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CLIMATE RESILIENT AGRICULTURE: TRANSLATING DATA TO POLICY ACTIONS

Case Study of AquaCrop Simulation in Tunisia

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Overview

Within the framework of an initiative supported by the Swedish International Development Cooperation Agency (Sida) on “Promoting food and water security through cooperation and capacity development in the Arab region”, ESCWA prepared reports on the impact of changing water availability due to climate change on agricultural production in selected Arab countries.

A technical country team[1] was established and trained by ESCWA, the Food and Agriculture Organization (FAO) and the Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD) to assess the impact of projected climate change, expressed in terms of water availability, temperature and carbon dioxide (CO_2) changes, on selected crops and locations in Tunisia. The assessment findings, derived from a national case study report,[2] are used as a baseline to recommend adaptation measures to key actors in promoting water and food security under changing climate.

The assessments used the AquaCrop simulation programme developed by FAO. The assessments were carried out on selected irrigated and rainfed crops to identify the impact of climate change on crop productivity. The programme used the climate-variable projections of the Regional Initiative for the Assessment of the Impact of Climate Change on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR),[3] while soil, yield and crop data were acquired from national sources. The climate change projections correspond to representative concentration pathways (RCP), i.e., greenhouse gas concentration trajectories adopted by the Intergovernmental Panel on Climate Change, of two levels: RCP 4.5: generally describing a moderate-emissions scenario; and RCP 8.5: generally describing a high-emissions or ‘business-as-usual’ scenario. In a way, RCP 4.5 and RCP 8.5 correspond to a more ‘optimistic’ and more ‘pessimistic’ scenario, respectively. The time horizons for the two RCPs consider the periods 2020-2030 (represented by 2025) and 2040-2050 (represented by 2045). Furthermore, to analyse the effect of elevated CO_2 on crop yield loss, two sets of projected CO_2 concentration changes, for each of the RCP scenarios, were simulated: one which considered the effects of increasing CO_2 concentrations; and another which kept CO_2 concentrations at the baseline level.

The present case study provides a general background of the assessment, and the main findings of the AquaCrop simulation undertaken to identify a variety of country-specific recommendations on adaptation measures in the agricultural sector.

Contents

1. Country Background

Tunisia is characterized by a Mediterranean climate, with irregular precipitation patterns that are unequally distributed among seasons and regions. Average annual rainfall exceeds 1,500 mm in Ain Draham in the far north, and is less than 150 mm in the far south. Tunisia covers around 16.4 million ha, including 4.9 million ha of agricultural lands of which only 402,000 ha are irrigated. Agricultural activities are mainly located in the northern and central parts of Tunisia, with a climate characterized by hot dry summers and cool moist winters.

The agricultural sector in Tunisia is one of the fundamental pillars of the national economy. It contributes 8 per cent of GDP and employs 16 per cent of the labor force. However, this sector has declined significantly in recent years, with its contribution to GDP dropping from 17 per cent in the 1990s to 8 per cent in 2018. This decline has contributed to the continuing deficit in food import by about 30 per cent.[4] In addition, this decline is most severely felt by the most vulnerable groups such as rural women and young people (box 1).

Tunisia is characterized by a wide range of farming areas, owing to significant climatic variations. The cultivated area is partitioned equally between cereal, olives and other mediterranean crops, and fallow land. Most of the rainfed and irrigated crops are located in the north and east of the country, and the most notable crops include citrus fruits and vegetables (north-eastern region), olive trees (Sahel and south-eastern region), and dates (southern region).

Table 1. Agriculture land use in Tunisia

Land type	Million (ha)	Percentage of total land
Arboriculture	2	20
Field crops	2	20
Fallow	0.7	7
Other crops	0.3	3
Permanent rangeland/pastures	4	40
Forest and woodlands	1	10
Total agriculture land	**10**	**100**

Source: United States Department of Agriculture, Global Development Solutions, 2017.

2. Selected Crops and Areas for AquaCrop Simulations

The assessment study applied the AquaCrop simulation model to identify the impact of climate change on crop productivity for the following two major cropping systems in two regions of Tunisia:

(1) Rainfed wheat in Koudiat region, Jendouba province in north-western Tunisia, where 65,580 ha of land are mainly rainfed cereal areas with an average cereal production rate of 2.4 tons per ha;
(2) Irrigated wheat in Chebica region, Kairouan province in central Tunisia, where 11,000 ha of land are irrigated cereal areas with a grain production rate of 3.5 ton per ha.

With cereals covering nearly one third of the cultivated agricultural area, different types of cereals (durum wheat, tender wheat, barley and triticale) in rainfed or irrigated fields require further analysis and simulation using AquaCrop to compare and determine which species are most adapted to future climatic conditions with low rainfall and high temperature conditions.

Box 1. Rural women and youth empowerment

Agriculture is one of the largest employment sectors for women in Tunisia, with women comprising 58 per cent of agricultural labour. Women are mostly involved in the field with livestock, and in processing and storage of products. About 20 per cent of those women earn their own income (compared to 65 per cent of rural men), and just 4 per cent of promoters of agricultural projects are women.

Although Tunisia has implemented significant policy changes to promote gender equality, women's work is still largely considered as unpaid family labour. Women's access to land ownership is hindered, and they are excluded from decision-making processes regarding planning, financing, technologies and infrastructure.

Young people represent around 40 per cent of the Tunisian population, and still face challenges in employment, active participation, and inclusion in decision-making. About 33 per cent of young people living in rural areas are out of work and out of school or occupational training (compared with 20 per cent of urban youth). Moreover, few young Tunisian women are working: less than one in five women in rural Tunisia (18.5 per cent) and less than two in five women in urban Tunisia (39.8 per cent) have a job. Young women's wages are also a quarter lower than those of young men.

Multiple initiatives have been undertaken to support youth involvement and participation in the agriculture sector and in migration-prone areas, such as the National Agency for Employment and Independent Work.

Sources: World Bank, Tunisia: Breaking the Barriers to Youth Inclusion, 2014;
World Bank, Climate Variability, Drought, And Drought Management In Tunisia's Agricultural Sector, 2016.

3. Assessment Methodology

The assessment evaluated the impacts of climate change on agriculture productivity using the FAO AquaCrop simulation programme (version 6), and the RICCAR climate-variables projections.

The following steps were involved in the use of AquaCrop:

- **Data collection,** including on climate, soil, crop types, and crop management. Climatic data was collected from the National Agricultural Research Institute of Tunisia, the General Directorate of Water Resources, and the National Institute of Meteorology with climate gauging stations located in Jendouba (Koudiat) and Alkirwan (Chebica);
- **Daily data including rainfall,** maximum and minimum temperature, and wind speed from 2007 to 2017 were collected for Koudiat. As for Chebica, data were limited to daily rainfall, and maximum and minimum temperature. Soil management and crop yield data were provided by the National Institute of Major Agriculture;
- **Calibration** provided the AquaCrop model with actual parameters that can simulate the actual productivity of wheat within an acceptable accuracy range. Calibration was done for rainfed (Koudiat) and irrigated (Chebica) conditions, using 10 years of field data (from 2007-2008 to 2016-2017). Data included soil characteristics, groundwater depth, irrigation scheduling, main farm management, climate data, and crop yield;
- **Simulation** of the impacts of climate change on wheat productivity were carried out using the prediction of the RICCAR project models (EC-Earth, CNRM-CM5, and GFDL-ESM2M) for two periods: the 2020 -2030 period represented by 2025 and the 2040-2050 period represented by 2045, and for two scenarios RCP 4.5 and RCP 8.5. The reference period is 1985-2005. Moreover, two sets of projected changes were implemented: one which considered the effects of both CO_2 concentrations and associated climatic changes (temperature and water); and one which considered temperature and water changes only and no change in CO_2 concentrations (i.e., keeping CO_2 concentrations at the baseline level). This allowed to disaggregate the mitigating effect of elevated CO_2 on yield losses derived by adverse impacts of temperature rise and water scarcity, and account for related uncertainties;
- **Testing deficit irrigation as an adaptation measure** to overcome the impact of reduced water availability due to climate change on irrigated wheat, by using two deficit irrigation measures: reducing irrigation by 25 and 40 per cent of the allocated irrigation amount for both RCP scenarios and both periods respectively.

4. Description of Assessment Findings

The calibration results showed that the actual field productivity and the final simulated productivity for each of the study sites during the 10 years do not significantly conform. The observed high yield variation between years might correspond to periods of strong anomalies due to drought or rainfall above averages, for the rainfed wheat of Koudiat. Furthermore, the rainfall in Tunisia is local and varied, and the fact that the station measuring rainfall is away from the field with respect to Koudiat could also lead to higher anomalies. As for the irrigated wheat of Chebika, the yield variation between years can be explained by the change in the crop variety grown over the 10 year period.

Overall, all climate models and scenarios over the two areas projected a decrease in precipitation and an increase in temperature.
For both regions, the CO_2 concentration is projected to change from the reference period value of 350 ppm to 550 ppm in 2050. The assessment results showed that the actual and the simulated productivities for each of the study sites, during the 10 years, differ on average by 0.07 ton/ha and 0.04 ton/ha, respectively, for the Koudiat and Chebika regions. The increase in CO_2 concentration increased crop yield for the two sites as it enhances the photosynthetic rate of plants while reducing transpiration. This in turn leads to better transpiration efficiency and ultimately to increases in potential production. Nevertheless, the actual quantification of the 'increase' (biomass and yield) remain largely uncertain and may carry over risks of over- estimation.

- **Koudiat site findings**

Climate variability projections

During the 2025 period, seasonal rainfall is expected to decrease by 5.8 and 8.5 per cent for RCP 4.5 and RCP 8.5, respectively, as compared with the average reference period (1985-2005) of 399 mm/year. However, during the 2045 period, seasonal rainfall is expected to decrease further by 13 and 19.3 per cent for RCP 4.5 and RCP 8.5, respectively.

Crop productivity projections

In case of fixed CO_2 concentration under both scenarios, RCP 4.5 and RCP 8.5, the climate models used show significant decreases in rainfed wheat yields productivity. Further impacts of the model when comparing with the reference period (1986-2005) are addressed in box 2. Overall, the results show that the impact of climate change will be negative for RCP 4.5, with fixed CO_2 concentration on crop productivity. They also show that temperature increases led to a decrease in the length of the growing season, which accelerates most physiological processes and the growth process by accelerating the ageing stage. In terms of total water consumption, actual evapotranspiration and reference evapotranspiration decrease. In the case of changing CO_2 concentration, a positive change in crop yield is expected, reaching 17.41 per cent for the 2045 period.

Box 2. Main findings of AquaCrop simulation in Koudiat

- Under the RCP 4.5 scenario:

  Seasonal precipitation is predicted to drop by 13 per cent for the mid-century period compared to an average reference period of 399 mm/year;

  The productivity of rainfed wheat decreases by about 7.0 and 2.8 per cent for the 2025 and 2045 periods, respectively. In case of changing CO_2, productivity increases by 5.7 and 17.4 per cent for both periods, respectively;

  Crop water productivity decreases by 2.5 and 3.7 per cent for the 2025 and 2045 periods, respectively. In case of changing CO_2, crop water productivity increases by 11.3 and 26 per cent for both periods, respectively.

- Under the RCP 8.5 scenario:

  Seasonal precipitation is predicted to drop by 19.3 per cent for the mid-century period compared with an average reference period of 399 mm/year;

  The productivity of rainfed wheat decreases by 4.4 per cent for the 2025 period, and negligibly increases (0.2 per cent) for the 2045 period. In case of changing CO_2, productivity increases by 4.2 and 13.9 per cent for both periods, respectively;

  The crop water productivity decreases by 3 per cent and increases by 1.7 per cent in the 2025 and 2045 periods, respectively. In case of changing CO_2, the crop water productivity increases by 22.9 and 33.3 per cent for both periods, respectively.

• Chebika site findings

Climate variability projections

Seasonal rainfall is expected to decrease by 12.4 and 8.7 per cent for RCP 4.5 and RCP 8.5, respectively, for an estimated average reference period of 170 mm/year. Similarly, during the 2045 period, seasonal rainfall is expected to decrease by 16.4 and 23.3 per cent for RCP 4.5 and RCP 8.5, respectively.

Crop productivity projections

In case of fixed CO_2 concentration, under both scenarios RCP 4.5 and RCP 8.5, change in irrigated wheat productivity showed to be negligible as supplementary irrigation offset shortages in rainfall. Productivity is expected to increase since supplementary irrigation may offset shortages in rainfall. Furthermore, irrigated crops that are grown after wheat harvesting will provide the opportunity for optimal initial moisture for the start of the following crop cycle. Further impacts of the model when comparing with the reference period (1986-2005) are addressed in box 3.

• Application of deficit irrigation

Applying deficit irrigation as an adaptation measure in Chebika, by reducing water allocated for irrigation by 25 per cent in the 2025 period and 40 per cent in the 2045 period, shows an increase in crop productivity for the RCP 4.5 and RCP 8.5 scenarios in case of changing CO_2 concentration, and a decrease in productivity in case of fixed CO_2 in both scenarios.

The maximum decrease is witnessed under the RCP 8.5 scenario reaching 8.1 per cent for the 2025 period, and 5.5 per cent for the 2045 period. The maximum increase reaches 4.7 per cent (RCP 4.5) for the 2025 period and 12.3 per cent (RCP 8.5) for the 2045 period.

Box 3. Main findings of AquaCrop simulation in Chebika

- Under the RCP 4.5 scenario:

  Seasonal precipitation is predicted to drop by a maximum of 16.4 per cent compared with the average reference period of 170 mm/year;

  The productivity of irrigated wheat increases slightly over the two periods in case of stable CO_2. In case of changing CO_2, productivity increases by 12.3 and 19.3 per cent for both periods, respectively;

  Crop water productivity increases by 2.5 and 6.3 per cent in the 2025 and 2045 periods, respectively. In case of changing CO_2, the crop water productivity increases by 16.2 and 28.2 per cent for both periods, respectively.

- Under the RCP 8.5 scenario:

  Seasonal precipitation is predicted to drop by a maximum of of 23.3 per cent compared with the average reference period of 170 mm/year;

  The productivity of irrigated wheat increases by 0.6 and 1.5 per cent over the two periods, respectively. In case of changing CO_2, productivity increases by 14.2 and 21.4 per cent for both periods, respectively;

  Crop water productivity increases by 3.6 and 10.6 per cent in the 2025 and 2045 periods, respectively. In case of changing CO_2, the crop water productivity increases by 19 and 36 per cent for both periods, respectively.

Table 2. Estimates of the impact of deficit irrigation on crop productivity in Chebika

Scenario	Period	Reference period crop yield (ton/ha)	Change in crop yield (%)	Change in precipitation (mm)
RCP 4.5 changing CO_2	2020-2030*	5.38	4.7	-21.1
	2040-2050*		11.7	-27.9
RCP 4.5 fixed CO_2	2020-2030	5.21	-6.7	-21.1
	2040-2050		-5.5	-27.9
RCP 8.5 changing CO_2	2020-2030	5.39	4.4	-14.8
	2040-2050		12.3	-39.4
RCP 8.5 fixed CO_2	2020-2030	5.23	-8.1	-14.8
	2040-2050		-5.5	-39.4

*Reducing irrigation by 25 per cent in the 2025 period and 40 per centin the 2045 period

5. Analysis of Assessment Findings

The impact of rising temperatures and reduction of rainfall, observed in all climate change scenarios, on crop yields, particularly rainfed, is expected to be severe and will pose significant risks to farmers, particularly those with limited income. The shortening of the growing-season duration, and the negative impact of high temperature on vegetation, will reflect negatively on the quantity and quality of grain production. This situation will necessitate investment in high density precipitation gauging networks to allow for more accurate research and analysis.

In addition to high temperatures, especially maximum temperatures and a reduction in rainfall, Tunisia is expected to witness an increase in the intensity and frequency of extreme weather events, such as long-term drought, severe heat waves, storms and floods, which would in crease existing pressures on farmers, soil fertility, water resources and cultivated areas. It is therefore necessary to take these impacts into account in determining agricultural policies that would, in turn, affect the Tunisian national economy.

Cereals in Tunisia are strategic for agriculture, with cereal cultivation areas spanning 1.6 million ha. Climate change repercussions in Tunisia will increase risk of widening its trade deficit, following a decrease in the yield of rainfed wheat. Since only 15 per cent of the total area cultivated in wheat is irrigated, the negative results for the yield of rainfed wheat could undermine the country's trade position and subsequently its food security. As such it is critical to apply adaptive measures like scaling up conservation-agriculture practices in rainfed areas, to modify seeding dates and account for shifting periods of rainfall, to develop the use of new crop varieties that could easily adapt to expected climate changes, and to and improve research on saline agriculture.

Furthermore, farmers dependent on rainfed agriculture, who live in predominantly rural areas, are at a very high risk of poverty. Small and medium agricultural producers represent 62 per cent of cereals producers, and operate on 21 per cent of the total agricultural land allocated to cereal production. Improving access to credit for small farmers is important to alleviate climate repercussions, in addition to revising social safety nets for those farmers in poor rural areas in the west of the country that rely on rainfed agriculture, and encouraging economic development for more stable income for farmers.

The study also provides evidence on the optimization of the irrigation schedule for irrigated crops, thereby helping to verify the quantities of water required to achieve comparable rates of measured productivity. The result of this optimization is often that less water is used for the same productivity, which is useful for developing guidelines for saving irrigation water. In fact, no significant change in yield for crops under 25 and 40 per cent deficit irrigation was observed. However, in cases of changing CO_2, yield was observed to increase.

Furthermore, while results show that overall climate change does not seem to limit the productivity of irrigated wheat in Chebika, it is imperative to identify the relationship between reduction in rainfall and its impact on irrigation requirements and sources.

Box 4. Economic impact of climate change on wheat production

Farming investment represents 8 per cent of total investment in the national economy, worth 1,297.3 million Tunisian dinars. Agricultural exports account for 9.7 per cent of total exports, covering more than 70 per cent of the country's food imports.

The negative results for wheat yields pose a major concern for the income and employment security of those involved in its production, as almost 248,000 farmers are engaged in cereal production. More specifically, the farmers in Koudiat face a greater risk of increased poverty, since rainfed wheat cultivation in the area is expected to decrease by 4.4 per cent in the 2025 period for the pessimistic scenario.

Wheat production losses could range between 6,925.25 and 11,017.44 tons following the different scenarios for the Koudiat region in the 2025 period. With a producer price of $298.9 per ton of wheat in 2016, as per the most recent data, losses for Koudiat could range between $2.07 million and $3.3 million per year. Although such numbers should be taken with caution due to price volatility in the wheat market, they could nonetheless provide an order of magnitude of the potential incurred costs in the 2025 period.

At the macro level, a decrease in the yield of rainfed wheat is likely to worsen the widening Tunisian trade deficit. As only 15 per cent of the country's total wheat area is irrigated, a projected decrease in the yield of rainfed wheat should be a cause of serious concern for policymakers. In 2017, imports of wheat in Tunisia amounted to $415.18 million, equalling 1.03 per cent of the country's GDP. Although it would be hard to quantify the effect of the decrease in wheat yield on the Tunisian economy, it is certain that it will put pressure on the country's balance of trade and jeopardize its food security.

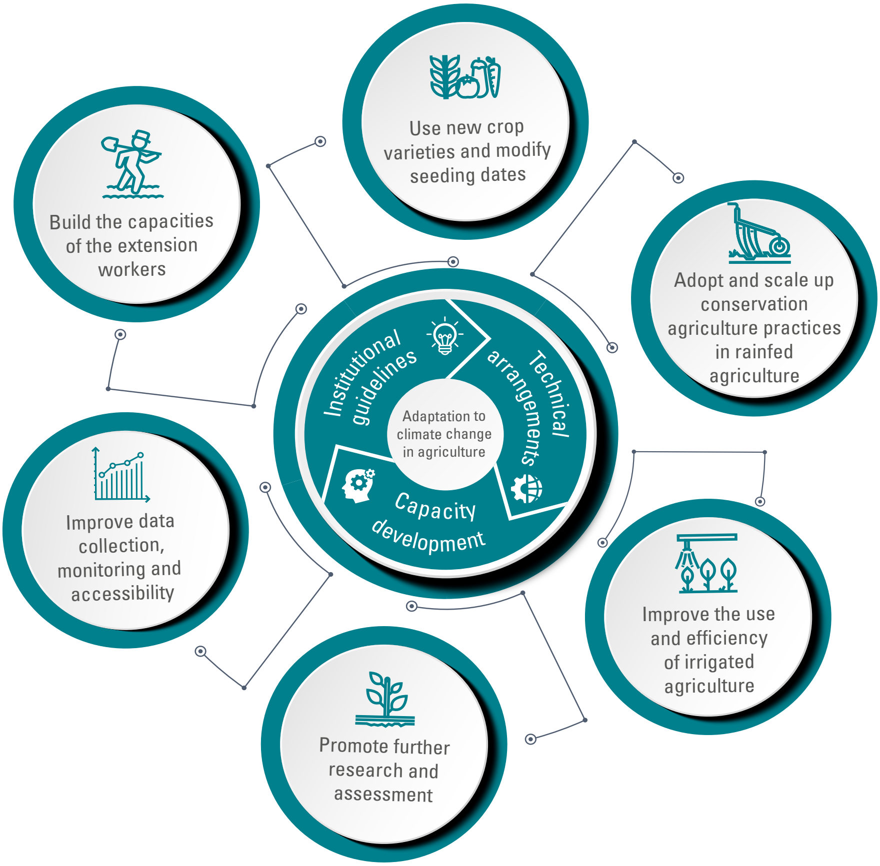
It is important to note that poverty in north-western Tunisia, where the region of Koudiat is located, already increased from 17.9 per cent in 2010 to 29 per cent in 2015, and is expected to increase further in the event of decreasing crop yields aggravated by climate change.

Source: World Bank, Climate Variability, Drought, And Drought Management In Tunisia's Agricultural Sector, 2016; FAO, FAOSTAT Trade: crops and livestock products, 2019; FAO country profile, Tunisia, May 2019.

6. Recommendations for Enhancing the Resilience of the Agriculture Sector

To improve the resilience of the agriculture sector in Tunisia, it is recommended to improve efficiency of conservation agricultural practices, including improved irrigation practices (within sustainable limits), while establishing water accounting

Figure 1. Framework for actions to adapt to climate change



Source: Designed by UN-ESCWA.

systems, monitoring water allocations to the irrigation sector, and promoting the use of non-conventional water resources, such as rainwater harvesting.

It is also recommended to adopt appropriate socioeconomic development policies that include economic diversification and climate insurance at the local level through off-farm economic activities. This would provide a better buffer and safety nets for small- scale famers (rural men and women) more vulnerable to climate change impacts.

Table 3 lists the suggested actions for each key recommendation for agriculture in Tunisia. Recommendations are identified based on the multiple dimensions they are connected to, including institutional, policy and financial arrangements, knowledge generation, and capacity development.

Table 3. Key recommendations and actions for adapting agriculture to climate change

1. Adopt and scale up conservation-agriculture practices in rainfed agriculture

Policy and financial arrangements:

- Develop comprehensive policies/incentives that encourage conservation practices, such as targeted subsidies, reducing taxes and providing incentives to farmers applying conservation agriculture practices/technologies (minimum tillage, permanent soil cover, and diverse crop rotation);
- Provide social safety nets (equitable micro-insurance schemes) for the most vulnerable farmers, especially farmers relying on rainfed agriculture;
- Increase investment in water harvesting infrastructure and techniques to provide opportunities for farmers to adopt supplementary irrigation in rainfed areas;
- Encourage adoption and financing of traditional agriculture systems for biodiversity conservation and knowledge preservation (Ramli cropping practices, and hanging gardens).

Knowledge generation:

- Undertake research to compare yields, soil properties development and plant growth phases, under the conditions of conservation agriculture and those of traditional agriculture, and publish results.

Capacity development:

- Build the capacity of farmers on conservation agriculture practices, especially on linked technology used, and highlighting its profitability;
- Enhance information flow in both directions, taking into consideration farmers' local initiatives and experiences to improve local ownership of management strategies.

2. Improve the use and efficiency of irrigated agriculture

Institutional and financial arrangements:

- Establish suitable water accounting systems to monitor water resources availability and control water allocations to irrigation, within sustainable limits of water consumption, based on regional guidelines for water allocation for agriculture sector developed by ESCWA and FAO for the Joint High-level Technical Committee on Water and Agriculture;
- Promote the Government's 2030 agenda that aims to improve yields through efficient water use (improving overall efficiency and favouring the most productive uses of water);
- Encourage and provide incentives and financing for the use of non-conventional water resources, such as rainwater harvesting, by developing a related national strategy.

Knowledge generation:

- Enhance irrigation scheduling and deficit irrigation;
- Identify irrigated crops to be used in each region;
- Evaluate irrigation water productivity and analyse the marginal benefit of water use for different crops and seasons;
- Improve research on saline water irrigation.

Capacity development:

- Build the capacity of farmers to use a variety of non-conventional water resources;
- Build the capacity of farmers to benefit from water-saving irrigated agriculture through participatory processes of water cooperatives that identify best irrigation practices within sustainable consumption limits and provide pertinent subsidies.

3. Develop the use of new crop varieties and modify seeding dates

Financial arrangements:

- Invest in promoting innovative approaches and technologies related to new crop varieties and/or modify seeding dates to maintain or increase crop yields under climate change conditions.

Knowledge generation:

- Provide the necessary financial resources for research institutes to perform related studies. This may be through dedicating programmes for adaptation in the agricultural sector;
- Encourage coordination and collaboration between universities, research institutes (INRAT, IRESA, ESIAT) and technical centres to perform assessment studies and benefit from their research (IQBA, ICARDA, ACSAD).

Technical arrangements:

- Diversify farming activities, which includes high-value horticulture, such as tomatoes, which tolerate higher salinity levels;
- Scale up saline agriculture and test halophytic crops;
- Encourage field crops that require less water;
- Apply organic fertilizers that have better water retention properties, and increase use of fertilizers on farms while assessing health and environmental risks;
- Test the modification of seeding dates and crop sequence to account for shifting periods of rainfall;
- Change planting dates and crop varieties to cater for shorter seasons.

4. Empower farmers

Institutional and financial arrangements:

- Empower rural workers with the skills needed for additional income-generating activities to mitigate the negative effects climate change can have on the local population;
- Adopt a comprehensive policy that includes innovation in measures to reduce and transfer risks through climate insurance, and to promote economic diversification at the local level through off-farm economic activities. This would provide a better buffer and safety nets for small scale famers vulnerable to climate change impacts.

Capacity development:

- Through targeted farmer field schools, provide farmers with improved skills to enhance farm husbandry, including the use of new crop varieties, leading to higher adaptation capacity and enhanced farm resilience;
- Encourage farmers to adopt higher valued crops.

5. Improve data collection, monitoring and accessibility

Institutional arrangements:

- Establish institutional coordination mechanisms to monitor the effects of climate change on different sectors and environments, and share with agencies and ministries;
- Develop tools to enhance the climatic unit model in the National Weather Observatory, to create a system for monitoring and sharing knowledge;
- Establish a database that provides reliable data required for calibrating and simulating the AquaCrop model and allows for easy download and display of readily available data.

Knowledge generation:

- Produce interactive maps using geographic information systems that represent the impact of climate change on agriculture areas to display and download data as a tool to support and formulate future agricultural and food policies;

- Downscale the vulnerability maps of agriculture for pertinent and informed adaptation policy, and incorporate it into different topics and sectors;
- Build a dense precipitation gauging network due to the high spatial variability of precipitation in Tunisia to allow for more accurate research;
- Update the climate change data projection through cooperation between national (National Institute of Meteorology), regional, and international institutions;
- Encourage use of big data for local assessment.

6. Promote further research and assessments

Institutional arrangements:

- Encourage partnership between research institutes and universities to perform studies on other crops and regions and agricultural environments using the AquaCrop and RICCAR climate datasets;
- Establish and join a regional network of AquaCrop practitioners, and collaborate with the Near East and North Africa (NENA) Regional and Global Network of AquaCrop practitioners;
- Build on already established plans and collaborations such as the Regional Collaborative Strategy on Sustainable Agricultural Water Management;
- Identify a focal point/coordinator to follow up on the implementation of the assessment programme for different crop types and different regions in the country.

Knowledge generation and sharing:

- Expand the scope of the study by applying AquaCrop to several cereal-growing sites to get a comprehensive vision of crop production in different climatic conditions, and to further prove the effectiveness of the model and its suitability to different environments;
- Perform AquaCrop simulation using RICCAR climate datasets to analyse areas where rainfed agriculture/irrigated crops are widespread with their various geographical features, climates (sub-humid versus semi-arid) and soil types;
- Assess optimization of water use in irrigation for the main crops in irrigated areas using AquaCrop model, and analyse various irrigation methods and systems using the AquaCrop model;
- Apply field experiments to assess the application of deficit irrigation on various crops, and compare to model results;
- Encourage publication of research using the AquaCrop model and RICCAR climate datasets to provide more evidence-based adaptation measures for the agricultural sector under climate change conditions.

Capacity development:

- Conduct training of trainers on the application of AquaCrop and RICCAR climate datasets through GIS for crop and water productivity assessments;
- Hold training sessions and workshops at different institutions and universities that facilitate the use of AquaCrop and mainstream the AquaCrop simulation tool and methodology;
- Develop training programmes on the use of simulation tools (water deficit irrigation) linked to AquaCrop and RICCAR;
- Disseminate the training material and methodology developed in the project to encourage further research and applications.

Endnotes

1. The country team comprised three experts from the Ministry of Agriculture, Water Resources and Fisheries, and the Institut National des Grandes Cultures.
2. ESCWA, Assessment of the impacts of changing water availability due to climate change on agricultural production in Tunisia, 2019. Available at www.unescwa.org/sites/www.unescwa.org/files/uploads/national-assessment-report-tunisia-arabic.pdf.
3. ESCWA, RICCAR Arab Climate Change Assessment Report, 2017. Available at www.unescwa.org/publications/riccar-arab-climate-change-assessment-report.
4. ESCWA, Assessment of the impacts of changing water availability due to climate change on agricultural production in Tunisia, 2019.

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