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CLIMATE RESILIENT AGRICULTURE:
TRANSLATING DATA TO POLICY ACTIONS

Case Study of AquaCrop Simulation in Lebanon

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UNITED NATIONS
Beirut

References to dollars ($) are to United States dollars, unless otherwise stated.

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United Nations publication issued by ESCWA, United Nations House,
Riad El Solh Square, P.O. Box: 11-8575, Beirut, Lebanon.

Website: www.unescwa.org.

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 Lebanon. 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 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.

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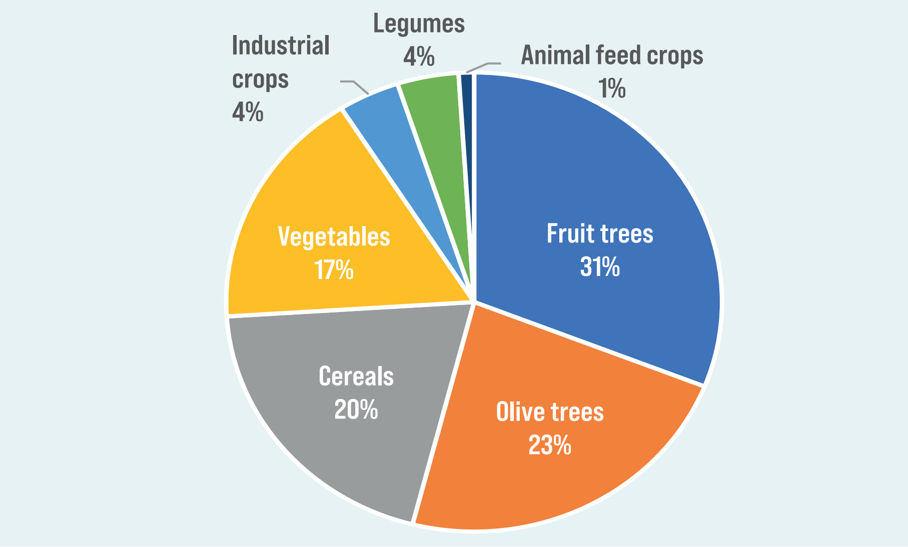
1. Country Background

Lebanon covers an area of 10,452 km^2 and has a Mediterranean climate. According to the most recent agricultural census in 2010, the total area of cultivated land in Lebanon is approximately 223,000 ha, of which half is irrigated. The agricultural area includes perennial crops representing 54 per cent of the total cultivated land, followed by seasonal crops at 44 per cent and protected crops at 2 per cent. The distribution of crop types in Lebanon by area is shown in figure 1.

Cereal crops include wheat, field corn, sweet corn and barley. Wheat is considered a strategic crop and a fundamental component of national food security. It accounts for about 70 per cent of the total cultivated cereal area, with roughly 50 per cent of this area being irrigated, and is grown in regions that receive an average precipitation of 400–600 mm/year. Lebanon produces about 100,000 tons of wheat, and imports roughly 300,000 tons per year. The average wheat yield varies from 2 to 5 ton/ha, depending on the region and the agricultural practices used.

Lebanon is considered a major food importer, as domestic food production only provides about 20 per cent of its needs. At the same time, the agricultural sector provides income for thousands of workers in rural areas. Box 1 highlights the need for women's empowerment in agriculture.

Figure 1. Distribution of crop types in Lebanon (by area)



Source: Ministry of Agriculture.

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 one major cropping systems in the central Beqaa Valley, Lebanon: wheat that is irrigated to supplement the rainy season.

The central Beqaa Valley, with an altitude ranging from 700 to 1,200 m above sea level, has a precipitation range of 150–600 mm per year, affecting what winter crops are grown. The cultivated area in the Beqaa region reaches around 90,000 ha, half of which is irrigated. Cereals are the main crops grown in this area, with a total cultivated area of about 40,000 ha, most of which is used to grow a variety of hard wheat unsuitable for flour production. The second most important crops grown in the Beqaa Valley are fruit trees, with a cultivated area of about 27,000 ha, followed by vegetable crops, at around 24,000 ha.

Wheat is of strategic importance and is widely cultivated in the Beqaa Valley, accounting for around 44 per cent of the total area of wheat cultivated in Lebanon. All wheat in the Beqaa region is irrigated to supplement the rainy season and most irrigation is sporadic and depends on the availability of irrigation water for farmers. Supplementary irrigation occurs in the spring to cover the water shortage and is applied two or three times during the season.

Box 1. Women's empowerment

Lebanese labour law stipulates equal participation and pay for women and men, but it excludes those working in the agriculture sector, thus depriving them of basic social insurance and protection. Agriculture workers are only eligible for the National Social Security Fund if they are permanent agricultural employees, which is rarely the case. Around 75 per cent of female workers in the agriculture sector are hired on a seasonal basis and are thus ineligible for these benefits.

Given the lack of legal protection for women's work in agriculture, they remain marginalized in terms of their ability to contribute to decision-making, receive benefits and influence spending. In addition, rural women lack access to essential resources, limiting their productive capability.

Rural women are also among the most vulnerable to the impacts of climate change on agriculture, even though they have an integral role in Lebanese local food systems and the agriculture value chain. No specific legislation addressing rural women exists in the Lebanese Labour Law (UNDP, 2019).

A number of initiatives are ongoing in Lebanon to promote the role of rural women and youth, generally involving capacity-building. For instance, the Rural Empowerment and Entrepreneurship Forum (REEF) launched by the Faculty of Agricultural and Food Sciences at the American University of Beirut aims to build a platform including all developmental actors in rural areas in Lebanon. One of its components, CLIMAT "Climate-Smart Livelihoods Initiatives and Market Access Tailoring" aims to sustainably improve the skills and capacities of local youth, women and farmers in alternative and climate-smart agricultural crop production and agro-food processing in the following three value chains:

- Small ruminant production;
- Alternative and climate-smart agricultural crop production;
- Agro-food processing.

Source: United Nations Development Programme, Gendered Value Chains Study: Barriers and Opportunities (2019).

3. Assessment methodology

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

The following steps were involved in the use of AquaCrop:

- **Data collection** was required for climate, soil and crop types. The required daily climate data included maximum and minimum temperatures, wind speed, relative humidity, solar radiation and rainfall. Weather, soil and crop data for the study area were collected at the Tal Amara Research Station of the Lebanese Agricultural Research Institute in the central Beqaa Valley. The climate data used in the AquaCrop Model correspond to the period 2003–2014.
- **Calibration** of AquaCrop to simulate the productivity of wheat in the central Beqaa Valley, using 10 years of field data, with the objective of providing the model with parameters simulating the actual productivity of wheat within an acceptable accuracy range. Data included soil characteristics, groundwater depth, irrigation scheduling, main farm management, climate data and crop yield. The specific calibrations for wheat were as follows: planting on 1 December and conducting three supplementary irrigation procedures at different rates and times during the growth of the wheat with total available water in the soil at 100 per cent. The calibrated model was then used to simulate the crop yield under future climate change.
- **Simulation** of the impacts of climate change on the productivity of wheat were carried out based on the RICCAR project for two periods: 2020–2030 (represented by 2025) and 2040–2050 (represented by 2045) and for the two scenarios of RCP 4.5 and RCP 8.5. The reference period is 1986–2005. Moreover, two sets of projected changes were used: 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 for disaggregation of the mitigating effect of increased CO_2 on yield losses due to temperature rise and water scarcity.

4. Assessment findings

Overall, the assessment clearly shows that wheat yields would rise for all scenarios under fixed and changing CO_2 concentrations. The projected increase in yield is the result of changes in precipitation patterns during the growing season, with rainfall delayed until the end of mid-season, in addition to the mitigating effect of the elevated CO_2 concentration.

The temperature increase leads to a shortening of days to maturity of wheat (more pronounced under RCP 8.5), with a reduction of 8 days by 2045. Reference crop evapotranspiration decreases over the simulated periods because of the anticipated higher temperatures shortening the number of days to maturity, with the lowest rates reached by 2045. However, results should be considered carefully as other non-linear limiting factors may counteract the positive effect on yield, particularly the reduced recharge of groundwater aquifers, thus affecting the availability of water for irrigation.

- **Central Beqaa Valley site findings**

The AquaCrop calibration resulted in an acceptable 76 per cent correlation between projections and actual yields recorded in field experiments.

Climate variable projections

The climate models (CNRM-CM5,[4] GFDL-ESM2M[5] and EC-Earth projections)[6] provided varying results for precipitation and temperature change in the 2025 and 2045 periods under the RCP 4.5 and RCP 8.5 scenarios, as illustrated in tables 1 and 2 respectively.

Table 1. RCP 4.5 scenario

Parameter	2020–2030	2040–2050
CNRM-CM5		
Seasonal precipitation (mm)	+2	+18
Annual precipitation (mm)	+15.7	+0.5
Maximum temperature (°C)	+1	+1.4
Minimum temperature (°C)	+0.7	+1
EC-Earth		
Seasonal precipitation (mm)	+41	-26
Annual precipitation (mm)	+102	-45
Maximum temperature (°C)	+0.8	+1.38
Minimum temperature (°C)	+0.7	+0.9

Parameter	2020–2030	2040–2050
GFDL-ESM2M		
Seasonal precipitation (mm)	-40	-18
Annual precipitation (mm)	-72	-20.4
Maximum temperature (°C)	+0.8	+1.4
Minimum temperature (°C)	+0.4	+0.9

Table 2. RCP 8.5 scenario

Parameter	2020–2030	2040–2050
CNRM-CM5		
Seasonal precipitation (mm)	+16	-15
Annual precipitation (mm)	-26.6	-62.1
Maximum temperature (°C)	+1.2	+1.5
Minimum temperature (°C)	+0.7	+0.9
EC-Earth		
Seasonal precipitation (mm)	+3.9	+20
Annual precipitation (mm)	+13	-7
Maximum temperature (°C)	+1.2	+1.8
Minimum temperature (°C)	+0.9	+1.2
GFDL-ESM2M		
Seasonal precipitation (mm)	+10.5	-75
Annual precipitation (mm)	+22	-77
Maximum temperature (°C)	+1	+1.8
Minimum temperature (°C)	+0.8	+1.2

Crop productivity

The climate models show significant increases in wheat yields under both scenarios (RCP 4.5 and RCP 8.5) and under both fixed and changing CO_2 concentrations compared to the baseline period of 1985–2006. This is due to changes in precipitation patterns during the growing season, with rainfall delayed until the end of mid-season, with positive impacts on yields. It should be noted that, under each climate change model considered, the distribution of rainfall was always adequate and spread throughout the growing season. Rainfall at the end of the growing season in particular has a major impact on wheat production.

Results also show a reduced reference crop evapotranspiration rate. The overall increase in yield is also accompanied by an increase in water productivity. Further findings of the model in comparison to the reference period (1985–2005) are addressed in box 2.

Box 2. Main Findings of the AquaCrop Simulation in Central Beqaa Valley

- Under the RCP 4.5 scenario:

  Days to maturity for wheat decrease to 177 and 173 days in the 2025 and 2045 periods.

  Wheat productivity increases by 8.3 and 13.4 per cent in the two periods under fixed CO_2. Under changing CO_2, productivity increases by 22.5 and 35.8 per cent.

  Crop water productivity increases to 1.1 and 1.2 kg/m^3 in the two periods in case of fixed CO_2. With changing CO_2, crop water productivity increases to 1.3 and 1.8 kg/m^3.

- Under the RCP 8.5 scenario:

  Days to maturity for wheat decrease to 176 and 173 days in the two periods.

  The productivity of wheat increases by 10.2 and 17.4 per cent in the two periods under fixed CO_2. Under changing CO_2, productivity increases by 26.1 and 42.2 per cent.

  Crop water productivity increases to 1.2 and 1.3 kg/m^3 in the 2025 and 2045 periods respectively under fixed CO_2. Under changing CO_2, crop water productivity increases to 1.4 and 1.6 kg/m^3.

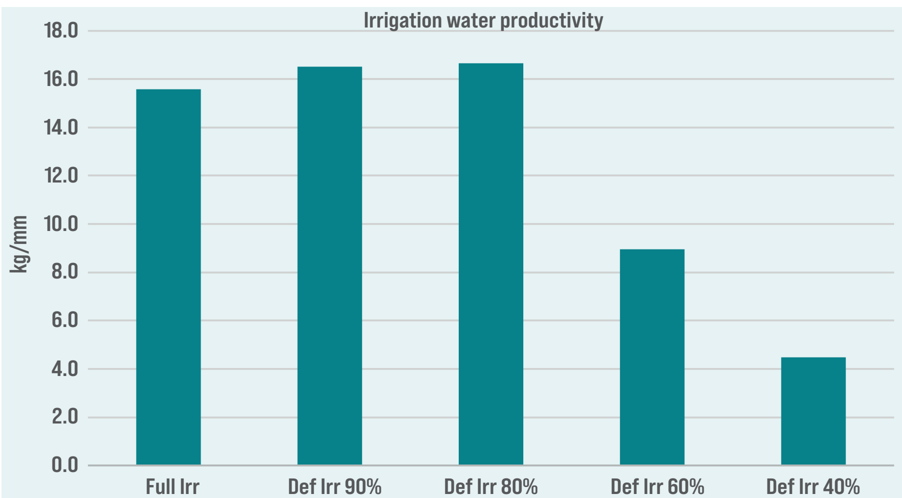
5. Simulation of deficit irrigation as adaptation measure

As part of the ESCWA project "Enhancing resilience and sustainability of agriculture in the Arab region", further trainings were conducted to build the capacities of Lebanese officials to use the AquaCrop model for irrigation management (deficit irrigation) as an adaptation measure.

A case study was prepared for potatoes in the central Beqaa Valley using AquaCrop to simulate different deficit irrigation patterns (irrigation at 90 per cent, 80 per cent, 60 per cent and 40 per cent) while maintaining soil fertilization levels of "near optimal" (95 per cent). The study was conducted over the 2007–2018 period, for which climatic data was available from the in the Tal Amara meteorological station. Other data including crop yield and soil management information were retrieved from the Lebanese Agriculture Research Institute (LARI). The calibrated model performed well with a root mean square error of 0.17 and an r of 1.0. Under deficit irrigation, crop yields fell somewhat, but water productivity rose under the 90 and 80 per cent scenarios, as illustrated in figure 2.

Four deficit irrigation scenarios (90, 80, 60 and 40 per cent) were investigated under "near optimal fertilization levels" of 95 per cent to determine their impact on crop productivity and water productivity compared to full irrigation (658 mm/season).

Figure 2. Impact of deficit irrigation on potato water productivity



Source: Ministry of Agriculture.

Table 3. Impact of deficit irrigation on potato yields and water productivity

Simulation	Qty of water for irrigation (mm)	Change in yield (%)	Change in water productivity (%)
		Near optimal fertilization (95%)	
Full Irr	658		
Deficit Irr 90 per cent	592	-4.54	-1.43
Deficit Irr 80 per cent	527	-14.53	-3.84
Deficit Irr 60 per cent	395	-65.53	-51.07
Deficit Irr 40 per cent	263	-88.52	-77.23

Simulation results using different deficit irrigation scenarios are shown in table 3 and adaptation measures proposed by the country team are described in box 3.

Box 3. Proposed adaptation measures for potato production using deficit irrigation

- If water is the limiting factor, the same amount of water currently used to irrigate one hectare (658 m^3) to produce 10.25 tons of potatoes can be used to irrigate 1.25 hectares of land under deficit irrigation at 80 per cent, increasing water productivity and producing 10.96 tons of potatoes.
- Broader application of the AquaCrop program nationally and in different regions and to different crops can help determine the optimal water use to achieve the highest water productivity and help inform decisions to obtain the highest possible financial return.

6. Analysis

Unlike some other regions of the Arab region and world, climate models predict increased wheat yields in the Beqaa Valley for all scenarios studied, due to changes in rainfall patterns and the benefit of increased CO_2 concentrations. However, wheat farming is dependent on irrigation, and irrigation is under stress due to frequent droughts in recent years, the depletion and degradation of groundwater and the rising cost of fuel. Distribution networks also require improvement in their efficiencies as they contain most water losses in the system. Investment must be promoted to modernize irrigation systems, especially for small agricultural holdings, in order to increase the efficiency of water use and improve land and water productivity.

Proper water accounting systems are also needed to monitor the availability of water resources and keep water allocations for irrigation within sustainable limits. Deficit irrigation is recommended to maximize the water productivity of key irrigated crops in Lebanon such as wheat and potatoes grown in the Beqaa, North and South governorates and Akkar valley.

More collaborative work is needed between the Ministry of Agriculture, the Ministry of Energy and Water Resources, the Litani River Authority, research institutions and farmers to ensure food security in Lebanon amid the many challenges it faces. While the Ministry of Agriculture has developed a comprehensive strategy for improving the agricultural sector in general, intersectoral collaboration and research will be necessary in order to increase agricultural productivity, expand water storage and improve its distribution in order to optimize resource use. Research is also needed to explore new sources of water, possibly including treated wastewater.

Box 4. Economic impact of climate change on agriculture

Lebanon is a major importer of food products as local production meets only 20 per cent of domestic consumption needs. The total value of agricultural and food imports reached $3.423 billion in 2013, while exports reached around $729 million, for a deficit of $2.694 billion. Lebanon produces about 100,000 tons of wheat per year and imports roughly 300,000 tons. The country imported 640,901 tons of wheat in 2017, worth $130.796 million according to FAO, representing 0.629 per cent of its total import bill.

Despite the importance of the agricultural sector, the Ministry of Agriculture's budget is only 0.5 per cent of the budget for other sectors. The agricultural sector in Lebanon provides income for thousands of workers in rural areas, but the lack of funding and poor governance have led to its share of GDP declining from 6.45 per cent in 1994 to 4.04 per cent in 2011.

Climate change further exacerbates the situation and undermines the country's food security. However, the AquaCrop simulation expects an increase in wheat yields. Large increases of up to 42 per cent in the yield of wheat could help curb a very large import bill for Lebanon. Lebanon could save $9,387,746 as a result of increased wheat yields and reduced imports. This could come in handy as the country currently faces a currency crisis and is in desperate need for hard currency, which it could be wasting on wheat imports.

Gains from increased wheat production would also benefit rural communities in the Beqaa valley, a region which has been sidelined from economic development since the creation of modern Lebanon. Regional inequality has been at the centre of recent protest movements in the country and at the core of popular grievances. Increased wheat yields could help lessen these inequalities and provide much needed income for farmers in rural areas.

Source: http://www.fao.org/faostat/en/#data/TP.

7. Recommendations

The national report studies the effect of climate change on wheat yields, due to the crop's strategic importance for food security. The Beqaa valley was chosen for the study region since most wheat production, around 100,000 tons/year, originates there. Major challenges faced by the agricultural sector in Lebanon include degradation of agricultural land due to water scarcity, poor soil fertility

Figure 3. Framework for actions to adapt to climate change

and decreasing productivity due to current agricultural practices, weak extension services, high production costs compared with neighbouring countries and poor market access, especially with the loss of some markets as a result of the current political instability.

Table 4 lists the suggested actions for each key recommendation generated for this study. Recommendations are identified based on the multiple dimensions they are connected to, including institutional, policy and financial arrangements, knowledge generation and capacity development.

Table 4. Key recommendations and actions to adapt agriculture to climate change

1. Increase the efficiency of irrigated agriculture

Institutional and Financial arrangements:

- Establish proper water accounting systems to monitor water resource availability and keep water allocations for irrigation within sustainable limits
- Collaborate with different research centres such as the Lebanese Agricultural Research Center (LARI), the Advancing Research Enabling Communities Center (AREC) and the National Council for Scientific Research (CNRS)
- Invest in maintenance of irrigation networks to reduce water losses
- Invest in modern irrigation technologies and optimize the use of available water resources by using the most water-saving irrigation techniques
- Develop water harvesting techniques to replenish groundwater reserves
- Increase investment in water harvesting infrastructure and techniques to provide the opportunity for farmers to adopt supplementary irrigation
- Expand the use of treated wastewater by developing wastewater collection networks and operating treatment plants already available

Knowledge generation:

- Identify the water requirements of crops and schedule irrigation accordingly to reduce the waste of irrigation water
- Evaluate irrigation water productivity and analyse the marginal benefit of water use for different crops and seasons
- Apply deficit irrigation to maintain or even increase wheat and potato yields

Capacity development:

- Encourage farmers to move to irrigated agriculture through participatory processes that identify best irrigation practices within sustainable consumption limits
- Provide incentives for farmers applying conservation practices/technologies and enable them to adopt them through education and technical assistance
- Modernizing irrigation systems such as localized irrigation technologies in irrigated areas to increase land and water productivity.
- Optimizing the utilization of available water resources by using the most water-saving irrigation techniques such as identifying the water requirements of crops and scheduling irrigation

2. Improve land use productivity

Institutional and financial arrangements:

- Encourage collaboration and coordination between the Ministry of Agriculture, the Ministry of Energy and Water, the Litani River Authority, research institutions and farmers to adopt mechanisms to maintain and develop agricultural land
- Build on and develop the current programmes and projects of the Ministry of Agriculture to increase agricultural productivity, encourage good agricultural practices and develop infrastructure
- Encourage the implementation of an integrated water resource management system to increase water storage and improve its distribution
- Provide the necessary financial resources for research institutes to perform related studies, including programmes on agricultural adaptation
- Establish a system to expand the use and distribution of fertilizers, consistent with the types of lands and the conclusions of agricultural research
- Support the transition to and application of intensive production systems
- Increase productivity to achieve a degree of self-sufficiency in crops with comparative advantages
- Strengthen the competitiveness of agricultural products and build capacities among actors in the domestic agricultural sector to compete with imported products

Knowledge generation:

- Identify the fertilizers needed by crops at different levels of soil fertility and based on data from agricultural research
- Apply organic fertilizers that have better water retention properties and increase use of fertilizers on farms while ensuring they do not lead to contamination of the water table

Capacity development:

- Prepare advisory programs for fertilizer use according to the crops and areas under cultivation
- Promote further research and assessments

3. Empower Farmers

Institutional and financial arrangements:

- Adopt a comprehensive policy that includes innovations in measures to reduce risks through climate insurance and promote economic diversification at the local level through off-farm economic activities
- Provide social safety nets (equitable insurance schemes) for the most vulnerable farmers
- Distribute additional income from increased wheat yields and channel into financing development in rural areas
- Ensure income is distributed fairly and channelled into financing development in rural areas
- Encourage farmers to adopt higher value crops

Capacity development:

- Empower rural workers with the skills needed for sound economic growth to mitigate the effects of climate change on the local population
- Implement targeted field schools to 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. Also provide them with methods to optimize irrigation scheduling

4. Promote further research and assessments

Institutional arrangements:

- Promote scientific research and development of agriculture technologies
- Link research topics to address problems in various facets of agriculture and highlight and implement them by the relevant ministries
- Encourage partnership between research institutes and universities to perform studies on other crops and regions using the AquaCrop and RICCAR 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, established and managed by FAO.
- Build on already established plans and collaborations such as Regional Collaborative Strategy (RCS) on Sustainable Agricultural Water Management.
- Identify a focal point/coordinator to follow up on the implementation of an assessment programme for different crop types and different regions in the country.

Knowledge generation and sharing:

- Expand the scope of the study to different varieties of crops, to assess the impact of climate change on a number of strategic agricultural crops such as potatoes.
- Perform AquaCrop simulation and analysis on rainfed areas and other irrigated areas.
- Assess the optimization of water use in irrigation for the main crops in irrigated areas using the AquaCrop model and analyse various irrigation methods and systems.
- Compare several types of irrigated fields to see which species can produce the highest yields with the same amount of water.
- Encourage publication of research using the AquaCrop model to provide more evidence-based adaptation measures for the agricultural sector under climate change conditions.

Capacity development:

- Train trainers on the application of the AquaCrop and RICCAR data sets through GIS for crop and water productivity assessments.
- Facilitate the use of AquaCrop and mainstream the AquaCrop simulation tool and methodology.
- Develop training programmes on the use of AquaCrop simulation tools (water deficit irrigation).
- Disseminate the training material and methodology developed in the project to encourage further research and applications.
- Develop training programs on the use of AquaCrop simulation tools (water deficit irrigation)
- Disseminate the training material and methodology developed in the project to encourage further research and applications

5. Improve data collection, monitoring and accessibility

Institutional arrangements:

- Implement data monitoring and sharing between agencies and establish institutional coordination mechanisms to monitor the effects of climate change on different sectors and environments.
- Develop tools to enhance weather station data monitoring, recording and data dissemination.
- Enhance work done by the Lebanese Agricultural Research Institute to provide climate data for agricultural areas.
- Conduct an agricultural census by the Ministry of Agriculture, as the latest one was conducted in 2010.
- Establish a database providing reliable data required for calibrating and simulating the AquaCrop model and allowing for easy download and display of data.
- Update the climate change data projection through cooperation between national, regional and international institutions.
- Use data to establish an emergency warning and preparedness system for droughts and floods.

Knowledge generation:

- Produce an interactive map using geographic information systems to show the impacts of climate change on agricultural areas and display and download data, as a tool to support and help formulate future agricultural and food policies.
- Increase the granularity of agricultural vulnerability maps in order to inform relevant adaptation policies and incorporate them into different topics and sectors.

Endnotes

1. National Team composed of experts from the Ministry of Agriculture and Lebanese Agricultural Research Institute.
2. ESCWA, Assessment of the impacts of changing water availability due to climate change on agricultural production in Lebanon, 2019. Available at www.unescwa.org/sites/www.unescwa.org/files/uploads/national-assessment-report-lebanon-arabic.pdf.
3. ESCWA, RICCAR Arab Climate Change Assessment Report, 2017. Available at www.unescwa.org/publications/riccar-arab-climate-change-assessment-report.
4. A version of the general circulation model CNRM used in phase 5 of the Coupled Model Intercomparison Project (CMIP5).
5. Earth System Model – Geophysical Fluid Dynamics Laboratory.
6. A global climate model system based on the use the world-leading weather forecast model of the ECMWF (European Centre for Medium-Range Weather Forecasts) in its seasonal prediction configuration as the base of climate model.

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