International Journal of Science, Environment and Technology, Vol. 7, No 5, 2018, 1615 – 1630
ISSN 2278-3687 (O)
2277-663X (P)

WHY DON'T ADAPT TUNISIAN AGRICULTURE TO CLIMATE CHANGE?
3. MITIGATION ET ADAPTATION

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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.
To reduce future risks associated with negative impacts of climate change, both mitigation and adaptation actions are needed. Strategies adopted concern several aspects ranging from plant and practices to government decisions. These strategies aim to help a producer to be able to increase crop productivity and profitability while also reducing the long-term economic risk from climate change. Changes in the mean climate away from current states may require several adjustments: current practices, type of farming, water management, new crop and others strategies.
Keywords: Agriculture, mitigation, adaptation, Tunisia.

Introduction

To reduce future risks associated with negative impacts of climate change, both mitigation and adaptation actions are needed. Mitigation actions reduce the impact of climate change while adaptation measures reduce the negative effects of climate change on agricultural production or amplify the positive ones by adjusting the ecological, social or economic systems [1]. Strategies adopted concern several aspects ranging from plant and practices to government decisions. These strategies aim to help a producer to be able to increase crop productivity and profitability while also reducing the long-term economic risk from climate change.

They imply a good understanding of the impact of climate change on available water resources and on agricultural systems, and a set of policy choices, and investments and managerial changes to address them [2].

Adaptation in response to climate change varies by geography, cropping systems, topography and soils, and local experience with climate and weather [3, 4].

*Received Aug 15, 2018 * Published Oct 2, 2018 * www.ijset.net*

Changes in the mean climate away from current states may require several adjustments: current practices, type of farming, water management, new crop and others strategies… Some of these strategies are discussed below.

1. Developing Climate-ready Crops

The breeding of novel crops and the adaptation of current crops to the new environment are required to ensure continued food production. Breeders will need to identify genetic resources with traits that can be used to develop varieties that will be able to thrive in extreme climatic conditions. In recent years, research of this kind has progressed for tolerance of drought, salinity, submergence and heat stress in major food crops [5].

Many traits of tolerance or resistance to drought, salinity, pests and disease from wild relatives or autochthonous species and genotypes, should be used to breed new varieties or incorporated into modern crop varieties.

Breeding has been a success story in increasing yield [6]. Plant breeding may help in developing new cultivars with enhanced traits better suited to adapt to climate change conditions using both conventional and genomic technologies [7].

Breeding strategies should improve adaptation to crop season with different growth durations to escape or avoid predictable occurrences. This strategy has already been successfully tested in different Poaceae such as, wheat, rice, maize, and barley [8,9, 10].

Significant results in abiotic stress tolerance traits introgression were obtained also in Triticum. Wheat was improved in drought and salt stress tolerance by the wild relatives *Aegilopsumbellulata* and *Agropyronelongatum* [11, 12, 13].

More recently, interesting abiotic stress-related loci were described in wild barley [14]. These results show that the study of landraces and wild relatives is useful to design strategies aiming at the improvement of the abiotic stress response in Poaceae.

In breeding program, farmers must participate in decision in setting breeding objectives [15] because they know better than others what traits they are looking for. These objectivesmay change from location to location and with time.

Participatory plant breeding (PPB) produces resilient varieties with high levels of phenotypic plasticity that often differ across locations depending on local climate and ecosystems, as well as social, cultural and economic factors influencing farmer preferences [16].

To increase yield in low rainfall rainfed areas, breeders should select characters, which maximize the capture of water from the soil, the transpiration in relation to evaporation, the transpiration efficiency and the harvest index [17, 18]. They don’t focus only on yield which has a low heritability especially under drought.

There are morphological and physiological characters with high heritability and easy to measure in cereals, which confer resistance to drought to wheat in Mediterranean rainfed areas. Among those, we cite flowering date, plant height, seed size, initial vigor, tillering, isotopic discrimination of carbon 13 and leaf glaucousness.

In Tunisia, durum wheat varieties such as Oum Rabia and Khiar have confirmed their quality of drought tolerance and their good adaptation to the difficult conditions occurring at crop cycle end [19]. The newly released durum variety Maali, which is up to 4 days earlier and more drought tolerant than the widely grown variety Karim and the bread wheat variety Utique [20] will certainly result in a substantial increase in grain yields under the simulated climate projection.

2. Use of biodiversity

Biodiversity is among the issues to face and adapt better to climate change and its adverse impacts. In fact, genetic resources for food and agriculture can play a central role in meeting the challenges of climate change to food security and nutrition, and in maintaining and improving agricultural productivity, rural livelihoods, sustainability and resilience [21, 22]. Diversification of plant resources could offer flexibility to reconcile performance and robustness of cropping systems. [23] qualified diversification as the basis of a new agro-ecological engineering applying the concepts of ecology to agricultural production. In fact, genetic uniformity inherent in monocultures can restrict the crop’s ability to tolerate diverse abiotic environmental stresses, pests and diseases, thereby leading to a potential decrease in the stability of the cropping system [24]. In addition, when the produced crop is negatively affected by climate change, farm income may be severely affected. For these reasons, moving toward diversification reduces the risks of maladaptation [25] and maximizing returns even with low levels of technology and limited resources [26].

Increased genetic variability is better equipped to adapt to future. It helps to establish greater resilience and improves yield stability [27].

Some components of biodiversity can improving soil health, reduce pest pressure and erosion, increase water and nutrients availability, enhance soil carbon storage and help to mitigate climate change [28]. Biodiversity may offer complementarities, redundancy, facilitation but also competition and antagonistic relations. All these mechanisms could be interesting to mobilize in farming systems to increase their ability to adapt, to be resilient and their ability to reconcile different types of performance.

The expected benefits of diversity in agriculture are better distribution of the risks to which agricultural exploitations are exposed, the reduction of parasitic risks, the improving of complementarities between species and finally the optimizing of inputs use. The schedule of agricultural work may also be better spread out to reduce the overload periods of work for farmers.

Genetic diversity is also a vital resource for the livestock sector. Most livestock diversity is maintained *in situ* by farmers and pastoralists.

The protection of landraces and indigenous livestock breeds is worthwhile despite their lower yields since they often possess valuable traits such as disease and pest resistance and are better adapted to harsh conditions and poor quality feed, which are qualities desirable for low-input, sustainable agriculture. The *in situ* and *ex situ* conservation of crop and livestock genetic resources is important for maintaining options for future agriculture needs.

For Tunisia, massive and accelerated erosion is causing the disappearance of many plant species well adapted to the local conditions of the environment [29]. The fifth national report on biodiversity states that local varieties are in the danger of extinction given the trend towards intensification of agriculture and the use of varieties introduced. According to the General Manager of the Gene Bank, local breeds cattle have totally disappeared and plant genetic diversity is seriously threatened [29].

Gene Bank should add crop wild relatives to its collections since they have genetic traits that can be used in the development of well-adapted crops for use in climate change-affected production systems.

Tunisia also needs to change its strategy for crop cereals based on wheat monoculture. It is important to renewal mono-cropping systems by improving other crops such as grain legumes and new crops. Instead of cereal monoculture, incorporating legumes in rotation systems has long been proven to enhance crop yields and environmental benefits.

Rustic species such as barley [30], pearl millet [31], quinoa [32] and moringa [33] are resilient systems for which family farming should deserve special attention and government should promote their installation. In addition, maintenance or restoration of halophytic plants can offer increased protection of coastal areas to sea level rise and extreme weather events.

Tunisia must strengthen its strategies for the safeguarding of its genetic resources and should adapted agricultural practices and promote crop varieties resistant to drought and pest. Tunisia must also restore degraded areas.

3. Use of novel crops

New cereal species adapted to new or different environments may also be options for accelerated domestication to satisfy food demand. The options available for domestication of locally adapted new cereal crops will vary with region. Large numbers of species could be considered for specific environments or regions.

3.1. Introduction of spineless cactus (*Opuntia spp*.) as alternative forage crop and for rangeland rehabilitation. It is well recognized for its ability to survive severe drought and the harsh environmental conditions. As an animal feed, cactus is a good source of water, vitamin A and Ca and is best utilized by animals in combination with saltbush. In sandy and deep soils, it may successfully establish with mean annual rainfall of 100-150 mm. The characteristics of cacti plant offer most of the requirements of a drought-resistant forage crop. The introduction of spineless cactus had already been adopted in North Africa region where thousands of hectares are in production of cactus pads for animal feed and fruits for human consumption [34].

In Tunisia, it covers an area of about 600 000 ha, distributed mainly in west-central regions on the plains of Kasserine [35]. *Opuntia* species have the ability to withstand prolonged drought, high temperatures, as well as wind and water erosion. This ability, plus a range of economic uses, makes them ideal for agricultural development in areas affected by the world's two biggest environmental problems: desertification and climate change [36].

Actually, there is a remarkable development of its culture considering its multiple uses and especially it is particularity to be established as buffer feed reserves as a strategy to mitigate the effects of drought in animal production systems of arid and semiarid zones.

3.2. Agroforestry practice

Given the large contribution of land use conversion and the forestry sector to GHG emissions, agroforestry presents an opportunity to counter the adverse impacts of climate change through the joint action of adaptation and mitigation. Trees on farms enhance the coping capacity of small farmers to climate risks through crop and income diversification, soil and water conservation and efficient nutrient cycling and conservation. Agrofoestry may also ameliorate carbon sequestration potential and had effect on soil fertility.

3.3. Adoption of novel crops like Extremophiles which can evolve and reproduce in very marginal habitats such as highly saline environments that may also be prone to drought and heat, flooding, sodicity and alkalinity [37]. Their adoption or domestication as crops appears to be a feasible strategy to develop agriculture in marginal environments. They also may serve as a valuable source of novel genes/allelic variants that can be incorporated in other crops.

3.4. Quinoa

Quinoa has gathered much attention in recent years for its high level of salinity tolerance [38, 39]. As halophytes are likely to be tolerant to other types of abiotic stress [40], quinoa may for example, represent an opportunity for farmers in a drier climate [41]. It is demonstrated that reducing water use by up to 50 % of full irrigation has no effect on quinoa crop yield [39, 42].

Quinoa could also serve for revegetation and remediation of salt affected lands [43].All these positive properties make it a good candidate in cropping in marginal agricultural areas as an additional cash crop for Tunisian agriculture.

3.5. Neglected and underutilized species are important components of agrobiodiversity [44]. These comprise a broad variety of agricultural and wild crops in different countries, which are traditionally used, and that may have potential for adaptation to climate change, medicinal properties, as well as resistance genes against pests and diseases. Many neglected and underutilized species are traditional crops that are still cultivated by farmers at a local scale. Farmers have an increasing role as guardians of traditional crops as well as neglected and underutilized species. [45] cited “We all lose when crops that could improve nutrition, health and income are abandoned by communities marginalized by agriculture, ignored by science, and eliminated from the diet of consumers”

Several neglected and underutilized species (*Brassica juncea, Salicorniabigelovii, Amaranthuscruentus…*) and medicinal crops can provide alternatives to the staple crops to sustain farm productivity in desert environments constrained by water scarcity, poor soil fertility and other such yield-limiting factors.

4. Farmer’s attitude

Farmer adaptive responses to changes in climate and weather can vary from making no changes in the farm operation to incremental adjustments to transformations in land uses and the farm enterprise. Adaptive management in agriculture can entail minor adjustments in practices to major changes to the farm operation [46].

As published by [46] in his research “a good farmer pays attention to the weather”; farmers are the protagonists of the gradual evolution of agriculture. In fact, adaptation to climate change necessitates that farmer’s first notice that the climates has changed, and then identify useful adaptations and implement them [47]. In their actions, they would be supported by governments, international organisations, research institutes and civil societies. Their behaviour and working methods may be old and transmitted through the preservation of knowledge and knowhow or are new and seek to provide solutions to international or local issues.

Farmers will undertake many adaptation actions to meet changing climate conditions and will often do so without any government intervention. However, when such actions provide both private and public benefits, the public sector may play a role in how these are developed. Farmers can have several strategies that increase the climate resilience of agriculture also help to mitigate GHG emissions [48]. Among them, we can cite: changing a cropping calendar, choosing the appropriate varieties, switching mono-crop to multi-crop system, installing different management practices, establishing and investing in irrigation equipment, reallocating land from crop production to grazing…[49, 50]..….

Farmers must adjust their practices and adapt their adjustments to changes that operate in their region. They are trying to adapt or, at a minimum, to "resist" the impacts of climate change, and are putting at stake several mechanisms, individually or collectively.

In these decisions, they must take into account their own land [51, 52]. Indeed, small and marginal farmers should use native species and their own traditional techniques to adapt their production system to cope with drought [53]. In fact, without adaptation by farmers, global crop yields in 2050 would be 6.9% below estimated yields without climate change; cereal yields would be lower by as much as 10% in both developed and developing regions [54].

[55] indicates that local coping strategies are the basis for adaptation to long term climate change. Local coping strategies are adaptation initiatives by communities, usually triggered by market or welfare changes induced by actual or anticipated climate variability [56].

Local adaptation could be a solution that can make a significant difference to local communities. For example, when choosing crop varieties better suited to local conditions or when applying better soil management practices, farmers benefit directly from such actions. In addition, crop production may need to adapt to a changed or more variable environment or move to new production environments

Farmers in dryland countries (like Tunisia) are already hard-hit by climate change. As a result, there is an urgent need to strengthen agricultural resilience to support rural livelihoods and maintain domestic food production. Failure to do so risks an unhealthy reliance on imported food, which would expose ordinary people to the vagaries of global commodity markets. In this context, Tunisia can also learn from the experiences of developed countries that find themselves on the front-line of climate change.

The immediate challenge facing Tunisian farmers is how to be well prepared and to build the required capacity that will allow them to compete more effectively, and to fully participate and assume a dynamic role in the global trading system. Even so, in some localities (like oases) cropping systems have been managed in ingenious ways, allowing small farming families to meet their subsistence needs in the midst of environmental variability without depending much on modern agricultural technologies. These systems which are traditional, are based in particular on the plant diversity in the form of poly-cultures and/or agro-forestry patterns (date palm, arboriculture and vegetable crops).

5. Sustainable agriculture

Sustainable agriculture frequently encompasses a wide range of production practices, including conventional and organic. There are many practices commonly used by people working in sustainable agriculture and sustainable food systems. Growers may use methods to promote soil health, minimize water use, and lower pollution levels on the farm

Sustainable agricultural practices are intended to protect the environment, expand the Earth's natural resource base, and maintain and improve soil fertility. Based on a multi-pronged goal, sustainable agriculture seeks to increase profitable farm income, promote environmental stewardship, enhance quality of life for farm families and communities and increase production for human food.

5.1. Organic agriculture

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 [57]. 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 [58]. Other crops include dates, jojoba, almonds, fruits and vegetables, honey and aromatic plants [59]. In recent years, organic livestock husbandry in Tunisia has expanded significantly.

5.2. Cover Crops/Crop Rotations

Cropping sequences that include a fallow period tend to reduce soil carbon levels as compared to continuous cropping, which tends to increase soil carbon levels. Cover crops and nitrogen-fixing legumes are often recommended to both enhance fertility and increase the soil organic matter content. Cover crops also help ensure that soil is protected during intense rainfall events by absorbing raindrop impact, which reduces erosion and nutrient runoff; they also protect the soil during periods of drought, when wind erosion can remove topsoil. A greater number of rotations in any given crop rotation cycle can also help to reduce pest pressure, thus enhancing a field's productive capacity.

5.3. Conservation Tillage

Conservation tillage reduces soil compaction and erosion and increases soil organic matter and infiltration capacity - all of which reduce runoff and increase drought resilience. Tilling the field exposes soil organic matter/carbon to oxidation and makes the soil more susceptible to erosion, both of which result in carbon depletion and, as a consequence, less productive soils.

5.4. Vertical Farming

Vertical farming environment is secured with bio-security procedure that restricts disease and pest attacks on crops. This eliminates the need of herbicides, pesticides and foliar sprays in cropping systems and results in less holding time. This bio-security also leads to the termination of expensive post harvesting processing and product damage washing. Thus, cost effectiveness and reduced usage of harmful chemicals in this system is expected to uplift the vertical farming market. The global vertical farming market in terms of technology is segmented into hydroponics, aeroponics and aquaponics. Across different regions, growing crops through hydroponics technology in vertical farming market is predominant and accounted for more than 50% share in 2016. The economics of growing crops through hydroponic mechanism is its key driver for vertical farming market expansion. On the other hand, this is expected to fall gradually as more sustainable and innovative technologies for growing plants such as aeroponics and aquaponics are coming up.

In terms of technology, hydroponics will continue to hold lion's share of the vertical farming market by 2024, However aeroponics and aquaponics growth mechanism are likely to exhibit rapid gains during the forecast period taking up the market share of hydroponics. Less usage of water in comparison with hydroponics and traditional farming methods will spur the market for aeroponics expertise. Rising adoption of small scaleaquaponics systems among farmers due to its cost benefits is playing a vital role in the growth of aquaponics technology.

Conclusion

Agriculture remains vital to the economy of most African countries and its development has significant implications for food security and poverty reduction in the region. Therefore, developing adaptation mechanisms to deal with the negative effects of climate change must be a high priority. The search for balance between food security, sustainable and resilient agricultural production is a challenge that Tunisia should take into account to face and adapt better to climate change and its adverse impacts. Strategies must be developed and adapted to climate change from the farm to national levels.

Tunisia's government set up a management strategy for the sustainable use of available resources. With groundwater and renewable water resources being scarce, improved irrigation management is possible only by using new agricultural technologies and adopting a better understanding of yields responses to changing climate variability and water scarcity. New agricultural techniques will need to be developed and introduced to farmers to be able to cope with projected change. Farmers will need assistance in order to be able to adapt to climate changing conditions and in order to be able to build up capacity to minimize crop sensitivity to climate change and effective water management in stress conditions.

It is recommend that the “national agricultural map” already developed by the Tunisian government can be revised in the new context of climate change; using further socioeconomic data, and applied for an optimal restructuring of agricultural production in Tunisia.

Stakeholders should consider climate science information in their decision-making in the aim to establish an adequate plan of action with a permanent monitoring system.

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. Research should address the needs of marginal farming areas, and work to benefit smallholders by increasing agricultural productivity and natural resources conservation, and by helping to diversify cereal-farming systems to higher value products.

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