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WHY DON'T ADAPT TUNISIAN AGRICULTURE TO CLIMATE CHANGE?

2. HOW CLIMATE AFFECTS AGRICULTURE?

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Abstract: Climate change is characterized locally by several changes that modify the conditions of production. In fact, increasing temperature may affect the whole plant metabolism like rate of photosynthesis, respiration, and grain filling. In addition, water scarcity and low precipitation events and variability precipitation patterns even in small changes could influence the future of crop.
Under climate change, pressures from pests, weeds, and diseases are also expected to increase, with detrimental effects on crops and livestock.
The potential impacts of climate change include sea level rise, 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.
Climate change affects livestock production in multiple ways, both directly and indirectly. The most important impacts are experienced in animal productivity, yields of forages and feed crops, animal health and biodiversity.
Key words: temperature, rainfall, pests, sea level, Tunisia.

Introduction

Global climate change is characterized locally by several changes that modify the conditions of production. [1] found that without adaptation by farmers, global crop yields under climate change would be 6.9% below estimated yields without climate change.

Several studies reveal that increasing temperature and the changing pattern of rainfall have a substantial impact on food production [2,3]. In fact, phenology [4] nutrient allocation and accumulation [5] and key soil processes [6] have been shown to be affected by rainfall and temperature manipulations.

What does this mean for agriculture and food production? In short, declining productivity, shorter growing seasons, and less cultivable land.

The dry areas (Tunisia case) are highly vulnerable to the impacts of climate change. Rising temperatures and increasing water scarcity – already bad – are expected to get significantly worse.

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1. Increase temperature impacts

Temperature affects the whole plant metabolism like rate of photosynthesis, respiration, and grain filling. When temperature exceeds optimum plant required, all physiological processes would decline or stop. The rise in temperature, even by a single degree beyond the threshold level, is considered heat stress in plants [7].

In this context, several researchers have predicted that warming in Mediterranean region would decline yields by up to 30% by the 2050, again dependent on crop [8,9,10,11]. In these countries, cereal yields are limited by water availability, heat stress andthe short duration of the grain-filling period [12].

[13, 14, 15, 16] estimated that 20–30 % wheat yield losses will occur by 2050 in developing countries (where around 66 % of all wheat is produced) as a result of a predicted temperature increase of 2-3°C. If temperatures rise by 4 ° C, as some models predict, vast swathes of the dry areas would see their growing seasons cut by more than 20% [17]. The areas occupied by cereals would decrease from 1 021 000 ha to 854 000 ha (-20% by 2030) [18].

[19] found negative relationships between wheat, maize and barley with temperature.They predicted that warm temperature could lead to the reverse of the vernalizing effects of cold temperatures in wheat.

Warmer temperatures may increase agricultural productivity in some temperate zones by extending the growing season. However, the increase in both the regularity and severity of droughts (Tunisia case) will likely negate these positive factors.

In arid regions, higher temperatures may be more immediately detrimental, increasing the heat stress on crops and water loss by evaporation. The change in variability of temperatures exceeding the optimal range for yield formation was more important in explaining the yield variability change than other abiotic stresses, such as temperature below the optimal range for yield formation and soil water deficit [20]. In fact, at 28°C local warming at low latitudes, wheat production could decrease by nearly 10 % [21]. The same authors stipulated that small increases in temperature in low latitudes may have a greater impact than in high latitudes, possibly because agriculture in parts of these regions is already marginal. [22] indicated that a few days of extreme temperature (≥ 32°C) at the flowering stage of many crops can drastically reduce yield. Researchers found that wheat production would fall by 6% for every 1°C increase in temperatures [23, 24]. Previously, [25] reported 3-4% reductions in wheat yield for every 1°C rise in temperature.

Wheat production in Northern Africa is expected to be vulnerable to warming trends [26]. Estimates of yield losses elsewhere (including CO_2 fertilization) are 18% for wheat in Northern Africa and 22% for maize in southern Africa [27].

Grassland productivity is likely to be reduced by warming and precipitation changes in the Mediterranean[28].In North Africa, depending on the model used, rising temperatures and increasing water scarcity could cause rain-fed cereal production to decline by as much as 6.5% and production from the region's grasslands by 49-33 %. It's predicted also that climate change could also reduce the nutritional content of wheat [29, 30].

Permanent crops (olive, grapevine, fruit trees etc…) are therefore more important in this region. These crops are affected by extreme weather events (such as hail and storms) which can reduce or completely destroy yield.

Legumes and C_3 summer crops showed a general reduction of yields in all the hot spots of the Mediterranean basin [31].

Several Tunisian researchers [32, 33] had found that impact of climate change is now perceptible, particularly in the Tunisian central region (Kairouan) where projected climate change will result in worsening conditions for rain-fed crops. In fact, the length of the wheat-growing season was estimated for different levels of temperature increase as projected by the IPCC scenarios (1.3°C, 2°C, 2.5°C and 4°C). Results show a shortening of the growing season that varies in relation to the temperature increase. In actual climate conditions and in the experimental field, the wheat growing duration is equal to 193 days. By 2100, the wheat growing season would be shortened by 10 days for 1.3°C temperature increase conditions, by 16 days for 2°C, by 20 days for 2.5°C and by 30 days for 4°C. Similarly, crop cycle mean duration is reduced of approximately 25 days at Jendouba [34]. Other researchers [35, 36] found that Béjà region may record losses in cereals by 2030 common wheat would be the most affected.

It is expected that wheat production in areas with similar climatic and geographical conditions may be affected in similar ways. Important cuts of cereal areas in NW and CW of Tunisia are predicted [37].

The impact of annual temperature on olive output is negative and statistically significant, with a 1% increase in temperature leading to more than a 0.27% decrease in olive production for all regions. Thus, the temperature effect reveals that central and southern regions are more affected by heating than other regions in the north [38].

It has been shown that the rise in maximum temperatures in northern Tunisia could decrease growth and flowering cycles of olive by three weeks in 2050 [39].

Declining wheat productivity and rising wheat prices will affect most severely North African countries with high rates of poverty and high dependence on wheat for their food security [1]. As climate change will affect many crops around the world, the price of some foods such as wheat, corn, soybeans ... will increase, which will have a negative economic impact on these regions. In addition, the combination of rising prices and decreases in production will inevitably lead to deterioration in the level of food security.

According to [40], many of countries, particularly in North Africa, the Middle East and South-East Asia show high exposure to price increase, in its stress test, including Morocco, Bangladesh, Tunisia and Indonesia.

2. Effect of rainfall decrease

Water is vital to plant growth, so varying precipitation patterns have a significant impact on agriculture. Water resources are particularly vulnerable to climate change. The main indirect problem caused by climate change is water scarcity, as rainfed agriculture represents 90% of Tunisia's agricultural area [41]. Projections of future precipitation changes often influence the magnitude and direction of climate impacts on crop production [42, 43].

[44] estimated future increases in irrigation water requirements by over 50% in developing regions and by about 16% in developed regions.[45] pointed to the risk of increasing irrigation water requirements under climate change in some regions, including the Mediterranean. These conclusions are complemented by a number of local-scale studies, focused on a reduced number of crops. [46] estimated that eastern and southern Mediterranean will need around 35% more water than today, with the highest values under 3 and 5°C global warming, respectively

In 2030, conventional water resources will only cover 91% of needs [47].

Projections using HadCM3 model under A2 scenario for Tunisia show overall decrease in mean precipitations. This decrease is relatively moderate by 2020 but will intensify by 2050. The frequency of drought years is projected to increase by 10% to 30% by 2050.The models show that conventional water resources will decrease of about 28% by 2030. This decrease will mainly affect shallow aquifers with high salinity, coastal aquifers and non-renewable aquifers. In particular, the decrease in surface water reserves will be of about 5% by 2030. The confrontation between available water resources and increasing water demand shows that this demand will not be met by 2030 without the implementation of more efficient water conservation strategies and programs of activities. According to these forecasts, the areas reserved to irrigated crops would slightly decrease from 389 000 ha during the period 2006-2011 to 376 000 ha by 2030 [48]. The needs in water for irrigation would reach almost 1.2 billion m^3 by 2030 [48]. Whatever the considered scenario. This water demand has to be compared to availability deducted from water resources forecasts under climate change. But in Tunisia, fresh water mobilization has reached its limits and any further investments for water mobilization will be very costly [49].

Northern Africa is expected to experience a drier future in both global and regional projections under modest to high warming scenarios, with significant decreases in winter and spring rainfall in the northern basin of Tunisia that is the rainiest part of the country [50, 51].

Increased occurrence and duration of droughts could reduce yields and pasture productivity, increase risk ofcrop failures, livestock deaths, soil erosion and land degradation [52, 53].

Water scarcity will impact crop productivity. In fact, low precipitation events [54] and variability precipitation patterns even in small changes could influence the future of crop. In this context, [55] report that a change in growing season precipitation by one standard deviation can be associated with as much as a 10% change in production. [56] estimated that drought related yield reductions would increase by more than 50% by 2050 for the major crops.

[57] showed, the yields of wheat production in Kairouan will decrease by 48% if precipitation decreases by 10% and the temperature increases by 1.5°C, and by 12% if rainfall alone decreases by 10%. With a temperature rise of 1.3°C, the growing season is shortened by 10 days.

Precipitation is not the only influence on water availability. Increasing evaporative demand owing to rising temperatures and longer growing seasons could increase crop irrigation requirements globally by between 5 and 20% , or possibly more, by the 2070 or 2080 [58]. In fact, regional studies project increasing irrigation demand in the Middle East and North Africa [59, 60]. Increased irrigation has already led to increased erosion and salinity in Mediterranean soils [61].

Heavy rainfall events leading to flooding can wipe out entire crops over wide areas, and excess water can also lead to other impacts including soil water logging, anaerobicity and reduced plant growth. Indirect impacts include delayed farming operations [62]. The proportion of total rain falling in heavy rainfall events appears to be increasing. Such events are becoming more common in summer in Tunisia. [63] showed that heavy rainfall in August was linked to lower grain quality, which leads to sprouting of the grain in the ear and fungal disease infections of the grain. [64] predicted that rainfed olive production will fall by 50% by 2030 and 2050 in the center and the south of Tunisia by water scarcity.

The fall in production will be accompanied by a 50% reduction in cultivated areas. [65] projected a 18.5% increase in irrigation water requirements of olive trees in the Mediterranean region for 2050. In addition, all other agricultural trees, especially olives, grapes and fruit trees, show high increases in water requirement [66]. The same researchers indicated that with population growth, 5°C global warming, no realization of CO_2 fertilization, no improvements in irrigation technology, Algeria, Libya, Israel, Jordan, Lebanon, Syria, Serbia, Morocco, Tunisia and Spain would not have enough water for satisfying irrigation requirements in 2080–2090. This result was corroborated by [44] who stipulated that the Middle East and northern Africa may be affected by a high water scarcity index in 2080, designating potential difficulties for meeting future irrigation water requirements.

[67] simulated the impact of climate change on farm productivity and income by replicating the production system of El Khir which mainly produces rainfed (39% of the surface) and irrigated hard wheat (16%). The simulation results show a significant drop in land productivity and farm income: the decline in average land productivity is about 17 to 56%, and farm income drops from 4 to 69%, depending on the climate change scenario. The severity of these losses depends on the extent of changes in temperature and precipitation.

Also in Tunisia and in the case of droughts and for the scenario of slow economic opening, the production of cereals would decrease by 44% in 2030, that of olives by 52% in 2030 and that of meat by 33 to 66%, depending on the species [47].

3. Effect of Pests and Diseases proliferation

Under climate change, pressures from pests, weeds, and diseases are also expected to increase, with detrimental effects on crops and livestock [68].

[69] pointed out that pathogens and disease may also be affected by a changing climate. This may be through impacts of warming or drought on the resistance of crops to specific diseases and through the increased pathogenicity of organisms by mutation induced by environmental stress. It is also predicted that changes in climate variability may also be affecting the predictability and amplitude of outbreaks [70].

Increasing temperature will create conditions suitable for the invasion of weeds, pests and diseases adapted to warmer climatic conditions [71]. The speed at which such invasive species will occur depends on the importance of climatic change [72]. Studies have shown that increased temperature tends to have positive effects on insects [73,74]. Temperature can alter insect life-cycle duration, voltinism, population density, size, genetic composition, extent of host plant exploitation (both in time and space) and geographical distribution [75, 76].

In fact, higher temperatures shorten the generation interval in many pathogen species, enabling them to appear earlier in the season and to evolve more rapidly.

Climate change may increase the impact of pests by allowing their establishment in areas where they could previously not establish. Changes in temperature can result in changes in geographic ranges and facilitate overwintering [77]. The increase of temperatures in the Mediterranean Basin allows the establishment of tropical species that were not able to thrive in the region so far. In the majority of the studies, it has been estimated that with a 2 °C temperature increase, insects might experience one to five additional life cycles per season and produce more eggs [78]. Increasing temperatures increases insect vector expansion, feeding activity, transmission rates and increases the potential for new insect vectors [79]. An increase in the incidence of viral diseases is predicted to occur due to either increased winter survival of insect vectors with increasing temperatures or early spring migration of the insect vectors [80].

Wheat lands in North Africa are projected to suffer not only from heat stress and water scarcity but also from upsurges of insect pests and soil-borne pathogens.

Potential changes in temperature, rainfall and wind patterns associated with climate change are expected to have a dramatic effect on desert locust in Africa, the most dangerous of all migratory pests [81].

Stem and stripe rusts are important diseases of wheat, and moisture, temperature and wind are the three most important weather factors affecting epidemics [82]. They are especially serious in the Near East, Central Asia and Eastern and Northern Africa, creating severe epidemics and causing significant losses of up to 80 % in wheat production [1]. With climate change, they are likely to move and arrive in areas less prepared.

Importantly, negative impacts can also be expected because of the increased vulnerability of plants weakened by the direct impacts of climate change, as part of the classic triangle between plant hosts, pathogens and environment in causing disease [83].

In some experiments, warmer winters have been associated with an increase in viruses of many crops while warmer soils affect soil-borne viruses as the insect vectors will be able to infect crops at an earlier stage of crop growth [79].

4. Sea Level Rise impacts

The potential impacts of climate change include sea level rise, 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.

ASLR will damage the aquifer coastal formations and other underground sweet water resources due to the intrusion of seawater. The potential loss in coastal groundwater resources caused by saltwater intrusion is estimated at 53% of the current groundwater reserves [84].

ASLR will mostly harm humid places, such as lagoons, sebkhas and the lowest coastal marshes, due to submersion and salinization. The total amount of area potentially threatened by submersion is 18,000 ha [84].

At present, 1.4% of the coastline is protected, mainly by dykes, which are very vulnerable to ASLR. Thus, Tunisia’s 22 coastal ports, 19 fishing ports, 8 commercial ports and 8 recreational ports are threatened [84].

A great part of the irrigated agriculture (citrus fruit, irrigated cultures, etc.) is located in Tunisia’s coast [85]. Therefore, it is particularly vulnerable to salinization and soil erosion. The loss of agricultural land is estimated at about 16,000 ha in low-lying coastal areas and indirect loss of the potential is 38,000 ha of irrigable land by 2050, i.e. 10% of currently irrigated land [86]. In addition, ASLR can damage agricultural infrastructure, such as drainage and irrigation pipes.

The loss in agricultural production amounts to 81 million TD per year (2% of the agricultural GDP) owing to the submersion of farming land and the loss of irrigation potential caused by salinization.

The total costs related to ASLR are projected at 228 million TD, i.e. 0.63% of GDP, which hampers annual economic growth by 0.6%. In terms of employment, 35,000 jobs will be lost due to ASLR, i.e. 1% of the active population. Although employment rates in fishing will increase, those in agriculture and tourism will decline [84].

Regarding crop productivity, vulnerability is clearly greatest where large sea-level rise occurs in conjunction with low-lying coastal agriculture.

5. *Effect of climate change on Livestock and Rangeland*

Climate change affects livestock production in multiple ways, both directly and indirectly. The most important impacts are experienced in animal productivity, yields of forages and feed crops, animal health and biodiversity.

Climate change can impact livestock via three ways: water availability, heat stress, and the quality and quantity of feed [87, 88].

Extensive rangeland in Africa is already drought-prone, and regions like North Africa which are projected to become drier, will become even more vulnerable to livestock losses from prolonged drought conditions [68]. Deterioration of pastures during droughts and periods of overgrazing can result in the poor health and sometimes death of livestock.

Other negative impacts on livestock farming include greater water requirements for livestock from temperature increases as well as impacts on livestock from heat stress [89].

The agricultural area devoted to forage and fodder crops remains inadequate. Difficult climatic and edaphic conditions for crops and livestock production are reflected in the low and unstable productivity levels of rainfed production systems.

The availability of sufficient fodder is always the key question for livestock producers. Climate change affects feed in quantity and quality. It affects also the dynamics and balance of different grasslands species, and these may result in changes in livestock productivity [90] and would decline a set herd sizes [91].

As mixed crop–livestock systems are prevalent in much of the developing world [92], the climate change may affect in the future the relationship between crops and livestock in the landscape in these countries [93].Climate change could also increase the prevalence and distribution of livestock diseases like bluetongue among others [94].

Pastoralism, which the most practices in NA, is one of the most vulnerable sectors to climate change.

In Tunisia, after several years of drought, livestock (cattle, sheep and goats) numbers will drop up to 80% in the south and center and 20% in the north [95,48]. Climate change will reduce pasture productivity, especially in steppe areas where most Maghreb herds are concentrated. It will exacerbate pressures from land-use change and population growth. It will cause significant livestock losses during extreme events such as drought, heat waves and floods; intensify diseases such as leishmaniasis, brucellosis, bluetongue and African horse sickness, which are already causing hecatombs in the Maghreb animal population.

Most domesticated livestock species have comfort zones between 10 and 30°C. Above these temperatures, animals reduce their feed intake 3-5% per additional degree of temperature (NRC, 1981). The poultry industry may also be compromised by low production at temperatures higher than 30°C [96].

Concerning livestock production, [97]argued that “a warmer and drier climate may reduce forage production leading to changes in optimal farming systems and a loss of rural income in areas dependent on grazing agriculture”.

The potential effects of climate change on rangelands in North Africa are much more serious. Future climate change is likely to both reduce the productivity of rangelands and change the areas amenable to livestock production. In fact, a reduction in moisture availability would change the species composition in favour of woody, less palatable, plants. Climate change impacts species composition, change mixed grasslands and decrease feed quantity. In fact, droughts and extreme rainfall variability can trigger periods of severe feed scarcity, especially in dryland areas, which can have devastating effects on livestock populations [98].

Mixed crop–livestock systems are prevalent in much of the developing world [92] and climate change may affect the relationship between crops and livestock in these countries.

Decreases in plant cover may also increase erosion and lead to a nearly irreversible loss of productive potential [99].

By 2050, [100] and Allen-Diaz (1996) predicted that most of the steppe rangeland is expected to have given way to desert. This situation would have significant implications for the livestock industry. In fact, over 50% of the sheep industry is in the arid-steppe zone and would have to depend on imported feed and the international cereal market to survive [101].In Tunisia, grasslands cover nearly one third of the total land area [102].These areas vary quantitatively and qualitatively across bioclimatic zones[103, 104].Many are being destroyed by overgrazing and encroachment of agriculture [105].

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