'Agriculture Tunisienne et des Ecosystèmes aux Changements Climatiques [National adaptation strategy for adaptation in agriculture and ecosystems], Tunis. 52 pp.

[8] Horchani, A.; 2007. Agriculture Water Management. Proceeding of a Workshop in Tunisia. Laura Holliday, Editor. National Academies Press, pp. 88-96. Available at: www.nap.edu/catalog/11880.html.

[9] Mamou, A. and Kassah, A.; 2000. Economie et valorisation de l'eau en Tunisie. Sci. Changements Planétaires/ Sècheresse, 11 (4) : 249-256.

[10] Deghais, M.; Kouki, M.; El Gharb, M.S.; El Felah, M.; 2007. Les variétés de céréales en Tunisie. République Tunisienne, Ministère de l'Agriculture et des Ressources Hydrauliques, 445 p.

[11] Dhehibi, B.; Frija, A.; Aw-Hassan, A.; 2014. Performances, Policies, Challenges and Opportunities of the Tunisian Agriculture Sector from Natural Resources Management Perspective a SWOT Analysis. American-Eurasian J. Agric. & Environ. Sci., 14:1351-1358.

[12] F.A.S. (Foreign Agricultural Service); 2017. Reports on Tunisia agricultural sector. http://export.gov/usoffices.

[13] FIBL and IFOAM; 2017. The World of Organic Agriculture Statistics and Emerging Trends. 340 pp. Edited by Helga Willer and Julia Lernoud. http://www.organic -world.net/ yearbook/ 2017.html.

[14] Twarog, S.; 2006. Organic agriculture: a trade and sustainable development opportunity for developing countries. In: UNCTAD. Trade and Environment Review 2006. Geneva and New York. UNCTAD.

[15] IFOAM; 2003. Organic and like-minded movements in Africa. IFOAM, Bonn.

[16] Giorgi, F.; 2006. Climate change hot-spots. Geophysical Resources Letters, 33: 707-715.
[17] Rochdane, S.; Bounoua, L.; Zhang, P.; Imhoff, M.L.; Messouli, M.; Yacoubi-Khebiza, M.; 2014.Combining satellite data and models to assess vulnerability to climate change and its impact on food security in Morocco. Sustainability, 6: 1729-1746.
[18] Engelbrecht, F.; Adegoke, J.; Bopape, M.J.; Naidoo, M.; Garland, R.; Thatcher, M.; McGregor, J.; Katzfey, J.;Werner, M.; Ichoku, C.; Gatebe, C.; 2015. Projections of rapidly rising surface temperatures over Africa under low mitigation. Environmental Research Letters, 10(8):085004
[19] Adger, W.N.; Huq, S.; Brown, K.; Conway, D.; Hulme, M.; 2003.Adaptation to climatechange in the developing world. Prog. Dev. Stud., 3: 179-195.
[20] Agrawala, S.; Moehner, A.; Hemp, A.; van Aalst, M.H.; S.; Smith, J.; Meena, H.;Mwakifwamba, S.M.; Hyera, T.; 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.
[21] Seif-Ennasr, M.; Zaaboul, R.; Hirich, A.; Caroletti, G.N.; Bouchaou, L.H.; Morjani, Z.A.; Beraaouz, E.H.; McDonnell, R.A.; Choukr-Allah, R.; 2016. Climate change and adaptive water management measures in Chtouka Aït Baha region (Morocco). Science of the Total Environment, 573: 862-875
[22] Paeth, H.; Born, K.; Girmes, R.;Podzun, R.; Jacob, D.; 2009. “Regional Climate Change in Tropical and Northern Africa Due to Greenhouse Forcing and LandUse Changes.” Journal of Climat, 22(1): 114-132
[23] W.M.O. 2013. A Summary of Current Climate Change Finding and Figures. AWMO information note. World Meteorological Organisation, Geneva, Switzerland.8 pp.
[24] Elrafy, M.; 2009. Impact of Climate Change: Vulnerability and Adaptation of CoastalAreas. Report of the Arab forum for Environment and Development. Mostafa, K. Tolba and Najib,W. Saab Eds. AFED, 181 pp.
[25] Rosenzwieg, C. and Tubiello, F.N.; 1997. Impacts of global climate change on Mediterranean agriculture: current methodologies and future directions. An introductory essay. Mitigation and Adaptation Strategies for Global Change, 1(3): 219-232.
[26] P.N.U.; 2008. Climate change and energy in the Mediterranean. Plan Bleu. Centre d’Activités Régionales. Sophia Antipolis. Juillet 2008.

[27] Hoerling, M.P. and Kumar, A.; 2003. The perfect ocean for drought. Science, 299:691–694

[28] Simonneaux, V.; Cheggour, A.; Deschamps, C.; Mouillot, F.; Cerdan, O.; Le Bissonnais, Y.; 2015. Land use and climate change effects on soil erosion in a semi-arid mountainous watershed (High Atlas, Morocco). J. Arid Environ, 122: 64-75.

[29] Louati, M.H. and Bucknall, J.; 2010. Tunisia's experience in water resource mobilization and management. Development and climate change. Background note World development report.25pp.http://siteresources.worldbank.org/INTWDRS/Resources/4773651327504426766/8389626-1327509184256/WDR2010 BG-Note-Louati.pdf

[30] Hénia, L.; 2001. Les grandes sécheresses en Tunisie au cours de la dernière période séculaire, Eau, Environnement et milieux méditerranéens, ENS Editions,p. 25-36.

[31] Barkhordarian, A.; J. Bhend, J.; von Storch, H.; 2012. Consistency of observed near surface temperature trends with climate change projections over the Mediterranean region. Climate Dynamics, 38(9-10): 1695-1702.

[32] Vizy, E.K. and Cook, K.H.; 2012. Mid-twenty-first-century changes in extreme events over northern and tropical Africa. Journal of Climate, 25(17): 5748-5767.

[33] Magano, T.; Hoshikawa, K.; Donma, S.; Kume, T.; Onder, S.; Ozekici, B.;Kanber, R.; 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, 14-17February 2007, Valenzano, Italy). Option Mediterranean Series, CIHAM, B, 56(1): 293-302.

[34] Karas, J.; 2000. Climate change and the Mediterranean region, p13-17.
http://www.greenpeace.org/ raw/ content/international/press/reports/climatechange-and-the-mediter.pdf

[35] Cotton, W.R. and Pielke, R.A.; 1995. Human Impacts on Weather and Climate. Cambridge: CambridgeUniversityPress.125 pp.

[36] Jones, P.D.; 1994. Hemispheric surface air temperature variations: a reanalysis and an update to 1993. J. Climatol., 7: 1794-1802.

[37] IPCC, 2007. Climate change 2007. Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Eds: Metz, B.; Davidson, O.; Bosh, P.; Dave, R.; Meyer, L. Cambridge University Press. 863 pp.

[38] 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 Tunisiato the United Nations Framework Convention on Climate Change).Republic of Tunisia, 2001. http://unfccc.int/resource/docs/natc/tunnc1esum.pdf.

[39] GIEC ; 2014. Changements climatiques 2014 : Rapport de synthèse. Contribution des Groupes de travail I, II et III au cinquième Rapport d'évaluation du Groupe d'experts intergouvernemental sur l'évolution du climat [sous la direction de l'équipe de rédaction principale, R.K. Pachauri et L.A. Meyer].GIEC, Genève, Suisse, 161 pp.

[40] Nouaceur, Z.; Laignel, B.; Turki, I.; 2013. Changements climatiques au Maghreb : vers des conditions plus humides et plus chaudes sur le littoral algérien ? Physio-Géo, 7: 307-323

[41] Driouech, F.; Ben Rached, S.; El Hairech, T.; 2013. Climate Change and Food Security in West Asia and North Africa. Springer Science + Business Media, Dordrecht, 161-171.

[42] Tolba, M.K. and N.W. Saab; 2008. Arab Environment: Climate Change, Impact of Climate Change onArab Countries. Report of the Arab Forum for Environment and Development AFED, Beirut. 285 pp.

[43] Giorgi, F. and Lionello P.; 2008. Climate change projections for the Mediterranean region. Glob. Planet. Chang., 63: 90-104.

[44] I.P.C.C.; 2014. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, ed. CB Field, VR Barros, DJ Dokken, KJ Mach, MD Mastrandrea, et al. Cambridge, UK/New York: Cambridge Univ.Press, 350 pp.

[45] Tanasijevic L.; Todorovic M.; Pereira L.S.; Pizzigalli C.: Lionello P.; 2014. Impacts of climate change on olivecrop evapotranspiration and irrigation requirements inthe Mediterranean region. Agric. Water Manage., 144:54-68.

[46] Saadi S.; Todorovic M.; Tanasijevic L.; Pereira L.S.; Pizzigalli C.; Lionello P.; 2015. Climate change and Mediterraneanagriculture: impacts on winter wheat and tomato crop evapotranspiration, irrigation requirements and yield. Agric. Water Manage., 147 : 103–115.

[47] Abou-Hadid, A.F.; 2009. Arab Environment. Climate Change. Impact of Climate change on Arab countries. Report of Arab Forum for Environment andDevelopment. 2009. Eds MostafaK.Tolba and Najib W. Saab. AFED, 181 pp.

[48] Lobell, D. B.; Burke, M. B.; Tebaldi, C.; Mastrandrea, M. D.; Falcon, W.P.; Naylor, R. L.; 2008. Prioritizing climate change adaptation needs for food security in 2030. Science, 319: 607-610.

[49] 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.MostafaK.Tolba and NajibW.Saab Eds. 350 pp.

[50] Iglesias, A.; Garrote, L.; Flores, F.; Moneo, M.; 2007. Challenges to manage the risk of water scarcity and climate change in the Mediterranean. Water Res. Manag., 21: 775-788.

[51] 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.

[52] World Bank; 2004. Tunisia - Country Environmental Analysis (1992-2003) Final Report. Washington, DC: World Bank. Available at: http://documents.worldbank.org/curated/en /2004/04/5757452/Tunisia-country environmental- analysis-1992-2003-final-report.

[53] Luo, T.; Young, R.; Reig, P.; 2015. Aqueduct Projected Water Stress Country Rankings. Technical Note. World Resources Institute: Washington D.C. www.wri.org/sites/default/files/aqueduct-water-stress-country-rankings-technical-note.pdf

[54] Ashton, P. J.; 2002. "Avoiding conflicts over Africa's water resources," Ambio, 31: 236-239

[55] Iglesias, A. and Garrote, L.; 2015. Adaptation strategies for agricultural water managementunder climate change in Europe. Agric. Water Manag., 155: 113-124.

[56] N.I.C.; 2009. (NIC 2009-05, August 2009). Geopolitical Implications. pp 42.

[57] Sowers, J.; Vengosh, A.; Weinthal, E.; 2011. Climate change, water resources, and the politicsof adaptation in the Middle East and North Africa. Clim. Chang., 104: 599-627.

[58] Milano, M.; Ruelland, D.; Fernandez ; S.; Dezetter, A.; Ardoinbardin,S.; Fabre, J.; Thivet, G.; Servat, E.; 2013. Current state of Mediterranean water resources and future trends under climatic andanthropogenic changes, Hydrol. Sci. J., 58 (3): 498-518.

[59] Chouchane, H.; Hoekstra, A.Y.; Krol, M.S.; Mekonnen, M.M.; 2015. Water footprintof Tunisia from an economic perspective. Ecol. Indic., 52: 311-319.

[60] 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.

[61] 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).

[62] Dasgupta, S.; Laplante, B.; Meisner, C.; Wheeler, D.; Yan, J.; 2007. "TheImpact of Sea Level Rise on Developing Countries: A Comparative Analysis,"World Bank Policy Research Paper4136 (World Bank, February 2007).
http://wwwwds.worldbank.org/servlet/WDSContentServer/WDSP/IB/2007/02/09/000016420070209161430/Rendered/PDF /wps4136.pdf

[63] Selmi, A. et Abassi, M. ; 2013. La dégradation des terres : une mise en perspective à l'horizon 2050. Contribution à la réalisation d'une étude prospective sur « la sécurité alimentaire et environnementale en Tunisie ». ITES, 25pp.

[64] Vicente-Serrano, S. M.; 2006. Spatial and temporal analysis of droughts in the Iberian Peninsula (1910-2000). Hydrol. Sci. J., 51(1): 83-97.

[65] IPCC; 2001. Climate change 2001: the scientific basis. In: Houghton, J.T., Ding, Y., Griggs, D.J., Noguer, M.,van der Linden, P.J., Dai, X., Maskell, K., Johnson, C.A. (Eds.), Contribution of Working Group I to theThird Assessment Report. Cambridge University Press, Cambridge.

[66] Adger, W.N.; Huq, S.; Brown, K.; Conway, D.; Hulme, M.; 2003.Adaptation to climatechange in the developing world. Prog. Dev. Stud., 3: 179-195.

[67] I.P.C.C.; 2014. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, ed. CB Field, VR Barros, DJ Dokken, KJ Mach, MD Mastrandrea, et al. Cambridge, UK/New York: Cambridge Univ. Press, 350 pp.

[68] UNFCCC.; 2015. Report of the Conference of the Parties on its twenty- first session, held in Paris from 30 November to 13 December 2015. 42 pp.