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CLIMATE RESILIENT AGRICULTURE: TRANSLATING DATA TO POLICY ACTIONS

Case Study of AquaCrop Simulation in Sudan

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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 Sudan. 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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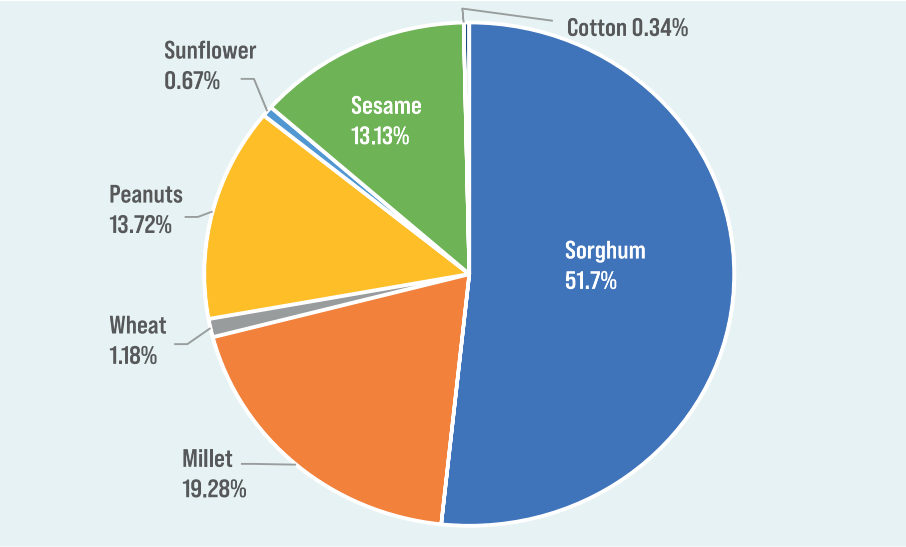
1. Country Background

Sudan covers an area of around 448 million acres, including 170 million acres of arable land, 144 million acres of natural rangelands, and 52 million acres of forest. While only 3 to 4 million acres of agricultural land are irrigated, 35 to 37 million acres rely on rainfed agriculture. The country has a variety of different climates, from lush savanna in the south to arid desert in the north. Forests and rangelands are among the most important natural resources in Sudan, alongside the country's rich water resources of rainfall, rivers and groundwater. Figure 1 shows the distribution of planted areas in Sudan.

Sudan is home to around 42 million people and is divided into 17 states. Large rates of migration from rural areas to the capital are related to drought, desertification and the uneven distribution of services such as education and health. Agriculture is of paramount socioeconomic importance in Sudan, as the majority of the country's population depends on it for their livelihoods. It is therefore of utmost importance to mitigate and adapt to the effects of climate change to ensure economic development in the country and bring stability to the region. Box 1 identifies initiatives to empower women and youth in the agricultural sector.

Figure 1. Planted areas in Sudan, 2016–2017



Source: General Administration for Agricultural Planning and Economy.

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 two major cropping systems in two regions of Sudan:

1. Rainfed sorghum in the state of Gadarif;
2. Irrigated wheat in the Gezira Scheme in the city of Wad Medani.

The state of Gadarif is located in eastern Sudan, where rainfed agriculture predominates due to the abundant agricultural land and fertile soil. The region is one of the largest agricultural producers in Sudan, and the largest producer of sorghum and sesame in the world. Sorghum is usually planted during July, and it is preferable to plant it early to allow for better growth. Sorghum yields fluctuate according to the quantity and distribution of precipitation. The highest average yield in Gadarif was 330 kg/acre in 2017 (for a total yield of around 2,077,000 tons), and the lowest was recorded in 2012 at 84 kg/acre (for a total of 193,000 tons).

The Gezira Scheme is located in central Sudan, between the Blue Nile and White Nile rivers. It was first established in 1925 and is one of the oldest agricultural projects in Sudan, as well as the largest irrigation project in the world, covering over 924,000 ha at an altitude of

Box 1. Women and youth empowerment

In Sudan, only 31 per cent of women participate in the labour force. Although rural women contribute more than half of export-oriented labour in Sudan, they make up over 60 per cent of the country's most vulnerable poor (UN Women, 2015).

Under the Joint Programme on Women, Natural Resources and Peace, a two-year project (2016–2018) "Promoting Gender-Responsive Approaches to Natural Resource Management for Peace" was implemented by UN Environment, UN Women and the United Nations Development Programme (UNDP) to train women in Al Rahad, North Kordofan, Sudan in farming, natural resource management and conflict resolution. The project trained women to use rainfed farming techniques, harvest Arabic gum, acquire land and access credit. A follow-up survey found that 87 per cent of participants increased their income from the crops and that their backyard gardens generated sufficient food to cover their daily needs. Furthermore, local women were able to mobilize their communities and collaborate with the Ministry of Agriculture and the Forests National Corporation to plant 6,000 trees to combat soil degradation.

In 2017, the Sudanese Government launched the ENABLE Youth Sudan Program in Khartoum. This program is one of the African Development Bank's ENABLE Youth Initiatives under the Bank's Feed Africa Strategy (2016–2025). The programme's objective is to create business opportunities and employment for young people in priority agricultural value chains in five states of Sudan, thus empowering 2,000 agricultural entrepreneurs in youth agribusiness incubation centres. These entrepreneurs are expected to each employ five other support workers, hence generating 12,000 jobs in total over the first 5 years of the programme, of which 6,000 are young women.

Source: UN Women, 2015. Supporting Women's Empowerment and Gender Equality in Fragile States. Sudan Research Brief. Sudan Enable Youth Program https://projectsportal.afdb.org/dataportal/VProject/show/P-SD-AAZ-006.

400 m above sea level with irrigation water flowing from the Sennar reservoir. The area produces cotton, corn, peanuts, wheat, sunflower, vegetables and fodder. Wheat is of major strategic importance in Sudan, where domestic production is nearly 400,000 tons, only around 20 per cent of total consumption of nearly 2 million tons. Wheat plantings have grown in recent years (particularly between 1999 and 2014), as have overall production and yields, with year-to-year fluctuations due to natural, technical and financial factors.

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. In the Gadarif area, climate, crop and soil data were obtained from the Gadarif Agricultural Research Station. In the Gezira area, data were obtained from the Gezira Agricultural Research Station (Wad Medani). For both areas, daily data on max. and min. temperatures and precipitation (2006–2016) were obtained from the Sudanese Meteorological Authority.
- **Calibration** of AquaCrop to simulate the productivity of rainfed sorghum in Gadarif and irrigated wheat in Gezira (2006–2016) for both crops. Data included soil characteristics, groundwater depth, irrigation scheduling, main farm management, climate data and crop yield. The calibrated model was then used to simulate crop yields under future climate change.
- **Simulation** of the impacts of climate change on the productivity of two crops, sorghum and 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 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 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 rising temperatures reduce yields of rainfed sorghum and irrigated wheat under fixed CO_2. Under changing CO_2, rainfed sorghum yields decrease while irrigated wheat yields rise for both scenarios. Temperature increase leads to a shortening of the growing season for both crops, which is highly pronounced in the case of irrigated wheat.

• Gadarif site findings

The calibration results for sorghum crop show a good correlation between simulated and observed yields with an R^2 value of 0.65, and a notable correspondence in the decreasing trend of sorghum yields in both simulated and observed values.

Climate variable projections

The climate models used (CNRM-CM5,[4] GFDL-ESM2M[5] and EC-Earth projections[6]) show a drop in average annual precipitation under the RCP 4.5 scenario, by around 1 and 38 mm for the 2025 and 2045 periods, respectively. Average seasonal precipitation drops by 10 mm in 2025 and rises by 8 mm in the 2045 period. Under the RCP 8.5 scenario, projections show a drop in

Box 2. Main findings of the AquaCrop simulation in Gadarif

Under the RCP 4.5 scenario:

- The length of the sorghum growing season decreased by around one and four days in the 2025 and 2045 periods, respectively.
- The productivity of rainfed sorghum decreases by 0.7 and 7 per cent in the two periods, respectively. Under changing CO_2, yields decrease by 2 and 8 per cent respectively.
- Crop water productivity decreases by 0.1 and 0.2 kg/m^3 in the two periods, respectively, under fixed and changing CO_2.

Under the RCP 8.5 scenario:

- The length of the sorghum growing season drops by around 2 and 5 days in the 2025 and 2045 periods, respectively.
- The productivity of rainfed sorghum decreases by 7 and 11 per cent in the 2025 and 2045 periods, respectively, under fixed CO_2. Under changing CO_2, yields decrease by 5 and 8 per cent for both periods, respectively.
- Crop water productivity decreases by 0.2 and 0.6 kg/m^3 in the 2025 and 2045 periods, respectively, under fixed CO_2. Under changing CO_2, crop water productivity decreases by 0.1 and 0.5 kg/m^3 in both periods, respectively.

average annual precipitation by 25 and 17 mm for the 2025 and 2045 periods, respectively, and a rise in average seasonal precipitation by 14 and 12 mm for both periods, respectively.

A rise in temperatures is also projected, in the range of 0.9–2.2 °C for max. temperatures, and of 0.75–1.63 °C for min. temperatures, compared to the baseline period under RCP 4.5. Temperatures are also expected to rise under RCP 8.5, with an increase in the range of 1.02–2.88 °C for max. temperatures, and 0.88–2.12 °C for min. temperatures.

Crop productivity

Results show a slight drop in rainfed sorghum yields and a shortening of the average crop growth cycle as compared to the baseline period. This is due to the drop in annual precipitation, change in the distribution of seasonal precipitation and rising temperatures. Further impacts of the model in comparison to the reference period (1986-2005) are addressed in box 2.

Wad Medani site findings

Calibration results for wheat (2006–2016) show a good correlation between simulated and observed wheat yields in the study area. A corresponding rise over the years can be noted in both simulated and observed values indicating a strong correlation (R^2=0.72).

Climate variable projections

Precipitation during summer was discounted as it has no effect on winter wheat crops. Projections under the RCP 4.5 scenario show a rise in temperatures in the range of 0.94–2.09 °C for max. temperatures, and of 0.80–1.54 °C for min. temperatures. Under the RCP 8.5 scenario, a rise in temperatures is also projected, in the range of 1.00–2.89 °C for max. temperatures, and 0.89–2.11 °C for min. temperatures.

Crop productivity

Results show a drop in yields of irrigated wheat under fixed CO_2 concentration from the baseline period's 3.28 tons/ha. This decrease is attributed to the expected rise in temperatures. Furthermore, a slight drop in crop water productivity is expected as a result of the drop in yield. However, under changing CO_2 concentration, yields of irrigated wheat increase. Further findings of the model in comparison to the reference period (1986–2005) are addressed in box 3.

Box 3. Main findings of the AquaCrop simulation in Wad Medani

Under the RCP 4.5 scenario:

- The length of the irrigated wheat growing season drops by around 5 and 6 days in the 2025 and 2045 periods, respectively.
- The productivity of irrigated wheat decreases by 8 and 11 per cent in the two periods, respectively. Under changing CO_2, yields increase by 4 and 6 per cent respectively.
- Crop water productivity decreases by 0.03 kg/m^3 in both periods from a reference of 0.72 kg/m^3 under fixed CO_2. Under changing CO_2, crop water productivity increases by 0.07 and 0.12 kg/m^3 in the 2025 and 2045 periods, respectively.

Under the RCP 8.5 scenario:

- The length of the irrigated wheat growing season drops by around 5 and 7 days in the 2025 and 2045 periods, respectively, under fixed CO_2. Under changing CO_2, the length of the growing season drops by around 5 and 8 days in the two periods, respectively.
- The productivity of irrigated wheat decreases by 8 and 13 per cent in the two periods, respectively, under fixed CO_2. Under changing CO_2, yields increase by 6 and 3 per cent in the two periods, respectively.
- Crop water productivity decreases by 0.02 and 0.04 kg/m^3 in the 2025 and 2045 periods, respectively, under fixed CO_2. Under changing CO_2, crop water productivity increases by 0.08 and 0.13 kg/m^3 in the two periods, respectively.

5. Analysis

Given changes in climate factors such as higher temperatures and decreased precipitation, Sudan needs to research and develop the use of new crop varieties such as heat-resistant wheat seeds with shorter growth cycles and fast-growing/maturing and drought-resistant sorghum strains, in addition to any other new varieties developed by agricultural research. Alternatively, irrigation could be applied only during sensitive phases of the growth cycle, which would significantly increase crop water productivity. Deficit irrigation techniques would reduce the amount of irrigation provided to wheat during non-sensitive phases of its growth cycle, with supplemental irrigation when rainfall is not sufficient through on-farm rainwater harvesting and management systems to reduce the stress on rainfed agriculture.

The Sudanese agricultural sector plays a leading role in the national economy and is of paramount socioeconomic importance, as it contributes 30–40% of national GDP, employs about 75% of the labour force and contributes more than 20% of the value of exports. Accordingly, the economic impacts of climate change on crop yields and the national economy must be assessed. Therefore, further analysis and simulation using AquaCrop could help predict the impacts of climate change on rainfed and irrigated agriculture in different areas of the country and determine what species are most adapted to future climatic conditions, be they millet, sesame, peanuts or cowpea.

The country also has a variety of different climates, from lush savanna in the south to arid desert in the north. Forests and farmlands are among the most important natural resources in Sudan, alongside the country’s rich water resources, from rainfall, rivers and groundwater reserves. Agricultural land must be maintained and developed by providing agricultural machinery to facilitate production processes while at the same time conserving soil and water resources. Natural resources should be rehabilitated through cultivation and densification of the Arabic gum belt, forest development and cultivation and diffusion and adoption of technologies for managing and improving Arabic gum farms.

Farmers need to be empowered and provided with good infrastructure to support agricultural production. Activities should include awareness-raising and agricultural information extension programmes on adapting to climate change. Also, there is a need for laws and policies to support and encourage the establishment of a financial and marketing system to provide strong financing to farmers and establish stable and attractive markets for products.

Adaptations to climate change in Sudan could include adopting and scaling up conservation agriculture practices, modifying seeding dates to account for shifting periods of rainfall, adopting early planting dates and applying water harvesting techniques suited to regional conditions. Modern irrigation technologies are necessary to reduce water waste and improve irrigation water use efficiency. As such, investments in irrigated areas are encouraged while establishing proper water accounting systems to monitor water resource availability and keep water allocations for irrigation within sustainable limits.

Box 4. Economic impact of climate change on agriculture

The agricultural sector in Sudan plays a leading role in the country's economy as it contributes around 30–40 per cent of its gross domestic product (GDP) and provides over 90 per cent of its food. In addition to being a main source of raw materials for local industries, the sector employs around 75 per cent of the workforce and 70 per cent of people living in rural areas. The value of agricultural exports is around $631.7 million, some 20 per cent of the total value of Sudanese exports. The value of Sudan's imports of food commodities was estimated at about $2.2 billion (Food Security Report, 2016).

Between 2014 and 2015, sorghum exports in the country increased from 18,300 to 107,300 metric tons, corresponding to values of $5.7 and $28.2 million respectively (Food Security Report, 2016). Between 2014 and 2015, wheat imports decreased from 2.648 to 1.523 million metric tons, i.e. values of $1,057.6 billion and $532.2 million respectively (Sudan Bank Food Security Administration, as cited in ESCWA, 2019).

Simulations for sorghum crops show a decrease in yields of up to 8%, which could jeopardize both the income of sorghum farmers and the country' macroeconomic situation. These effects could be mitigated through increased wheat yields but would entail some adaptation costs by farmers. Modest increases in wheat yields could be an opportunity for the country to curb its wheat imports, although only to a limited extent.

Source: Food Security Report (2016). Annual Report for the food security situation in Sudan for the year 2016 and 2016 indicators. General Administration of Agricultural Planning and Economy, Department of Food Security, Ministry of Agriculture, Khartoum.

ESCWA (2019). Assessment of the impacts of changing water availability due to climate change on agricultural production in Sudan.

6. Recommendations

The Sudanese government needs to prioritize enhancing agricultural financing, developing agricultural insurance institutions, developing agricultural extension and plant protection services, enhancing funding of scientific research institutions and improving marketing for products. The Sudanese policy of leasing and privatizing agricultural lands to foreign owners has not improved the incomes of the local population and has instead depleted water supplies, degraded indigenous people's lands and appeared at the core of the population's recent grievances in the Sudanese uprising of 2018/2019.

Figure 2. Framework for actions to adapt to climate change

Table 1 lists the suggested actions for each key recommendation generated by this study in Sudan. Recommendations are identified based on the multiple dimensions they are connected to, including institutional, policy and financial arrangements, knowledge generation, and capacity development.

Table 1. Key recommendations and actions to adapt agriculture to climate change

1. Improve the efficiency of irrigated agriculture

Institutional and financial arrangements:

- Establish proper water accounting systems to monitor water resource availability and control water allocations to the irrigation sector within sustainable limits of water consumption.
- Enhance the implementation of comprehensive water strategies and build on current policies, including the Integrated Water Resource Management policy and the Water Supply and Environmental Sanitation policy.
- Collaborate with different research centres in the field of irrigation and water use efficiency.
- Modernize irrigation systems and use localized irrigation technologies to increase land and water productivity.
- Improve investments in the agricultural sector in Gezira, as it represents the largest irrigation project in the world.
- Optimize the use of available water resources by using the most water-saving irrigation techniques.

Knowledge generation:

- Identify the water requirements of crops and schedule irrigation accordingly to reduce the depletion of irrigation water.
- Evaluate irrigation water productivity and analyse the marginal benefit of water use for different crops and seasons.

Capacity development:

- Enable farmers to move to irrigated agriculture through participatory processes that identify best irrigation practices within sustainable consumption limits.

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 practices/technologies to enhance soil water storage.
- Provide social safety nets (equitable insurance schemes) for the most vulnerable farmers, especially farmers relying on rainfed agriculture in Gadarif.

- Ensure income is distributed fairly and channelled into financing development in rural areas.
- Improve water management through on-farm rainwater harvesting and increased investment in water harvesting infrastructure.
- Adopt mechanisms to maintain and develop agricultural land by providing agricultural machinery to facilitate production processes while conserving soil and water resources.

Knowledge generation:

- Conduct and publish research to compare yields, soil properties and plant growth under conservation agriculture and traditional agriculture.
- Use crop rotations to preserve soil fertility and limit the spread of diseases and pests.

Capacity development:

- Enable farmers to adopt conservation practices through education and technical assistance.
- 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

- Empower rural workers with the skills needed for sound economic growth to mitigate the possible negative effects of climate change on the local population.
- 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. This would provide a better buffer and safety nets for small-scale famers who are more vulnerable to the impacts of climate change.
- Strengthen and support extension services to facilitate adoption of agricultural technologies by farmers through financial and technical support.
- Establish a financial and marketing system to provide strong financing to farmers and to establish stable and attractive markets to buy produce.

Capacity development:

- Develop modern agricultural extension programmes and provide them with financial subsidies and support.
- Implement targeted field schools to provide farmers with improved skills in farm husbandry and the use of new crop varieties, leading to higher adaptation capacity and enhanced farm resilience.
- Encourage farmers to adopt higher value crops.

4. Promote further research and assessments

Institutional arrangements:

- Encourage partnership between research, development, technology transfer and innovation institutes under the Ministry of Higher Education and Scientific Research to perform studies on other crops, regions and agricultural environments using the AquaCrop and RICCAR climate datasets.

- Activate the role of the Scientific Research and Innovation Commission unit and coordinate science, technology and innovation initiatives in the country to enhance the resilience of the agriculture sector to climate change.
- 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 by applying AquaCrop to different varieties of crops such as millet, sesame, peanuts and cowpea in Gadarif to study the impact of climate change on water productivity and agricultural production.
- Apply the model to susceptible agricultural areas in order to study the impact of climate change on different crops in rainfed or irrigated areas.
- Perform the AquaCrop simulation and analysis in areas where rainfed agriculture/irrigated crops are widespread, with various geographical features, climates and soil types.
- Assess the optimization of water use in irrigation for the main crops in irrigated areas using 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.
- Conduct training sessions and workshops at different institutions and universities to 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. Use of new crop varieties and modify seeding dates

Institutional and financial arrangements:

- Build on and improve established policies and regulations such as the Plan of Action (2015–2019) PoA: Resilient Livelihoods for Sustainable Agriculture, Food Security and Nutrition and the Agricultural Revival Program (ARP).

- Encourage coordination and collaboration between universities, research institutes and technical centres to perform assessment studies.
- Provide the necessary financial resources for research institutes to perform related studies through dedicated programmes for adaptation in the agricultural sector.
- Promote innovative approaches and technologies to develop new crop varieties and produce improved seeds with fast maturity and drought resistance to maintain or increase crop yields under climate change conditions.
- Provide preventive services to combat crop pests and diseases.

Knowledge generation:

- Test and develop new crops with characteristics that could adapt more easily to expected climate changes such as new heat-resistant wheat seeds with shorter crop growth cycles and fast-growing/maturing and drought-resistant strains of sorghum, in addition to any other new varieties developed by agricultural research.
- Introduce drought-tolerant plant varieties with low water consumption.
- Apply organic fertilizers that have better water retention properties and increase use of fertilizers on farms.
- Identify the crops most vulnerable to climate change and assess the changes in agricultural production due to climate change.
- Test the modification of 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 and Forestry, Ministry of Irrigation, Agricultural Research Institute, Ministry of Higher Education, and University of Khartoum.
2. ESCWA, Assessment of the impacts of changing water availability due to climate change on agricultural production in Sudan, 2019. Available at www.unescwa.org/sites/www.unescwa.org/files/uploads/national-assessment-report-Sudan-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-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.

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