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CLIMATE RESILIENT AGRICULTURE: TRANSLATING DATA TO POLICY ACTIONS

Case Study of AquaCrop Simulation in Palestine

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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 Palestine. 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 rainfed and 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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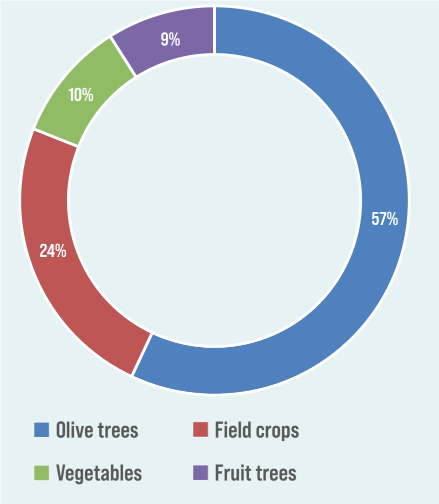
1. Country Background

The agricultural sector in the State of Palestine is diverse, taking advantage of the country's diversity in climate and terrain. The West Bank and the Gaza Strip cover a combined area of around 600,000 hectares, of which around 20 per cent (120,000 hectares) is used for agriculture, 90 per cent in the West Bank and 10 per cent in the Gaza strip.[4] According to Ministry of Agriculture data (2014-2015), average field crop yields are 49.2 kg/ha, and total annual production is estimated at 79,923 tons. 73 per cent of field crop production is concentrated in the four months of January, February, May and June.

Rainfed cultivation is predominant in Palestine, covering 81 per cent of the total area used for agriculture, with irrigation covering the remaining 19 per cent, concentrated in the Gaza Strip, the Jordan Valley and the semi-coastal areas of the West Bank. Groundwater is the main source of water in the State of Palestine in the absence of significant surface water sources and the inability of Palestinians to invest in the development of water infrastructure due to the constraints of the Israeli occupation. Agriculture in the State of Palestine is estimated to use less than 150 million m^3/year (60 million m^3/year in the West Bank and 90 million m^3/year in the Gaza Strip), representing 45 per cent of the country's total water use.

Overall, poor soil fertility and the dearth of investments in agriculture are the result of water scarcity, the lack of financial means and the high risk involved. These represent some of the main difficulties facing the agriculture sector in Palestine, where no more than half of all arable land is actually cultivated. The remaining area can be divided into: arable land that is not being cultivated, i.e. land that should be reclaimed; land that cannot be reclaimed (often land being used as pasture); land that has been used for urban and industrial development; and land that has been confiscated for various reasons.

Figure 1. Distribution of crops planted in the West Bank



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 following two major cropping systems, given their paramount importance to the country's food security and economic stability:

1. Rainfed wheat in Marj Ibn Amer, Jenin Governorate.
2. Irrigated potato in Marj Ibn Amer, Jenin Governorate.

The study area of Marj Ibn Amer (Jezreel Valley) is located in Jenin Governorate, northern West Bank. The governorate has a population of about 256,000 people and an area of 583 km^2, representing 9.7 per cent of the total area of the West Bank. The plains of Jenin Governorate are some of the most important agricultural lands in the West Bank in terms of their size, soil quality and access to wells. Jenin Governorate is considered the breadbasket of Palestine and is famous for growing wheat, barley, sesame, olives, watermelon and almonds.

Wheat is an important segment of the agricultural sector in the State of Palestine, with Jenin Governorate being the top producer of wheat in the West Bank (54 per cent of all wheat production in the State of Palestine), followed by Khalil Governorate (16 per cent) and Nablus Governorate (11 per cent). Total annual wheat production in the West Bank is estimated at 25,926 tons, or 5 per cent of the total production of field crops.[5]

Potato cultivation covers 1,083.5 ha in the West Bank, representing 3.2 per cent of the total area of field crop cultivation. Total annual potato yield in the West Bank is estimated at 37,552 tons, representing 7 per cent of the total production of field crops. Tubas Governorate is the top producer of potatoes in the West Bank, generating 43 per cent of total production, followed by Jenin Governorate at 27 per cent and then Nablus Governorate at 25 per cent.[6]

Box 1. Women and youth empowerment

The proportion of men employed in the agricultural sector in 2015 was 7.8 per cent of total working males, while 13.1 per cent of the total number of working females worked in the sector, indicating the relative importance of the agricultural sector for women.

Women have an essential role in securing the food basket as they carry out 54 per cent of the labour in plant production. Nonetheless, large gender gaps persist; only 6.7 per cent of all agricultural holdings are owned by women (PCBS, 2011) and an estimated 40 per cent of rural working women are unpaid. It is therefore important for the public and private sectors and civil society to empower women involved in agricultural activities. This may be through:

- Addressing challenges related to women's inheritance rights.
- Encouraging female farmers to join agricultural cooperatives.
- Enabling access to finance, markets and extension services.
- Holding information sessions that address social, technical and economic aspects of farming.

Source: PCBS, 2011. Agricultural Census Data – Final Results, Palestinian Territories.

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. Climate data, including daily precipitation rates and monthly temperatures, were collected for the period 1996-2015 from the Palestinian Meteorological Department. Data on wheat yields (2004-2015) and potato yields (2004-2014) were gathered from local crop experts and thus cannot considered entirely reliable.
- **Calibration** of AquaCrop to simulate the productivity of the two selected crops under local conditions using 12 years of data for rainfed wheat (2003-2015) and 11 years of data for irrigated potatoes (2003-2014). Data included soil characteristics, groundwater depth, irrigation scheduling, main farm management, climate data and crop yield.
- **Simulation** of the impacts of climate change on the productivity of the two crops based on the RICCAR project models (EC-Earth,[7] CNRM-CM5[8] and GFDL-ESM2M[9]) 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.
- **Testing** of deficit irrigation for potatoes as an adaptation measure given reduced water availability due to climate change. 20 per cent and 25 per cent reductions were tested for both RCP scenarios and both periods.

4. Assessment findings

The assessment clearly shows that under fixed CO_2, wheat yields would increase while potato yields would decrease. Under changing CO_2, yields of both crops are projected to increase. The projected increase in yield under changing CO_2 is the result of the mitigating effect of elevated CO_2. Deficit irrigation scenarios involving 20 per cent and 25 per cent reductions in irrigation for potato crops show slightly decreased yields.

- ## Climate variable projections

Yearly climatic projections for Jenin Governorate show an increase in max and min projected temperatures under the two scenarios, with max. temperatures rising in the range of 0.95-1.75 °C under RCP 8.5 and 0.51-1.31 °C under RCP 4.5 and min. temperatures rising in the range of 0.72-1.37 °C under RCP 8.5 and 0.4-1.0 °C under RCP 4.5.

In terms of precipitation, slight changes are projected in the two scenarios (increases and decreases) in seasonal precipitation, with much clearer changes in annual precipitation. Under RCP 4.5, results indicate an increase in yearly precipitation for both periods according to the CNRM-CM5 model and EC-Earth model, but a decrease in yearly precipitation by 13.9 and 42.4 mm according to the GFDL-ESM2M model for the 2025 and 2045 periods, respectively. All models indicate an increase in seasonal precipitation for the 2045 period. Under RCP 8.5, the EC-Earth model indicates an increase in yearly precipitation by 44.7 and 35.6 mm for the 2025 and 2045 periods, respectively. For the 2045 period, seasonal precipitation is simulated to increase by 9.8 and 22 mm under the CNRM-CM5 model and GFDL-ESM2M, respectively.

- ## Wheat productivity

For the most pessimistic scenario, RCP 8.5, wheat yields increase by around 39 per cent and 55 per cent for the 2025 and 2045 periods, respectively, under changing CO_2 concentrations. Increases in yield and crop water productivity, as well as a decrease in reference crop evapotranspiration rates, are projected under all scenarios for wheat. Such increases are more pronounced under scenarios of changing CO_2 concentration, revealing a positive aspect of the increase in CO_2, which, by facilitating the photosynthesis process, improves average yields. Further findings of the model in comparison to the reference period (1986-2005) are addressed in box 2.

- ## Potato productivity

For the most pessimistic scenario of RCP 8.5, potato yields are projected to increase under changing CO_2 concentrations and decrease under fixed CO_2 concentrations. The decrease in yield in irrigated potato under fixed CO_2 may be due to the decrease in days to maturity by 3 days under RCP 8.5 for the 2025 period. The lower days to maturity for irrigated potatoes is attributed to the temperature increase. Further impacts of the model in comparison to the reference period (1986-2005) are addressed in box 3.

Box 2. Main findings of the AquaCrop simulation for wheat

Under the RCP 4.5 scenario:

Days to maturity of wheat increase by 1 day for both periods under fixed and changing CO_2, compared to the reference of 150 days.

Wheat productivity increases by 17.8 and 30 per cent in the 2025 and 2045 periods, respectively. Under changing CO_2, yield increases by 33.8 and 56.2 per cent.

Crop water productivity increases to 0.68 and 0.76 kg/m^3 during the 2025 and 2045 periods, respectively. Under changing CO_2, crop water productivity increases to 0.8 and 0.95 kg/m^3 in the two periods.

Under the RCP 8.5 scenario:

Days to maturity of wheat increase by 1 day for both periods under fixed CO_2 while increasing by 2 days under changing CO_2, compared to the reference of 150 days.

Wheat productivity increases by 20 and 24 per cent in the 2025 and 2045 periods, respectively. Under changing CO_2, yield increases by 38.5 and 54.7 per cent for the two periods, respectively.

Crop water productivity increases to 0.7 and 0.74 kg/m^3 during the 2025 and 2045 periods, respectively as compared to the reference of 0.61 kg/m^3. Under changing CO_2, crop water productivity increases to 0.8 and 1 kg/m^3 when compared to the reference of 0.6 kg/m^3.

Box 3. Main findings of the AquaCrop simulation for potatoes

Under the RCP 4.5 scenario:

Days to maturity of potatoes decrease by 2 days for the 2025 and 2045 periods under fixed and changing CO_2, compared to the reference of 95 days.

Potato productivity decreases by 4 per cent in the 2025 and 2045 periods, respectively. Under changing CO_2, yield increases by 10.3 and 19.2 per cent respectively.

Crop water productivity decreases to 1.09 and 1.11 kg/m^3 during the 2025 and 2045 periods, respectively, as compared to the reference of 1.12 kg/m^3. Under changing CO_2, crop water productivity increases to 1.5 and 1.6 kg/m^3 in the two periods compared to the reference of 1.3 kg/m^3.

Under the RCP 8.5 scenario:

Days to maturity of potatoes decrease by 3 days and 1 day for the 2025 and 2045 periods under fixed and changing CO_2 respectively, compared to the reference of 95 days.

Potato productivity decreases by 3.38 and 3.01 per cent in the 2025 and 2045 periods, respectively. Under changing CO_2, yield increases by 11.6 and 23.8 per cent for the two periods, respectively.

Crop water productivity decreases to 1.22 and 1.26 kg/m^3 during the 2025 and 2045 periods, respectively, as compared to the reference of 1.24 kg/m^3. Under changing CO_2, crop water productivity increases to 1.5 and 1.7 kg/m^3 in the two periods compared to the reference of 1.3 kg/m^3.

- ## Deficit irrigation

Deficit irrigation was simulated as an adaptation measure, reducing water allocated for potato irrigation by 20 and 25 per cent for the 2025 and 2045 periods under both fixed and changing CO_2. Potato yields increase by 6.7 per cent under 20 per cent deficit irrigation for the 2045 period, under CO_2 and RCP 8.5. In all other cases, potato yields decrease, with the largest reduction being 28 per cent under 25 per cent deficit irrigation for the 2025 period, under fixed CO_2 and RCP 4.5. The impacts of deficit irrigation compared to the reference period (1986-2005) are shown in table 1.

Table 1. Changes in crop yield, evapotranspiration, and crop water requirement when applying 20 and 25 per cent deficit irrigation as an adaptation measure for potatoes under RCP 4.5 and 8.5

Scenario	Deficit irrigation	Yield change (per cent)			Evapotranspiration (mm)			Crop water requirement (kg/m^3)		
		Reference (tons/ha)	2025	2045	Reference	2025	2045	Reference	2025	2045
RCP 4.5	20%	6.16	-13.0	-8.4	555	470	470	1.12	1.19	1.14
	25%		-28.0	-24		448	448		0.98	1.05
	20%*	6.8	-11.5	-1.2	540.5	464	461	1.3	1.31	1.47
	25%*		-19.3	-10.4		448	445		1.22	1.37
RCP 8.5	20%	6.62	-19.5	-17	540.79	475	465	1.24	1.13	1.18
	25%		-25.0	-26.7		457	448		1.09	1.08
	20%*	6.8	-6.0	+6.7	540.7	474	462	1.3	1.36	1.59
	25%*		-13.7	-1.2		456	446		1.29	1.50

* Under changing CO_2.

5. Simulation of deficit irrigation applications as adaptation measures

As part of the ESCWA project "Enhancing resilience and sustainability of agriculture in the Arab region", further trainings were conducted to enhance capacities of Palestinian officials on the use of the AquaCrop model for irrigation management (supplementary and deficit irrigation) as an adaptation measure. Three case studies were prepared for rainfed wheat in Khalil, irrigated potatoes in Sumait plain, Nablus and irrigated maize in Deir Abu Deif valley/ Jenin using AquaCrop to simulate different management scenarios together with the impact of increasing or decreasing fertilization levels compared to current practices.

- ### Impact of supplementary irrigation on wheat productivity in Khalil Governorate

The study was conducted for the 2009-2018 period, with climatic data (rainfall, minimum and maximum temperatures) provided by a nearby weather station. Crop data were provided from farmers in the area. The calibrated model's performance was very good with an RMSE of 0.34 and an r of 0.96.

Table 2 presents simulation results of the impact of different fertilization levels (80, 60, 50, 40 and 24 per cent of current practice) on yield and water productivity in the study period. In each case, supplementary irrigation when soil moisture in the root zone approaches 10 mm above the wilting point was assessed to identify its impact on both yield and water productivity. These scenarios should be verified in field tests to identify the best option for decision-makers, and an economic feasibility assessment should be performed.

- ### Impact of deficit irrigation on productivity of sprinkler-irrigated potatoes in the Sumait plain, Nablus

The study was conducted over the 2009-2018 period, for which climatic data was available from the Jericho and Nablus meteorological

Table 2. Impact of supplementary irrigation on wheat yields in Khalil Governorate at various fertilization levels

Fertilization levels (%)	Change in yield (%)	Change in water productivity (%)
100 (current practice)	16.8	8.8
80	13.0	7.0
60	10.9	5.9
50	8.2	3.0
40	6.3	6.3
24	4.1	4.1

stations. Average temperature data from both stations were used and missing data was supplemented by the Al-Quds University datasets. Crop and water management data were obtained from farmers in the area and corrected by agriculture engineers in the agriculture extension department. Other data including soil management information were collected from the National Center for Agricultural Research. After removing a few outliers, the calibrated model's performance was within acceptable limits with an RMSE of 0.45 and an r of 0.37.

Table 3 presents simulation results of the impact of four deficit irrigation scenarios (72, 64, 56 and 48 per cent) and two fertilization levels (increased fertilization of 75 per cent and near-optimal of 90 per cent) on yield and water productivity. The scenarios were compared to full irrigation (232 mm/season) and 50 per cent fertilization levels currently applied by farmers. It was shown that reducing the amount of water used for irrigation under current fertilization levels negatively impacted crop yield but increased water productivity. Adaptation measures proposed by the country team are described in box 4.

Table 3. Impact of deficit irrigation on potato yields in the Sumait plain at various fertilization levels

Simulation	Qty of water for irrigation (mm)	Change in yield (%)			Change in water productivity (%)		
		Half fertilization (50%)	Moderate fertilizaation (75%)	Near-optimal fertilization (90%)	Half fertilization (50%)	Moderate fertilization (75%)	Near-optimal fertilization (90%)
Full Irr	232	Refer-ence	32.6	75.9	Refer-ence	31.6	74.6
Deficit Irr 72%	162	-2.7	27.7	65.5	5.1	35.6	74.7
Deficit Irr 64%	149	-5.2	22.7	56.6	6.8	35.6	71.9
Deficit Irr 56%	131	-10.2	13.0	40.2	6.2	31.0	61.8
Deficit Irr 48%	111	-14.3	6.8	25.4	9.0	33.3	54.4

Box 4. Proposed adaptation measures for potato production using deficit irrigation

- 72 per cent deficit irrigation while maintaining current fertilization levels is recommended, even if a slightly lower yield is achieved. The water saved can then be used to cultivate additional land.
- 64 per cent deficit irrigation while improving fertilization levels to moderate (75 per cent) is recommended if the cost of increased cost of fertilizer is less than the financial return resulting from the increase in productivity of 1.11 tons/ha and the amount saved on irrigation.
- 56 per cent deficit irrigation while improving fertilization levels to near-optimal (90 per cent) is recommended if the increased cost of fertilizer is less than the financial return resulting from the increase in productivity of 2.05 tons/ha and the amount saved on irrigation.

- ### Impact of deficit irrigation on productivity of irrigated maize in Deir Abu Deif valley/Jenin

The study was conducted over the 2009-2018 period, for which climatic data was available from the meteorological stations. Crop data were obtained from local experts. Other data including soil management information were collected from the National Center for Agricultural Research. After removing a few outliers, the calibrated model's performance was acceptable with an RMSE of 0.81 and an r of 0.09.

Table 4 presents simulation results of the impact of four deficit irrigation scenarios (76, 64, 57 and 48 per cent) and non-limiting fertilization levels on yields and water productivity. The scenarios were compared to full irrigation (220 mm/season) and "near-optimal" 90 per cent fertilization levels currently applied by farmers. Adaptation measures proposed by the country team are described in box 5.

Table 4. Impact of deficit irrigation on maize yields in Deir Abu Deif valley at various fertilization levels

Simulation Procedure	Qty of water for irrigation (mm)	Change in yield (%)		Change in water productivity (%)	
		Near-optimal fertil-ization (90%)	Non-limiting fertil-ization	Near optimal fertil-ization (90%)	Non-limiting fertil-ization
Full Irr	220	Reference	11.9	Reference	8.7
Deficit Irr 76%	168	0	12.1	1.8	10.8
Deficit Irr 64%	148	0	11.5	3.0	11.7
Deficit Irr 57%	126	-1	8.5	4.0	11.4
Deficit Irr 48%	106	-4	2.4	4.0	9.9

Box 5. Proposed adaptation measures for maize production using deficit irrigation

- 64 per cent deficit irrigation while maintaining fertilization levels at current levels (90 per cent fertilization) is recommended. The water saved per x units of land can be used to irrigate 3.34 additional hectares and produce an extra 27.59 additional tons of maize;
- 64 per cent deficit irrigation while improving fertilization levels to non-limiting is recommended if the increased cost of fertilizer is less than the financial return resulting from the increase in productivity of 0.95 tons/hectare.

6. Analysis

In the State of Palestine, 81 per cent of the total cultivated area is rainfed, and introducing and scaling up conservation-agriculture practices in these areas will obtain more value from water resources and preserve soil composition. Also, the quantity of water available for irrigation plays a major role in determining the amount of agricultural land to be irrigated, in addition to affecting yield and water productivity.

Groundwater is used as source for irrigation in Palestine, and overexploitation of groundwater has led to the deterioration of water quality and seawater intrusion, with only 10 per cent of wells producing drinking water. To reduce the stress on groundwater, it is essential to develop rainwater harvesting techniques and map out alternative sources of water such as treatment of wastewater or desalination. Such methods represent ways to preserve the sustainability of resources while reducing the risks of agricultural water scarcity, maintaining yields and increasing water productivity.

The national agricultural sector strategy (2017-2022) "Resilience and Sustainable Development" highlighted priority areas such as "establishing major water projects in arable irrigated areas focusing on water transfer, water collection or wastewater treatment and increased efficiency", and "developing and adopting policies and programmes to increase the agricultural sector's ability to adapt to and help mitigate the negative impacts of climate

Box 6. Economic impact of climate change on agriculture

Agricultural production in the State of Palestine has been declining for a decade, from a high value of $1.119 billion in 2011 to an estimated $390 million for 2017. Agriculture's share of GDP in the State of Palestine thus declined in the last decade to 2.8 per cent as of 2017, falling from 3.9 per cent in 2014 and 8.2 per cent in 2000.

Wheat-producing land amounts to 42.4 per cent of the total area of field crops in the West Bank. Potato production is also a notable source of income for Palestinian locals as it constitutes 7 per cent of the total production of field crops. Increases in wheat yields of up to 55 per cent (as shown in the AquaCrop simulation) would mean additional revenues of $44.026 million in the State of Palestine. Furthermore, increases in potato yields of up to 23.8 per cent (as shown in AquaCrop simulation) could amount to $26.315 million in revenues. Such revenues are sorely needed by residents of the West Bank, who are struggling with economic hardship and restrictions.

The main challenge for Palestinian agriculture however remains residents' inability to control water resources due to the occupation, and thus farmers' inability to access water. Challenges in accessing water include Israeli authorities cutting Palestinian farmers off from groundwater wells and diverting water resources to settlements in the West Bank. These restrictions make it much harder for Palestinians to capitalize on the effects on climate change and increase crop yields.

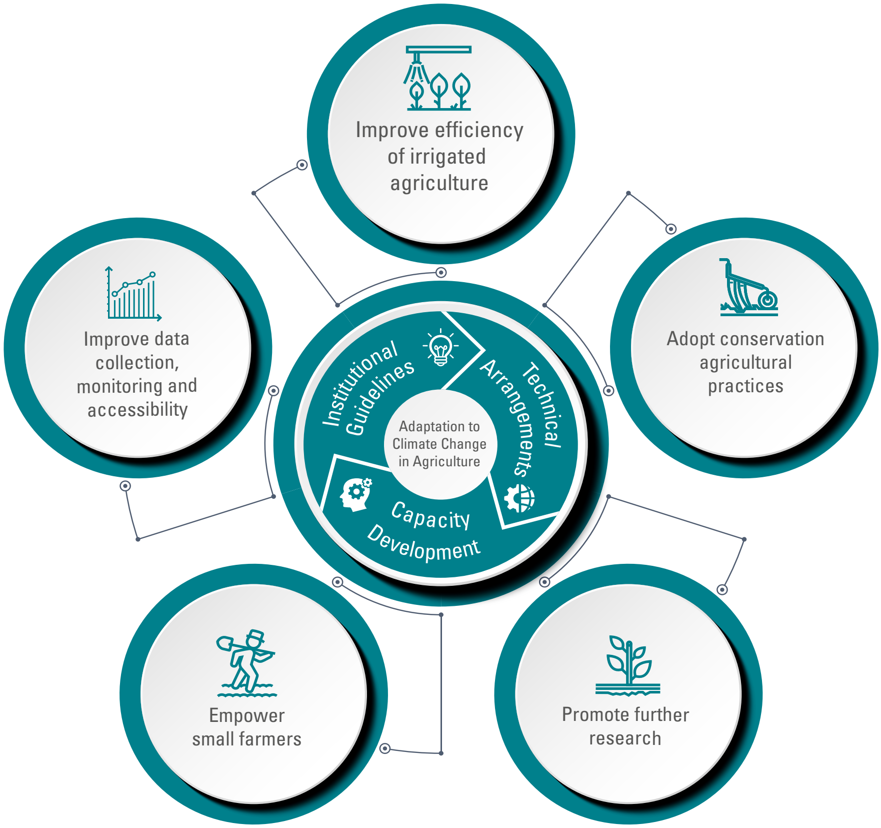
Sources: http://www.fao.org/faostat/en/#data.

change and natural disasters".[10] Therefore, effectively implementing this strategy entails improving the efficiency of irrigated agriculture by modernizing irrigation systems through localized irrigation technologies and enhancing sustainable community-level irrigation schemes and infrastructure to increase land and water productivity. It is important to encourage and empower farmers to acquire modern irrigation systems by developing agricultural information extension programmes to train them on suitable modern agriculture technologies and provide them with financial subsidies and support.

7. Recommendations

War and instability have ruined local infrastructure and greatly worsened the ability of the State of Palestine to manage its water resources. A major challenge faced by Palestinian farmers includes blocked access and restrictions on development in the water and irrigation sector, as well as restrictions on the import and export of agricultural products. In the Gaza Strip, farmers are still prevented from accessing their lands in what is known as the buffer zone, which extends along the eastern edge of the territory, with a width of 150

Figure 2. Framework for actions to adapt to climate change



meters to 1 km. At least 62 km^2 of agricultural land in the buffer zone is not being used due to associated risks, accounting for 40 per cent of agricultural land in the Gaza strip.

Table 5 lists the suggested actions for each key recommendation generated by this study in the State of Palestine. Recommendations are identified based on the multiple dimensions they are connected to, including institutional, policy and financial arrangements, knowledge generation and capacity development.

Table 5. 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.
- Boost collaborations between research centres and universities to research irrigation and water use efficiency.
- Modernize irrigation systems such as localized irrigation technologies in irrigated areas to increase land and water productivity.

Knowledge generation:

- Identify 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.
- Conduct field experiments to assess the impact of deficit irrigation on crop productivity and determine the accuracy of AquaCrop simulations.

Technical arrangements:

- Use additional and alternative water resources for irrigation, such as treated wastewater and desalinization.
- Rehabilitate water sources such as wells, canals and springs.
- Maintain distribution systems to control leakage.
- Increase efficiency and development of irrigation systems and use more efficient field irrigation practices than traditional methods.

Capacity development:

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

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

Policy and financial arrangements:

- Develop comprehensive policies encouraging conservation practices such as tax breaks and incentives for farmers applying conservation agriculture practices/technologies.
- Provide social safety nets (equitable insurance schemes) for the most vulnerable farmers, especially farmers relying on rainfed agriculture.
- Increase investment in water harvesting infrastructure and techniques to provide the opportunity for farmers to adopt supplementary irrigation.

Knowledge generation:

- Conduct research on yields, soil properties and plant growth under conservation agriculture and traditional agriculture.
- Test the modification of seeding dates and crop sequencing to account for shifting periods of rainfall.
- Developing rainwater harvesting techniques to improve groundwater reserves.
- Modify crop varieties, rotations and calendars, including planting and harvesting dates.
- Use organic fertilizers with better water retention.

Capacity development:

- Build capacity of farmers on conservation agriculture practices and technologies and highlight their profitability.
- Enhance information flow in both directions, taking into consideration farmers' local initiatives and experiences to improve local ownership of management strategies.

3. Empower farmers

Institutional and financial arrangements:

- Adopt a comprehensive policy that includes innovations in measures to reduce and transfer risks through climate insurance and to promote economic diversification at the local level through off-fam economic activities.
- Increase farmers' uptake of modern irrigation systems by providing them with financial subsidies and support.

Capacity development:

- Empower small farmers through implementation of targeted field schools, in both rainfed and irrigated areas.
- Build capacity of local farmers in farm husbandry and the use of new crop varieties, leading to higher adaptation capacity and enhanced farm resilience.
- Encourage farmers to plant higher value crops.

4. Promote further research and assessments

Institutional arrangements:

- Encourage partnership between research institutes and universities to study effects on other crops and regions using the AquaCrop and RICCAR climate datasets.
- Join the 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.

- 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:

- Promote further research and assessments on different varieties of crops and expand the use of the AquaCrop program to study the impact of climate change on water productivity and yields in different crops, with a focus on cash crops and areas with different climates, soils and water resources.
- Develop water harvesting techniques including rainwater harvesting to improve groundwater reserves.
- Map out alternative water resources for irrigation such as treated wastewater and desalinization, as overexploitation of groundwater has led to seawater intrusion.
- Conduct an economic assessment to assess the impacts of climate change on crop yields and the national economy.

Technical arrangements:

- Identify the water requirements of crops and schedule irrigation accordingly to reduce the waste of irrigation water.

Capacity development:

- Train trainers on the application of the AquaCrop and RICCAR data sets through GIS for crop and water productivity assessments.
- Develop training programmes on the use of simulation tools (water deficit irrigation) linked to AquaCrop.
- 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:

- Promote data monitoring and sharing between agencies and establish institutional coordination mechanisms to monitor the effects of climate change on different sectors.
- Support the Palestinian Meteorological Department by increasing the number of meteorological climate stations to cover the entire country.
- Establish a database of reliable data for calibrating and simulating the AquaCrop model and allowing for easy download and display of data.

Knowledge generation:

- Identify all unavailable information and data needed, particularly in the areas of soil and water resources and conduct new surveys to obtain unavailable data.
- Map the impacts of climate change on agricultural areas to display and download data as a tool to support and formulate future agricultural and food policies.
- Increase the granularity of agricultural vulnerability maps in order to inform adaptation policies and incorporate them into different topics and sectors.
- Update the climate change data projection through cooperation between national, regional and international institutions.

Endnotes

1. National Team composed of three experts from the Department of Soil and Land Classification, Department of Drought and Climate Change Monitoring, and the Department of Marginal Water Uses in the Ministry of Agriculture.
2. ESCWA, Assessment of the impacts of changing water availability due to climate change on agricultural production in Palestine, 2019. Available at www.unescwa.org/sites/www.unescwa.org/files/uploads/national-assessment-report-palestine-arabic.pdf.
3. ESCWA, RICCAR Arab Climate Change Assessment Report, 2017. Available at www.unescwa.org/publications/riccar-arab-climate-change-assessment-report.
4. Ministry of Agriculture. National Agriculture Sector Strategy (2017-2022).
5. Ministry of Agriculture data (2014-2015).
6. Ministry of Agriculture data (2014-2015).
7. 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.
8. A version of the general circulation model CNRM used in phase 5 of the Coupled Model Intercomparison Project (CMIP5).
9. Earth System Model – Geophysical Fluid Dynamics Laboratory.
10. State of Palestine, Ministry of Agriculture, **إستراتيجية القطاع الزراعي: صمود وتنمية مستدامة 2017-2022** (2016).

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