السويد
Sverige

CLIMATE RESILIENT AGRICULTURE: TRANSLATING DATA TO POLICY ACTIONS

Case Study of AquaCrop Simulation in Iraq

UNITED NATIONS
الاسكوا
ESCWA

Shared Prosperity **Dignified Life**

UNITED NATIONS
الاسكوا
ESCWA

Shared Prosperity **Dignified Life**

VISION
ESCWA, an innovative catalyst for a stable, just and flourishing Arab region

MISSION
Committed to the 2030 Agenda, ESCWA's passionate team produces innovative knowledge, fosters regional consensus and delivers transformational policy advice. Together, we work for a sustainable future for all.

E/ESCWA/CL1.CCS/2020/CP.7

Economic and Social Commission for Western Asia

CLIMATE RESILIENT AGRICULTURE: TRANSLATING DATA TO POLICY ACTIONS

Case Study of AquaCrop Simulation in Iraq

UNITED NATIONS
Beirut

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

Symbols of United Nations documents are composed of capital letters combined with figures. Mention of such a symbol indicates a reference to a United Nations document.

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 Iraq. 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.

Table of Contents

1. Country Background

The total area of Iraq is about 17.5 million hectares, of which approximately 16 per cent is arable land. Iraq is also home to around 37.9 million people (2016 census), 11.4 million of whom live in rural areas. Around 38.1 per cent of all cultivated land is used for rainfed agriculture, most of which is located in the northern and north-eastern regions of Iraq where the main crops are grains, specifically wheat and barley. Most irrigation takes place in the central and southern regions of the country.

The agricultural sector accounts for 3 per cent of total GDP and is currently facing severe challenges: successive years of drought, fluctuation in rainfall and environmental changes. Plus, with growing demand for agricultural products due to population growth, the country is increasingly reliant on agricultural imports and faces risks to its food security.

The impacts of food insecurity are intensely felt by vulnerable groups including rural women and youth. Box 1 highlights challenges for women in agriculture in Iraq.

Table 1. Productivity and area planted with various crops in Iraq (2016)

Parameter	Productivity (tons/ha)	Area (1,000 ha)
Grains	7.65	521.7
Oil crops	2.50	1.28
Industrial crops	38.06	0.31
Tubers and bulbs	53.98	3.67
Legumes	3.85	3.307
Forage crops	30.69	30.09
Vegetables	27.04	37.5

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 grown using surface irrigation in the Al-Suwaira region of the Wasit Governorate, on the west bank of the Tigris river:

1. Irrigated wheat.

2. Irrigated tomatoes.

Al-Suwaira is one of the most famed wheat-producing regions of Iraq. Its wheat production (136,000 tons/year) amounts to 20 per cent of that of the entire governorate, which in turn represents 20 per cent of that of the entire country, estimated at about 3 million tons/year. As the largest producer of wheat in the country, Wasit largely relies on surface irrigation, and its production is often affected by rainfall fluctuations.

The study area is also known to grow tomatoes, with local production amounting to 76 per cent of the tomato production of the entire governorate, which in turn represents 2 per cent of that of the entire country's production, which totals 286,600 tons/year. Tomatoes in Al-Suwaira are also grown using surface irrigation from March to June.

Box 1. Women's empowerment

Gender inequality is a major obstacle to the development of Iraq, which suffers from one of the world's lowest rates of women's participation in the labour force, at 11.5 per cent in 2019 (World Bank, 2019a).

The agriculture sector has the highest share of employment for women, where they make up over 50 per cent of the labour force compared to 9 per cent across all other sectors (World Bank, 2019b). Even though rural women are more economically active than urban women, they face greater food insecurity, more barriers to education and are more likely to be unprotected by Iraq's equal opportunity laws (UNDP, 2012). Data from the Central Statistics Administration reveal that the decrease in agricultural land due to drought and desertification is impacting women's ability to participate in the sector and has negatively impacted their quality of life; for instance, in cases of drought, women are required to bear the increased burden of fetching water and other basic household needs from longer distances. In addition, women in agriculture do not have control over resources and financial transactions, including price setting, accessing markets. As such it is imperative to develop and support women's empowerment initiatives specifically in rural areas to enhance active participation of women in agriculture and improve their quality of life.

Source: United Nations Development Programme (2012). Women's Economic Empowerment: Integrating Women into the Iraqi Economy. http://www.iq.undp.org/content/dam/iraq/IQ percent20Women percent20EE percent20- percent20Final.pdf.

World Bank (2019a). Labor force participation rate data. Available at: 2019https://data.worldbank.org/indicator/SL.TLF.CACT.FE.ZS?end=2019&locations=IQ&start=1990.

World Bank (2019b). With a Special Focus on Transforming Agriculture for Economic Diversification and Job Creation. Iraq Economic Monitor.

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. Historical data for the region (2008-2017) were collected from the Al-Suwaira weather station to measure various weather elements influencing agriculture including temperature, humidity, wind speed, solar radiation and evapotranspiration.
- **Calibration** of AquaCrop to simulate the productivity of irrigated wheat and tomato crops in Al-Suwaira using 9 years of data (2008–2016) for wheat and 10 years of data (2008–2017) for tomatoes. Data included soil characteristics, groundwater depth, irrigation scheduling, main farm management, climate data and crop yield. 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 two crops, wheat and tomatoes, were carried out based on the RICCAR project for two periods: 2020–2030 (represented by 2025) and 2040–2050 (represented by 2045) and for two the 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 CO2 concentrations and associated climatic changes (temperature and water); and one which considered temperature and water changes only and no change in CO2 concentrations (i.e., keeping CO2 concentrations at the baseline level). This allowed for disaggregation of the mitigating effect of increased CO2 on yields due to temperature rise and water scarcity.
- **Testing of adaptation measures** to overcome the impacts of reduced water availability due to climate change under two levels of deficit irrigation: reducing irrigation of both wheat and tomatoes by 20 per cent in the 2025 period and 40 per cent in the 2045 period for both RCP scenarios and under fixed and changing CO_2.

4. Assessment findings

Overall, rising temperatures reduce irrigated wheat and tomato yields under fixed CO_2, while yields of both crops rise for all scenarios under changing CO_2. The projected increase in yield is the result of the mitigating effect of the elevated CO_2 concentration. However, results should be considered carefully as other non-linear limiting factors may counteract the positive effect of changing CO_2 on yields, particularly the reduction of precipitation that will affect water stored in dams, which is a major source of irrigation water in some areas.

- ## Al-Suwaira site findings

Calibration results for wheat production show a relatively poor correlation between simulated values and data recorded in the field. Simulated wheat yields were higher than actual yields, despite the availability of adequate agricultural conditions, whether in terms of water quality and quantity, soil quality or other agricultural criteria specific to the Al-Suwaira district. This may be attributed to the lack of accurate information regarding the district's total production, as well as plot mismanagement by farmers. Also, two crop readings were eliminated (2007 and 2008) for being outliers. On the other hand, tomato yield calibration results indicate a good correlation between observed and calculated values.

Table 2. RCP 4.5 scenario

Crop	Wheat		Tomatoes	
Parameter				
	CNRM-CM5			
Seasonal precipitation (mm)	+23.3	-8.9	+18.3	+10.8
Annual precipitation (mm)	+18.3	+10.8	+2.4	-6.9
Maximum temperature (°C)	0.6	1.3	0.6	1.3
Minimum temperature (°C)	0.6	1.2	0.6	1.2
	EC-Earth			
Seasonal precipitation (mm)	-12.2	-23.6	-9.2	+2.0
Annual precipitation (mm)	-7.9	-16.8	-7.9	-16.8
Maximum temperature (°C)	0.5	1.4	0.5	1.4
Minimum temperature (°C)	0.4	1.1	0.4	1.1
	GFDL-ESM2M			
Seasonal precipitation (mm)	+25.1	+40.4	+ 13.8	+19.3
Annual precipitation (mm)	+25.1	+43.9	-7.9	-16.8
Maximum temperature (°C)	0.4	0.7	0.4	0.7
Minimum temperature (°C)	0.4	0.7	0.4	0.7

Table 3. RCP 8.5 scenario

Crop	Wheat		Tomatoes	
Parameter				
CNRM-CM5				
Seasonal precipitation (mm)	- 6.6	-7.1	-12.7	+5.6
Annual precipitation (mm)	-5.1	- 3.4	-5.1	-3.4
Maximum temperature (°C)	0.7	1.4	0.7	1.4
Minimum temperature (°C)	0.7	1.2	0.7	1.2
EC-Earth				
Seasonal precipitation (mm)	-2.8	-19.9	+13.0	- 7.9
Annual precipitation (mm)	-1.4	-4.7	- 1.4	- 4.7
Maximum temperature (°C)	0.7	1.6	0.7	1.6
Minimum temperature (°C)	0.6	1.3	0.6	1.3
GFDL-ESM2M				
Seasonal precipitation (mm)	+ 18.2	- 3.2	+15.2	+1.3
Annual precipitation (mm)	+24.5	+21.2	+24.5	+21.2
Maximum temperature (°C)	0.6	1.4	0.6	1.4
Minimum temperature (°C)	0.6	1.3	0.6	1.3

• Climate variable projections

The climate models (CNRM-CM5,[4] GFDL-ESM2M[5] and EC-Earth projections[6]) predict different changes in precipitation. Seasonal climatic projections for the wheat and tomato crops differ as wheat is grown in the winter and tomatoes are grown in the spring. Changes in precipitation and temperatures for the 2025 and 2045 periods for both regions are illustrated in tables 1 and 2 for the RCP 4.5 and RCP 8.5 scenarios respectively.

• Crop productivity

A meaningful drop in wheat and tomato productivity for both periods and scenarios is simulated under fixed CO_2 concentrations. However, under changing CO_2 concentrations, wheat and tomato yields increase for both simulated future periods and scenarios.

Days to maturity for both crops decrease due to rising temperatures. Shorter days to maturity result in reduced evapotranspiration rates for both wheat and tomatoes; both reference and actual crop evapotranspiration rates are shown to decrease with time over the simulated future periods as a result of the shortened days to maturity under both scenarios, with the lowest rates during the 2045 period. Further impacts of the model in comparison to the reference period (1985–2005) are addressed in boxes 2 and 3.

Box 2. Main findings of the AquaCrop simulation in Sana'a for wheat

Under the RCP 4.5 scenario

- Length of growing season for wheat decrease to 134.8 and 130.4 days in the 2025 and 2045 periods, respectively, as compared to 139.2 days in the reference period.
- Wheat yields decrease by 1.23 and 2.54 per cent in the 2025 and 2045 periods, respectively, under fixed CO_2. Under changing CO_2, yields increase by 6.99 and 9.17 per cent for the two periods, respectively.
- Crop water productivity remains constant at 0.8 kg/m^3 during the 2025 period and rises to 0.9 kg/m^3 during the 2045 period, under fixed CO_2. Under changing CO_2, crop water productivity increases to 0.9 and 1 kg/m^3 over the two periods, compared to 0.7 kg/m^3 in the reference period.

Under the RCP 8.5 scenario

- Length of growing season for wheat decrease to 132.3 and 127.6 days in the 2024 and 2045 periods, respectively, as compared to 139.3 days in the reference period.
- Wheat yields decrease by 2.56 and 3.65 per cent in the two periods under fixed CO_2. Under changing CO_2, yields increase by 10.79 and 15.08 per cent in the two periods.
- Crop water productivity under fixed CO_2 remains constant at 0.8 kg/m^3 during the 2025 period and rises to 0.9 kg/m^3 during the 2045 period. Under changing CO_2, crop water productivity rises to 1.0 and 1.1 kg/m^3 for the two periods, respectively.

Box 3. Main findings of the AquaCrop simulation for tomatoes

Under the RCP 4.5 scenario

- Length of growing season for tomatoes decrease to 91.6 and 91.3 days in the 2025 and 2045 periods, respectively, compared to 92.6 days in the reference period.
- Tomato yields decrease by 1.23 and 5.34 per cent in the two periods under fixed CO_2. Under changing CO_2, yields increase by 11.6 and 12.8 per cent for the two periods.
- Crop water productivity remains constant at 0.5 kg/m3 in both periods under fixed CO_2. Under changing CO_2, crop water productivity increases during the 2045 period to 0.6 kg/m3.

Under the RCP 8.5 scenario

- Length of growing season for tomatoes decrease to 91.4 and 90.8 days for the two periods, respectively, compared to reference value of 92.6 days in case of fixed and changing CO_2.
- Tomato yields decrease by 6.17 and 7 per cent for the two periods under fixed CO_2. Under changing CO_2, yields increase by 6.77 and 11.95 per cent for the two periods, respectively.
- Crop water productivity decreases to 0.4 kg/m3 in both periods under fixed CO_2, compared to 0.5 kg/m3 in the reference period. Under changing CO_2, crop water productivity remains constant during the 2025 period and increases to 0.6 kg/m3 during the 2045 period.

• Applying deficit irrigation

A variety of levels of deficit irrigation were simulated, with decreased irrigation of both wheat and tomatoes by 20 per cent in the 2025 period and 40 per cent in the 2045 period. This method was simulated as an adaptation measure to improve the productivity of wheat

Table 4. Changes in crop yields, evapotranspiration and days to maturity when applying deficit irrigation as an adaptation measure for wheat and tomatoes under RCP 4.5

Yield	Deficit irrigation	Yield change (per cent)			Actual evapotranspiration (mm)			length of growing season		
		Reference (tons/ha)	2025	2045	Reference	2025	2045	Reference	2025	2045
Wheat	20%	2.36	-2.0	--	279.6	277.4	--	139.2	134.8	--
	40%		--	-8.0		277.4	251.7		134.8	130.4
	20%*	2.44	+10.4	--	281.0	276.2	--	139.2	134.8	--
	40%*		--	+9.5		276.2	250.1		134.8	130.4
Tomatoes	20%	2.43	-6.5	--	517.4	469.6	--	92.6	91.6	--
	40%		--	-34.1		469.6	397.1		91.6	91.3
	20%*	2.50	+0.4	--	517.3	464.1	---	92.6	--	--
	40%*		--	-19.6		464.1	395.7		91.6	--

* Under changing CO_2.

Table 5. Changes in crop yields, evapotranspiration and days to maturity when applying deficit irrigation as an adaptation measure for wheat and tomatoes under RCP 8.5

Yield	Deficit irrigation	Yield change (per cent)			Actual evapotranspiration (mm)			length of growing season		
		Reference (tons/ha)	2025	2045	Reference	2025	2045	Reference	2025	2045
Wheat	20%	2.36	-3.4	--	282.7	272.5	--	139.3	132.3	--
	40%		--	-9.3		272.5	247.2		132.3	127.6
	20%*	2.44	+10.0	--	--	270.2	--	139.3	132.3	--
	40%*		--	+9.4	282.6	270.2	244.9		132.3	127.6
Tomatoes	20%	2.43	-14.0	--	517.6	463.6	--	92.5	91.0	--
	40%		--	-34.9		463.6	397.1		91.4	90.8
	20%*	2.51	-3.6	--	516.8	464.0	--	92.5	91.0	--
	40%*		--	-18.7		464.0	395.5		91.4	90.8

* Under changing CO_2.

and tomatoes under fixed and changing CO_2. Tables 4 and 5 below show the impact of reducing irrigation by 20 and 40 per cent for the RCP 4.5 and RCP 8.5 scenarios, respectively, under stable and changing CO_2 concentration. Yield losses are expected under fixed CO_2, but under changing CO_2, deficit irrigation can be applied to save water while actually increasing wheat yields.

5. Analysis

A major challenge facing agricultural production in Iraq is the low productivity per unit of land due to poor management of land and natural resources, including water resources. Irrigation efficiency in Iraq is around 60–70 per cent, with inefficiency reaching 33 per cent during transportation and 30-40 per cent during field applications. Groundwater is also used as a source for irrigation and supplementary irrigation, however it needs to be regulated to prevent excessive pumping and maintain storage. Most irrigation is conveyed using very poorly maintained distribution systems made of earth canals and ditches, increasing losses due to infiltration, seepage or leakage. In order to improve irrigation efficiency, efficient transportation and distribution systems must be developed, maintained and improved, such as by lining current canals, and efficient and modern field irrigation systems must be introduced. For instance, drip irrigation has been used for supplementary irrigation especially in rainfed areas and for cultivation of vegetables. Farmers should be encouraged to implement these modern irrigation systems by providing financial subsidies and developing "agricultural information extension" programs to train them in modern agricultural techniques.

Deficit irrigation could be used to save water while maintaining or even increasing wheat yields according to the simulation. On the other hand, tomato yields are very sensitive to any reduction in irrigation water. As such it is important to research improved varieties of tomatoes that have shorter life cycles, demand less water and achieve the same yields. Self-sufficiency should be pursued among crops with comparative advantages in the region by developing the skills of those involved in agriculture to increase productivity and implement quality systems to compete with imported products. An economic assessment is also needed of the impacts of climate change on crop yields and thus on the national economy, as well as an investment map showing opportunities for agricultural investment, based on a periodically updated database.

Furthermore, a large proportion of cultivated land in Iraq suffers from soil salinization and waterlogging, especially in the central and southern regions of the country, due to poor management and maintenance and the lack of integrated drainage networks. Mechanisms must be adopted to maintain and develop agricultural land by periodically analysing agricultural soil and categorizing land accordingly. Equally important is identifying fertilizer needs and establishing a system for distribution of fertilizer that is consistent with the types of land present and insights from agricultural research.

Several emerging national programmes are being run by the Ministry of Agriculture to pilot new practices and improve the productivity and efficiency of agriculture. New crops and varieties adapted to extreme conditions could be identified and produced in greater numbers, as they may well allow existing agricultural systems to successfully adapt to expected changes. Salt-tolerant, drought-tolerant and short-lived varieties would also be beneficial. These include projects for modern on-farm irrigation systems, wheat production improvement through the "National Program for Wheat Development" and the "High Quality Wheat Seed Innovation Program", development of drought and salt-tolerant crops and the establishment of an agricultural meteorology network. These projects must be further developed and built on.

Box 4. Economic impact of climate change on agriculture

The contribution of the agricultural sector to the country's gross domestic product (GDP) decreased to its lowest levels, dropping from 4.17 per cent in 2010 to 3.05 per cent in 2016. Successive years of drought and population growth have put Iraq's food security at risk as it has become highly reliant on agricultural imports, with a 45.2 per cent deficiency in wheat production and 76 per cent deficiency in tomato production (based on 2016 data). In total, dependence on food imports in Iraq rose from $2 billion in 1985 to around $11 billion in 2017 (World Bank, 2019).

The study area of the Al-Suwaira region produces around 4.5 per cent of the country's wheat and roughly 2 per cent of the country's tomatoes. In this assessment, simulations for wheat and tomato yields under changing CO2 concentrations show increases in yields of up to 15.08 per cent for wheat and 11.95 per cent for tomatoes. Such increases highlight the opportunity for increasing the production of these two crops in Iraq, especially in Al-Suwaira, and increasing the local population's income.

Taking into consideration the most recent producer prices provided by the FAO, these increases could translate into $7,171,927 more in revenues from wheat sales and $13,335,865 more in tomato sales. Considering the current population of Al-Suwaira is 77,200 people, the potential increase in wheat and tomato yields could translate into an additional $265.65 of income per capita in Al-Suwaira.

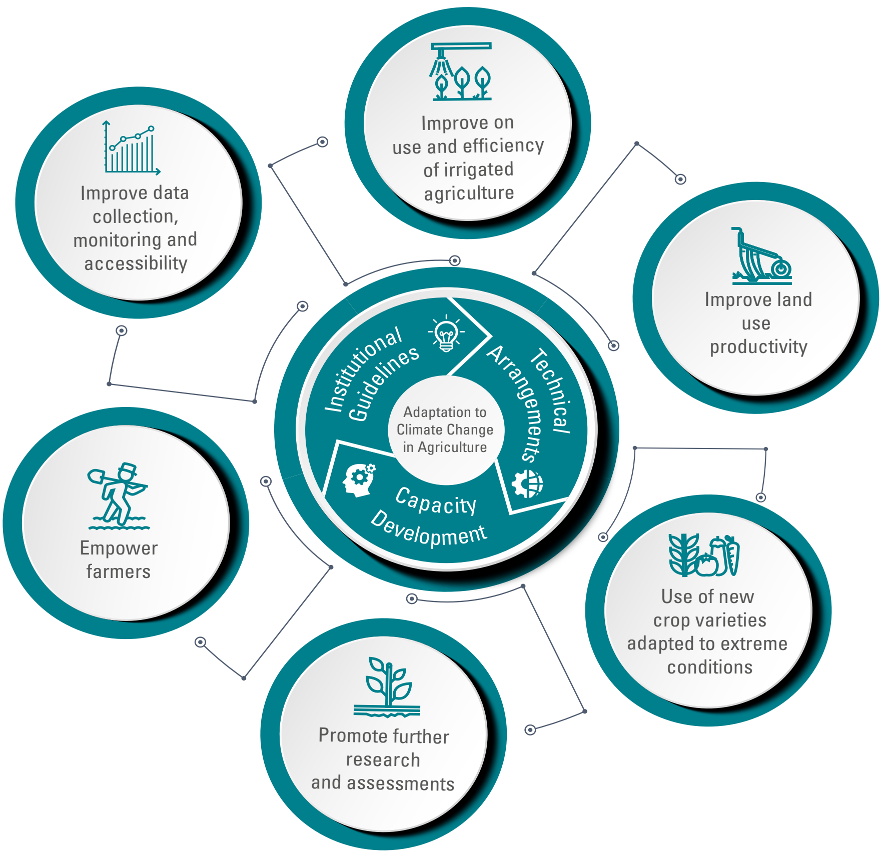
Source: World Bank, 2019. Iraq Economic Monitor Turning the Corner: Sustaining Growth and Creating Opportunities for Iraq's Youth.

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

6. Recommendations

Iraq uses around 80 per cent of its water resources for agriculture,[7] with most of this water being transboundary. Expansion of hydrological infrastructure in upstream countries is likely to impact the quantity of water made available to Iraq, greatly affecting agriculture and reducing the country's ability to reap the benefits of increased yields of wheat and tomatoes simulated under changing CO_2. Iraq already faces water scarcity problems that could be worsened by climate change. Wars and political instability have destroyed Iraqi infrastructure and greatly worsened its ability to manage its water resources.

Figure 1. Framework for actions to adapt to climate change



An integrated water resource management system such as the Iraq water system planning model is therefore essential.

Table 6 lists the suggested actions for each key recommendation generated by this study in Iraq. Recommendations are identified based on the multiple dimensions they are connected to, including institutional, policy and financial arrangements, knowledge generation and capacity development.

Table 6. Key recommendations and actions to adapt agriculture to climate change

1. Improve the efficiency of irrigated agriculture

Institutional and financial arrangements:

- Collaborate with different centres that perform research on irrigation and water use efficiency and build on the current Ministry of Agriculture "Modern Irrigation Technologies" project.
- Invest in maintenance of irrigation networks and transportation canals to reduce water losses.
- Develop integrated drainage networks and transportation and distribution systems.
- Improve investments in modern irrigation technologies and optimize the utilization of available water resources by using the most water-saving irrigation techniques.
- Establish proper water accounting systems to monitor the availability of water resources and keep water allocations for irrigation within sustainable limits.
- Develop water harvesting techniques to replenish groundwater reserves.
- Adopt an integrated water resource management system and use hydrology and mathematical models simulating available water resources for planning and incorporating changes such as the Iraq water system planning model.

Knowledge generation:

- Identify the water requirements of crops and schedule irrigation accordingly to reduce the waste of irrigation water.
- Conduct research to compare yields, soil properties and plant growth phases under conservation agriculture and traditional methods and publish results.
- 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 yields.

Capacity development:

- Encourage farmers to move to irrigated agriculture through participatory processes that identify best irrigation practices within sustainable consumption limits.
- Encourage farmers to acquire modern irrigation systems by providing support for 50 per cent of the price.
- Provide incentives to farmers applying conservation practices/technologies and enable them to adopt them through education and technical assistance.

2. Improve land use productivity

Institutional and financial arrangements:

- Adopt mechanisms to maintain and develop agricultural land by periodically analysing soils and categorizing land accordingly.
- Build on and develop the current programmes and projects of the Ministry of Agriculture to increase land use productivity such as the "Vegetable Seed Development Project" of the Department of Horticulture.
- Establish a system for expanding the use of fertilizers and the distribution of fertilizers consistent with the land types and insights from agricultural research.
- Increase productivity to achieve a degree of self-sufficiency for crops with comparative advantages.
- Support the transition to and application of intensive production systems.

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 negative health outcomes or contamination of the water table.

Capacity development:

- Prepare brochures and advisory programmes for fertilizer use according to the crops and areas under cultivation.

3. Empower farmers

Institutional and financial arrangements

- Encourage the formation of an organization of small farmers to work reclaimed land within a voluntary framework that guards their interests, organizes their production and assists in marketing their products.
- Adopt a comprehensive policy that includes innovations in measures to reduce and transfer risks through climate insurance and promote economic diversification at local level through off-fam economic activities. This would provide a better buffer and safety nets for small-scale famers most vulnerable to the impacts of climate change.
- Increase investment in water harvesting infrastructure and supplementary or deficit irrigation techniques.
- Fairly distribute additional income due to increases in yields of irrigated wheat and tomatoes and channel 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.
- Coordinate between farmer extension institutions and research facilities to properly apply research findings.
- 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.
- Develop agricultural extension programmes to train and prepare guides in needed specialties and train farmers in modern agricultural techniques through demonstration farms and field days.

4. Promote further research and assessments

Institutional arrangements:

- Enhance scientific research and agriculture technological development by preparing a national research plan for agricultural research that defines the main goals to be achieved, the programmes and research projects required and the budgets for each research programme or project and identifies evaluation criteria and time frames.
- Link research topics to address problems in various fields of agriculture and highlight and implement them among relevant ministries.
- Establish agreements for joint cooperation between multiple research agencies to discuss topics identified by the national agricultural research plan and periodically evaluate these agreements to maximize returns.
- Encourage partnerships between research institutes and universities to perform studies on other crops and regions 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, 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 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 in Iraq.
- Perform AquaCrop simulation and analysis on rainfed areas, including northern and north-eastern regions of Iraq.
- 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 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 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:

- 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.
- Establish a reliable database for calibrating and operating the AquaCrop model and allowing for easy download and display of data.

- Establish an effective weather and crop monitoring system during the growing season.
- Update the climate change data projection through cooperation between national, regional and international institutions.
- Develop a national report on every crop type in Iraq, in line with the country's environmental map, with the indicators in this report used for the development and planting of crops. Collaboration is needed with agricultural extension offices to monitor the implementation of the decisions and recommendations made in the national report.
- Enhance the work of agricultural meteorology centres to provide climate data for agricultural areas.
- 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 adaptation policies and incorporate them into different topics and sectors.

6. Use new crop varieties and modify seeding dates

Institutional and financial arrangements:

- Encourage coordination and collaboration between universities, research institutes and technical centres to perform assessment studies.
- Build on Ministry of Agriculture projects including the National Program for Wheat Development, the High-Quality Wheat Seed Innovation Program and other programmes of the Research Department for the Development of Grain Crops.
- Provide the necessary financial resources for research institutes to perform related studies through dedicated programmes for adaptation in the agricultural sector.
- Invest in innovative approaches and technologies using new crop varieties and/or modified seeding dates to maintain or increase crop yields under climate change conditions.
- Strengthen the competitiveness of agricultural products and enhance those involved in agriculture using quality systems such as ISO to compete with imported products.

Knowledge generation:

- Test new crops with characteristics that could adapt more easily to expected climate changes.
- Introduce drought-tolerant plant varieties with low water consumption and encourage field crops which requires less water.
- Research improved tomato varieties with fewer days to maturity, less demand for water and the same yield.
- Identify the crops most vulnerable to climate change and assess changes in agricultural production due to climate change.
- Promote salt-resistant and fast-growing varieties, such as those devised for the Tigris and Euphrates.
- Test modified seeding dates and crop sequencing to account for shifting periods of rainfall.
- Modify crop varieties, rotations and calendars, including planting and harvesting dates.

Endnotes

1. The country team comprised experts from the Ministry of Agriculture, Ministry of Water Resources and Ministry of Planning.
2. ESCWA, Assessment of the impacts of changing water availability due to climate change on agricultural production in Iraq, 2019. Available at https://www.unescwa.org/sites/www.unescwa.org/files/uploads/national-assessment-report-Iraq-arabic.pdf.
3. ESCWA, RICCAR Arab Climate Change Assessment Report, 2017. Available at ww.unescwa.org/publications/riccar-arab-climate-change-assessment-report.
4. A version of the general circulation model CNRM-that contributes to 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 of Medium Range Weather Forecast) in its seasonal prediction configuration as the base of climate model.
7. Abd-El-Mooty, M., Kansoh, R., & Abdulhadi, A. (2016). Challenges of water resources in Iraq. Hydrology Current Research, 7(4), 1-8.

21-00418