Food and Agriculture Organization of the United Nations

Strengthening agricultural water efficiency and productivity on the African and global level

WATER PRODUCTIVITY

Cover photo: © FAO/Eva Pek

The project

Africa is a rural continent, with agricultural production accounting for 17 percent of the Gross Domestic Product (GDP), and it relies on agriculture as a driving force for its social and economic development. The agricultural sector employs about 60 percent of the total labour force and most smallholders depend on rain-fed production for their livelihoods.

At the same time, irregular and unreliable rainfall is a main contributing factor to low agricultural productivity. Improved Agriculture Water Management (AWM) is thus crucial to increasing production levels and improving food security.

The GCP/INT/231/SWI project, "Strengthening Agricultural Water Efficiency and Productivity on the African and Global Level", strives for reducing hunger and poverty by focusing on improved AWM practices on the African and global level and mainstreaming AWM in national frameworks and processes.

In particular, **Output (1)** aimed at **"Enhanced capacity for improved crop water productivity in small scale agriculture in the three countries",** through the following activities:

- Conduct **training programmes** on the use of tools to enhance water productivity (AquaCrop);
- **Calibrate and apply the AquaCrop crop model** under small scale farming conditions for rainfed and irrigated agriculture and examine possible changes in crop water management practices; and
- Launch **information campaigns to promote recommended good practices in water management** and widely disseminate the results of the application of tools.

The overall approach of the project was a combination of **bottom up and top down activities** in the field of AWM and at different levels, from micro, working with extension agents and farmers' representatives; to meso, with research institutes and regional governance structures; up to macro levels, liaising with national governments. The **integrated approach of AWM** employed throughout the project was ensured by the **involvement of stakeholders** at all levels and their continuous interaction.

The commitment showed by national governments and the support of a relevant network of stakeholders have ensured the **project's sustainability** and the most effective **dissemination of its results.** Furthermore, to achieve a **long term impact** of the project's outcomes,the in-country findings and processes are synthesized so, on one side, they can be **scaled up at national level** and, on the other, they can be scaled out to other countries, in a regional cooperation framework and globally.

© FAO/Eva Pek

Multi-use water system, Vallée du Sourou, Burkina Faso

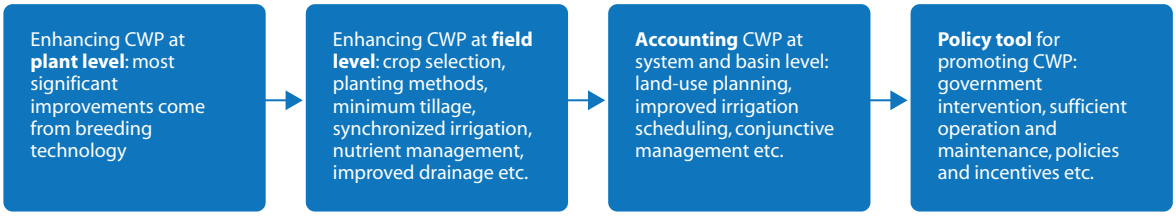
The definition and the approach

Given the demographic and economic growth of the world population, the rising competition on finite water resources and the uncertainties linked to climate change, increasing **Crop Water Productivity (CWP) and Water Use Efficiency (WUE) is essential to achieving water and food security.**

In general terms, water productivity is a **ratio between a unit of water input and a unit of output,** and in agriculture the CWP indicator is employed to measure the economic or biophysical gain from the use of a unit of water consumed in crop production.

Approaches to CWP assessment evolved over the years, as at first only land productivity was taken into account. The methods currently employed, however, evaluate a **set of relevant indicators such as water, soil,** according to the specific context. To maximize benefits from improved CWP during project implementation, currently applied methodologies also include **different AWM practices.**

Evolution of Crop Water Requirement Approach



In addition to the benefits brought to agricultural production, the **positive effects of enhanced CWP** are reflected in a number of sectors:

- **Economy**, by increasing the marketable yield of the crop for each unit of water;
- **Social**, by reducing hunger and exposure to food insecurity;
- **Ecological**, by strengthening resilience to climate change and extreme weather conditions;
- **Technical**, by introducing integrated and innovative solutions.

At its highest impact, CWP can support the attainment of relevant SDGs, such as: SDG1, Reduction of poverty; SDG2, End hunger; and SDG6, Integrated Sustainable Management of Water.

However, at project level, increasing CWP likely shows the most valuable effects and supports in the most relevant objectives:

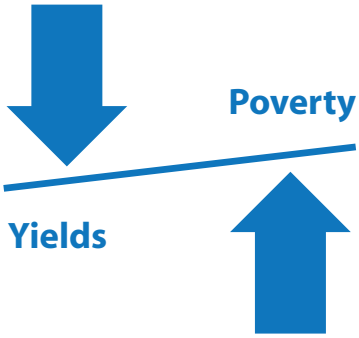
- **Optimizing** the use of rainwater for increased crop production
- **Maximizing** the utilization of existing irrigation schemes in a sustainable manner
- **Designing** new irrigation schemes in a sustainable manner
- **Developing** practical tools to enhance CWP at any irrigation condition

The project development approach

The AquaCrop crop growth model (http://www.fao.org/land-water/databases-and-software/aquacrop/en/) is a practical simulation tool developed by the Land and Water Division of the FAO to **address food security by evaluating the effects of the environment and of different management practices on crop production**. It, thus, supports the enhancement of agricultural production by **assessing the yields of major herbaceous crops as a function of water supply** and it is particularly **well suited to conditions in which water is a key limiting factor in crop production.**

The tool has been applied under small-scale farming conditions to serve two main scopes:

1. to **evaluate attainable yields** under local conditions
2. to **compare potential yield to actual production** in order **to diagnose yield gaps of selected crops.**

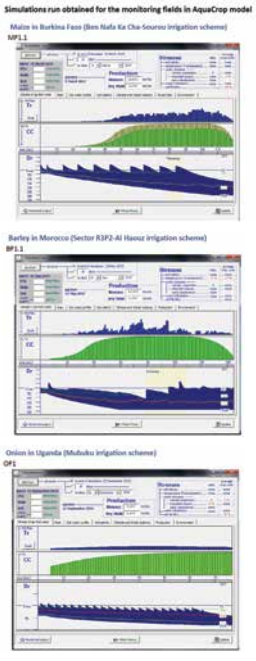


In the follow-up phase, the model was employed to aid in **formulating possible changes in crop water management practices aimed at improving CWP.**

Through a **case study approach**, three small-scale irrigation schemes (one site per country) were selected for the implementation of the project and a **tailored methodology** for assessing and improving on-farm crop WP in the selected irrigation schemes was designed.

The methodological approach was **tailored according to the targets** of the project and it covered **four main steps** and related activities:

Enhancing on-farm Water Productivity Methodological approach and related activities



Diagnosis and benchmarking	General data collection Farmers interviews Irrigation systems evaluations
Evaluation of attainable WP	Monitoring farms for parametrization/validation of AquaCrop Design and simulation of management scenarios
Identification of good agricultural practices	Design of agricultural practices guidelines Demonstration and control plots for implementation and dissemination
Promoting change in agricultural practices	Design of capacity building strategies Implementation of dissemination activities

Source: University of Cordoba (UCO)

The country at a glance

Climate and agro-ecological system

- Sahelian-tropical climate, with two main seasons: a rainy season with monsoon winds and a dry season with hot, dusty winds
- Rainfall rates are higher in the South (900-1 200 mm/year) and decrease at the North (300-600 mm/year).
- Three agro-ecologic areas: the Sahelian zone in the North, with a dry season between October and June; the North Sudanese area in central part of the country, with a rainy season between June and October; the South Sudanese region with a longer and more intense rainfall between May and October.

Agriculture and soil

- 6.07 million ha of cultivated lands (22 percent), of which 6 millions arable and the rest with permanent crops.
- Soils generally not too deep, vulnerable to water and wind erosion, affected by high demographic pressure and crop intensity.
- Yields on average poor of nutritive elements.
- Main irrigated crops are: rice, maize, cowpea, vegetables (onions, cabbage, lettuce), sugar cane and banana. Aside from the monoculture of the sugar cane, different rotations are practiced on different areas, from smaller to larger developments.

Irrigation

- Potentially irrigable area is estimated between 165 000 and 233 500 ha (erosion control sites included); potentially manageable shallows and plain areas are around 1.9 millions ha.
- In the 90s, private and community irrigation emerged, following the economic reforms and the direct engagement of the private sector in agricultural production.
- Fully controlled irrigated areas occupy around 30 000 ha, from large to small developments, while managed lowlands reached 24 545 ha under partial water control, for a total irrigated area of 54 275 ha.
- Equipped areas have been increasing by 7.8 percent/year since 2001 (4.4 between 1992-2012).
- Surface irrigation is largely dominant in the country. Sprinkler irrigation is employed for sugar cane production, while localized systems for vegetables and arboriculture.

Photos: © FAO/Eva Pek

Ben Nafa Ka Cha water system - Vallée du Sourou - Province du Sourou

Source: University of Cordoba (UCO)

Pilot site - Ben Nafa Ka Cha

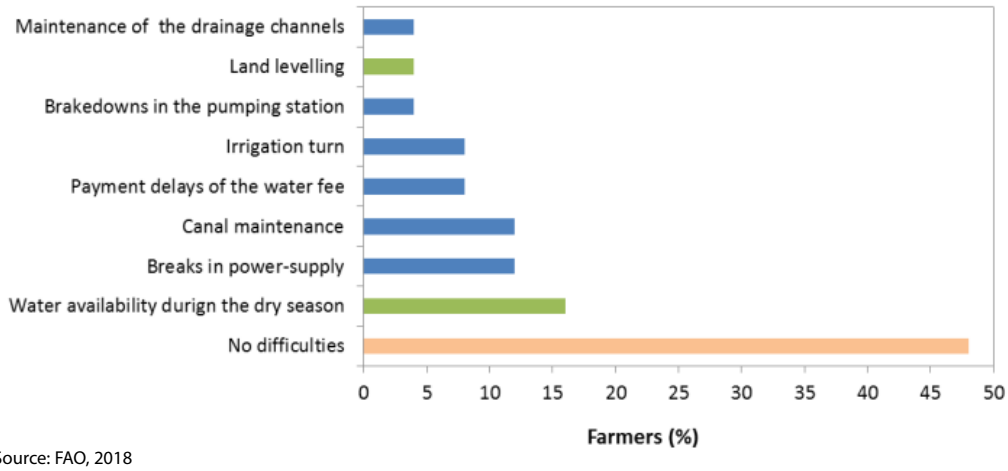
Overview

- **Location and characteristics:** In the landlocked northwestern valley of Sourou, on the border with Mali. 205 farmers, including 40 women, cultivate and share a 275 ha multi-cropping scheme dedicated to rice, maize, tomato, onion, peppers, amongst others. Farm sizes vary from 0.25 to 3 ha; average size is 1 ha.
- **Technical features:** A middle-sized development, started operating in 1997 with water from the Mouhoun-Sourou river system, is featured with low-quality and not modernized infrastructures, high operational and maintenance costs, increasing dependency from energy companies (Large pumps of 900 m^3/s for water withdrawal and gravity system for distribution).
- **Production:** Main crops are maize and rice, as household food security (rice, in the specific, is entirely for self-consumption), while tomato and onion are more profitable in economic terms, therefore, directed to wholesale market to provide farm income.
- **Operation:** The *Organisation des usagers de l'eau agricole* (OUEA) manages the pumps and the "module à masques" at main and secondary canal levels; farmers operate at tertiary level. The water service is established according to a rotation schedule, consisting of a turn every 5 days with duration of 7 to 9 hours (variable during the season).

The pilot site in the Sourou valley

Source: CIHEAM Bari

Difficulties in irrigation management reported by farmers of the scheme



Source: FAO, 2018

Pilot site - Ben Nafa Ka Cha

Field application: Facts & Figures

Design of the general methodological approach

Capacity Building on the CWP methodology:
Local technicians trained (April 2016)

Diagnosis and validation of current agricultural levels and irrigation practices:

Collect available relevant data about the irrigation scheme
Discuss with local stakeholders, verify information and identify gaps and constraints influencing CWP

Selected crops for WP pilot farms:

Maize and **Rice** > **food security**
Onion > **cash crop**

Production levels:

Maize below expected levels
Rice average and maximum acceptable but highly variable among farmers

Onion average and maximum to be improved and highly variable

Constraints in the water supply system:

Location of the farm along the secondary canal
Lack of control of water supply at farm level

Evaluation of irrigation performance at farm level and farmers' interviews:

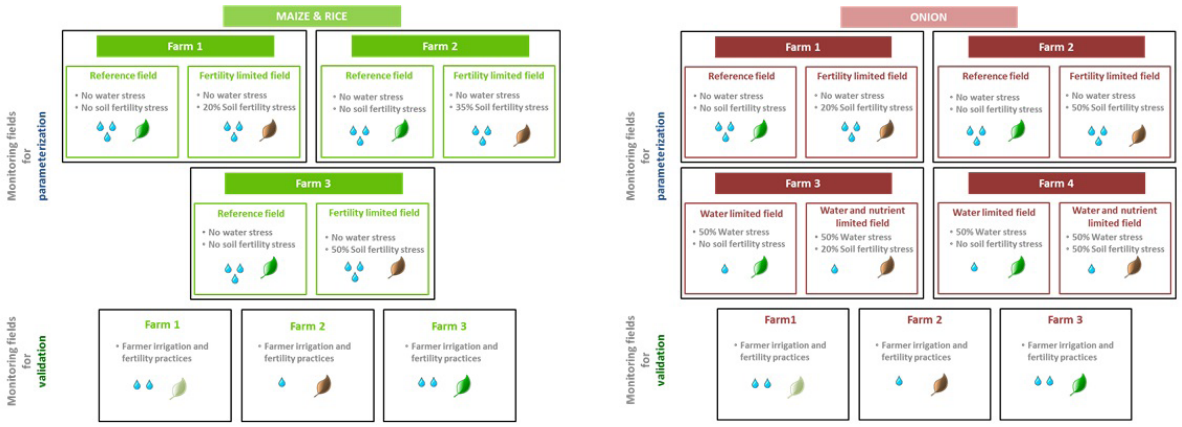
examine and assess performance of the irrigation system implemented at farm level

document and describe current agricultural production levels and on-farm irrigation and agronomic practices

assess farmers' perception of problems, risks and threats and their approach to solutions

Evaluation of potential and attainable yields with the AquaCrop model

Schematic view of the monitoring fields for the parameterization and validation process



Source: University of Cordoba (UCO)

Outcomes

Elaboration of CWP methodology and application of WP tool (AquaCrop)

- Assessment of field context: **collection of relevant data;** farmers' interviews (25 households); evaluation of current irrigation management practices.
- **Estimation of actual yield gaps** through the application of the WP tool and reasons identified:

© FAO/Eva Pek

Crop	Plots	Reasons for yield gaps
Maize	2 demonstration 2 control	• Scarce employment of fertilizers • Land levelling
Rice	2 demonstration 2 control	• Inadequate water level application after recession
Onion	2 demonstration 2 control	• Inadequate rate, duration and frequency of applied water • Inadequate pest, weed and disease management

Capacity building and Knowledge sharing

- **Inception workshop** (April 2016) with local and institutional representatives for project implementation
- **Meetings with local stakeholders** to present the new activities in the irrigation scheme and discuss about the supply of agro-inputs needed for the implementation of demonstration activities.
- **Design of agricultural practices guidelines** discussed and validated with local technicians

© Yapi Sinare

© University of Cordoba (UCO)

© FAO/Eva Pek

The country at a glance

Climate

- Semi-arid country with two main seasons.
- Irregular and uncertain rainfall, frequent season and pluri-annual dry spells, damaging floods.

Agro-ecological zones

- Higher rainfall in the North (700 mm/year) > irrigation farming.
- Lower levels in the South (25 mm/year) > irrigation essential for agricultural production.

Agriculture

- Between 15-20 percent of the GDP.
- Around 38 of economically active population employed at national level and 75 percent in rural areas.

Crops and Irrigation

- Highly variable productivity in rainfed areas due to differences in soil/climate conditions, plantation density, agronomic practices.

> **Need:** enhance transfer of technology to farmers.

- Main crops in rainfed areas are: cereals (extensive and intensive), legumes and olives; in irrigated agriculture are: citrus fruits and tomatoes

© ABHT, Marrakech

Final tillage stage (March 2017

© Mohamed Sabir

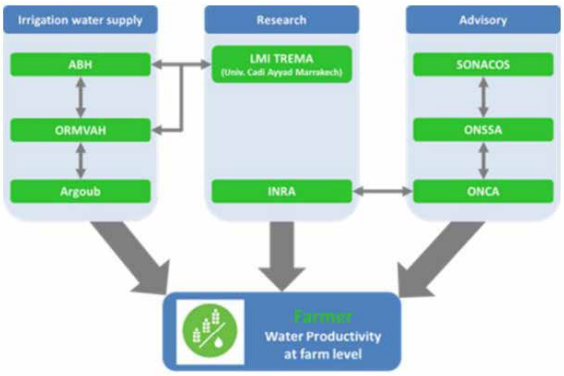
Panoramic view of the site (El Hoauz)

Pilot site - R3P2 Sector Al-Haouz

Overview

- **Location:** about 35 km at thenorth-east of Marrakech, in Ras El Ain rural community. The R3P2 sector covers 1500 ha within the Al-Haouz plain and is part of the Tensift River basin
- **Production:** cereals for seed production (wheat and barley), occupying about 57 percent of the area. About 16 percent of the area devoted to cereals, in rotation with vegetables (mainly, potato and melons). Intercropping practices in about 12 percent of the area within traditional olive orchards, while remaining is to intensive orchards of olive and citrus trees.
- **Irrigation:** around 85 percent of the area is with border and furrow irrigation, while the remaining 15 percent is with drip irrigation. Groundwater irrigation is also practiced (about 1/3 irrigation water), but level decreases by 1 m/year.
- **Governance and operation:** the scheme is operational since the 1970s, currently managed by 163 farmers.Distribution of irrigation water is managed by the Office Regional de Mise en Valeur Agricole du Haouz and the irrigation scheduling by the Water User Association (Argoub).

© Mohamed Sabir

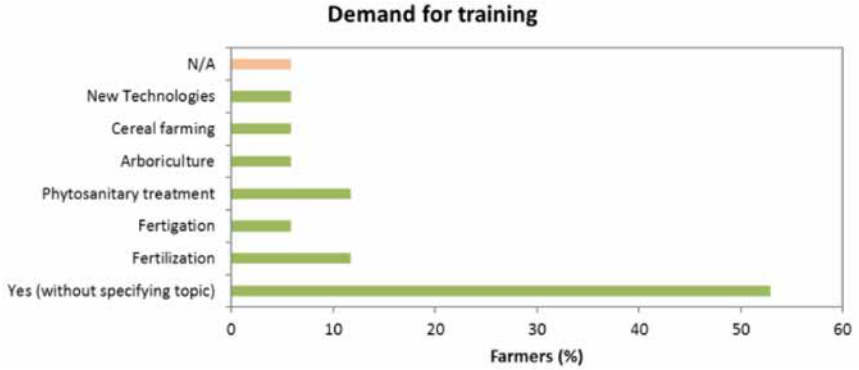


Mapping of the key stakeholders in the WP at farm level

Source: University of Cordoba (UCO)

© ABHT, Marrakech

The pilot site 3RP2 sector – Al Haouz



Farmers' interviews (November 2016)

Source: FAO, 2018

Pilot site - R3P2 Sector Al-Haouz

Field application – Facts & Figures

Design of the general methodological approach

Capacity Building on the CWP methodology:
Institutional representatives trained (October-November 2016)

Diagnosis and validation of current agricultural levels and irrigation practices:

Collect available relevant data about the irrigation schemes
Discuss with local stakeholders, verify information and identify gaps and constraints influencing CWP

Selected crops for WP pilot farms:

Wheat > Food security /Seed production
Olive
Barley

Production levels:

Areas for improvement mainly for cereals for food production

Constraints in the irrigation system:

Slow conversion to drip irrigation, due to insufficient technical support

Lack of flexibility in water service

Adequate recharge of aquifer

Evaluation of irrigation performance at farm level and farmers' interviews:

examine and assess performance of the irrigation systems implemented at farm level

document and describe current agricultural production levels and on-farm irrigation and agronomic practices

assess farmers' perception of problems, risks and threats and their approach to solutions

Evaluation of potential and attainable yields with the AquaCrop model

Average yields for the main crops

Crop	Yield (t ha^{-1})
Durum Wheat	4.5 – 5.0
Bread Wheat	5.0 – 6.0
Barley	2.5 – 3.5
Potato	25 - 35
	20 - 30
Melon	50 - 90

Olive orchard with alfalfa with basin irrigation and melon field with drip irrigation

Source: University of Cordoba (UCO)

Outcomes

Elaboration of CWP methodology and application of WP tool (AquaCrop)

- Assessment of field context: collection ofrelevant data; farmers' interviews (17 households); evaluation of current irrigation management practices.
- Estimation of actual yield gaps through the application of the WP tool and reasons identified:

Crop	Reasons for yield gaps
Barley	• Low fertilization levels • Problems in achieving crop water requirements
Wheat (durum)	• Deficient fertilization management • Problems in achieving crop water requirements
Orchard olives (traditional and intensive)	• Water stress

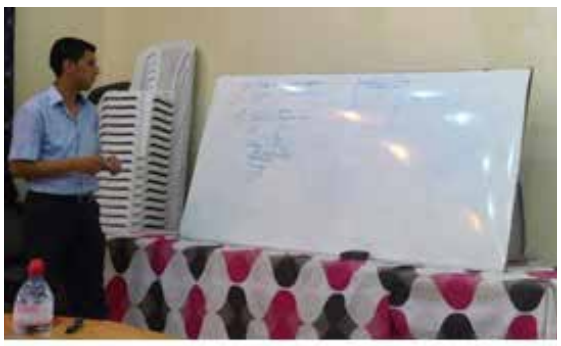
© University of Cordoba (UCO)

© University of Cordoba (UCO)

Capacity building and Knowledge sharing

- **Inception workshop** (October-November 2016) with institutional representatives to discuss, validate and improve methodologies and **to train local technicians**
- **Monitoring field activities** to evaluate: (i) drip irrigation for horticultural crops and new olive orchards; (ii) border irrigation for cereals, traditional olive orchards and alfalfa

© ABHT, Marrakech



© University of Cordoba (UCO)

The country at a glance

Climate

- Equatorial climate with small regional variations in annual temperature and humidity.
- Precipitations vary from 750 to 1 500 mm/year, with two rainfall peaks in the South (March-May and August-November) and dry seasons in the North (November-March and June-August).
- The Kasese District, located in western Uganda, experiences bimodal rainfall pattern, with rains between March and May and from August to November.

Agro-ecological system

- "Tall grass", highly productive area with bimodal rainfall and perennial cropping, South, South-West of Lake Victoria crescent.
- "Short grass", only annual crops, in the northern, eastern and western part of the country.

Agriculture

- Employs 92 percent of active population and represents 34 percent of national GDP.
- Around 70 percent of production is rainfed.
- 14 million ha estimated as cultivable areas, only 38 percent cultivated and 2.2 million ha under permanent crops.
- Rice, sugarcane and vegetable are the main crops, cultivated in around 13 000 ha

Irrigation

- Small scale "informal" irrigation spontaneously started in 1940s by smallholders.
- Below 1 percent of the total cultivated area is irrigated and only 12 percent of irrigable lands are managed.
- Main irrigation systems are full control, equipped wetlands and spate irrigation, covering around 12 000 ha.

Furrow irrigation performance evaluation ©Dennis Besigye

Vegetable cultivation (Artocarpus heterophyllus – Jackfruit) ©Dennis Besigye

Pilot site - Mubuku irrigation scheme

Overview

Location: 10 km North East of Kasese town, in the western Rift Valley. Bordered by River Sebwe and River Nyamwamba, the scheme covers an area of around 587 ha.

Background: developed in the 60s as resettlement scheme for farmers from all over Uganda. Officially started operating in 1964.

Governance and operation: cultivated by 167 farmers on a tenant basis, while the landownership remaining with the state. The system is divided into a set of divisions corresponding to a lateral, approximately, 14 farm holdings per division (farm holding of 3.2 ha each).

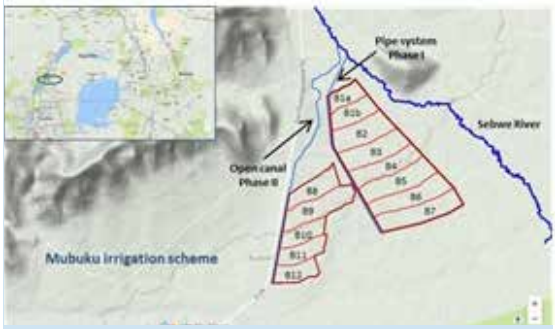
Production: in the 587 ha (approximately) rehabilitated area, 60 percent is devoted to maize and rice for seed production, wholesale and consumption while remaining 40 percent of crops (onions, tomatoes, hot peppers, beans, tree crops, etc.) are entirely for market production.

Irrigation: two branches diverting water on the right side of the River Sebwe. The upstream branch is an open canal system whereas the downstream branch is a pipe system. Scheme divided into 13 divisions.

© Eva Pek

© Laura Guarnieri

© Dennis Besigye



The pilot site - Mubuku irrigation scheme

Source: CIHEAM Bari

Pilot site - Mubuku irrigation scheme

Field application: Facts & Figures

Design of the general methodological approach

Capacity Building on the CWP methodology:
Local technicians trained (March 2016)

Diagnosis and validation of current agricultural levels and irrigation practices:

Collect available relevant data about the irrigation schemes

Discuss with local stakeholders to verify information and identify gaps and constraints influencing CWP

Selected crops for WP pilot farms:

Maize
Rice
Onion

Production levels:

enhance average yields while reducing employed water

reduce variability among farmers

minimize difference between minimum and average yields

reduce variability among producers

Constraints in the irrigation system:

non-flexible irrigation rotation does not reflect crop water demand

poor land levelling and furrows' deficiency does not allow a high distribution efficiency of water on the surface

Evaluation of irrigation performance at farm level and farmers' interviews:

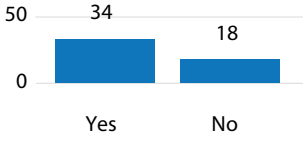
examine and assess performance of the irrigation systems implemented at farm level

document and describe current agricultural production levels and on-farm irrigation and agronomic practices

assess farmers' perception of problems, risks and threats and their approach to solutions

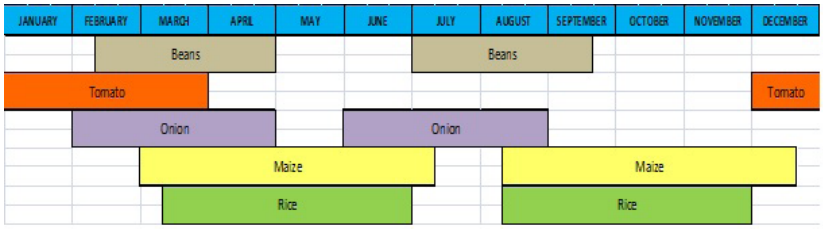
Evaluation of potential and attainable yields with the AquaCrop model

Frequent experience of failing production



Number of failed production cases reported by interviewed farmers of the scheme

Cropping calendar



Outcomes

Elaboration of CWP methodology and application of WP tool (AquaCrop)

- Assessment of field context: collection of relevant data; farmers' interviews (18 households); **evaluation of current irrigation management practices.**
- **Estimation of actual yield gaps** through the application of the WP tool and identified reasons:

© University of Cordoba (UCO)

Crop	Plots	Reasons for yield gaps
Maize	2 demonstration 2 control	• Improper irrigation timing • Reduced number of split fertilizer applications • Deficient pests and diseases management
Rice	2 demonstration 2 control	• Over-density of planting • Low germination rate • New diseases carried in with the trade
Onion	2 demonstration 2 control	• Fluctuating profitability

Capacity building and Knowledge sharing

- **Inception workshop** (March 2016) with institutional representatives and local stakeholders to formulate tailored protocols and enable project activities' implementation.
- **Training** of local technicians on **optimal farming practices** (March/August 2017) and on the methodology to disseminate the activities aimed at enhancing CWP.
- **Design of agricultural practices guidelines** for maize and rice, discussed and validated with local technicians

© University of Cordoba (UCO)

© University of Cordoba (UCO)

Key findings and assessed needs

The case study approach adopted by the project to assess and enhance CWP allowed a detailed **evaluation of different conditions existing in the three countries** according to relevant indicators.

The critical assessment of field conditions and evaluation of existing gaps proved therefore critical in the **definition of needs and follow-up actions.**

Irrigation Water Supply	Irrigation Water Management	Agricultural Practices
In each study area the irrigation water supply conditions are different, facing 3 representative scenarios of most irrigation schemes	The 3 countries face common challenges concerning on-farm irrigation system, albeit with specific needs to take into consideration	Increasing production or net returns per employed water unit requires due attention to all agricultural practices other than irrigation
Burkina Faso Poor state of water distribution infrastructures and drainage system > irrigation system design at farm level to be enhanced to avoid waterlogging	**Burkina Faso** Enhanced irrigation system design and land preparation	Adequate amount of allocated water according to crop demand Good seedbed preparation Suitable crop rotation Nutrient application and integrated pest management (IPM) Proper identification of pests and crop protection measures:
Morocco Limited flexibility of water services > optimize use of irrigation water	**Morocco** Promote deficit irrigation strategies and suitable joint management of water and soil fertility	Application of insecticides with cultural control measures; Use of a combination of phytosanitary products Application of specific treatments at right times
Uganda Low efficiency of water distribution among farmers > water service scheduling to be improved	**Uganda** Training of farmers on crop water requirement/irrigation scheduling Optimization of water allocation at field level	

Additionally, and in order to support the **project's sustainability,** a number of **lessons learned** are taken into consideration:

- **Diagnosis phase is critical** for successful establishment of project activities.
- Identification, design and implementation of suitable on-farm WP strategies highly benefits from **joint elaborations on water productivity and water use efficiency.**
- Insufficient and ineffective **communication** among stakeholders can negatively impact results.

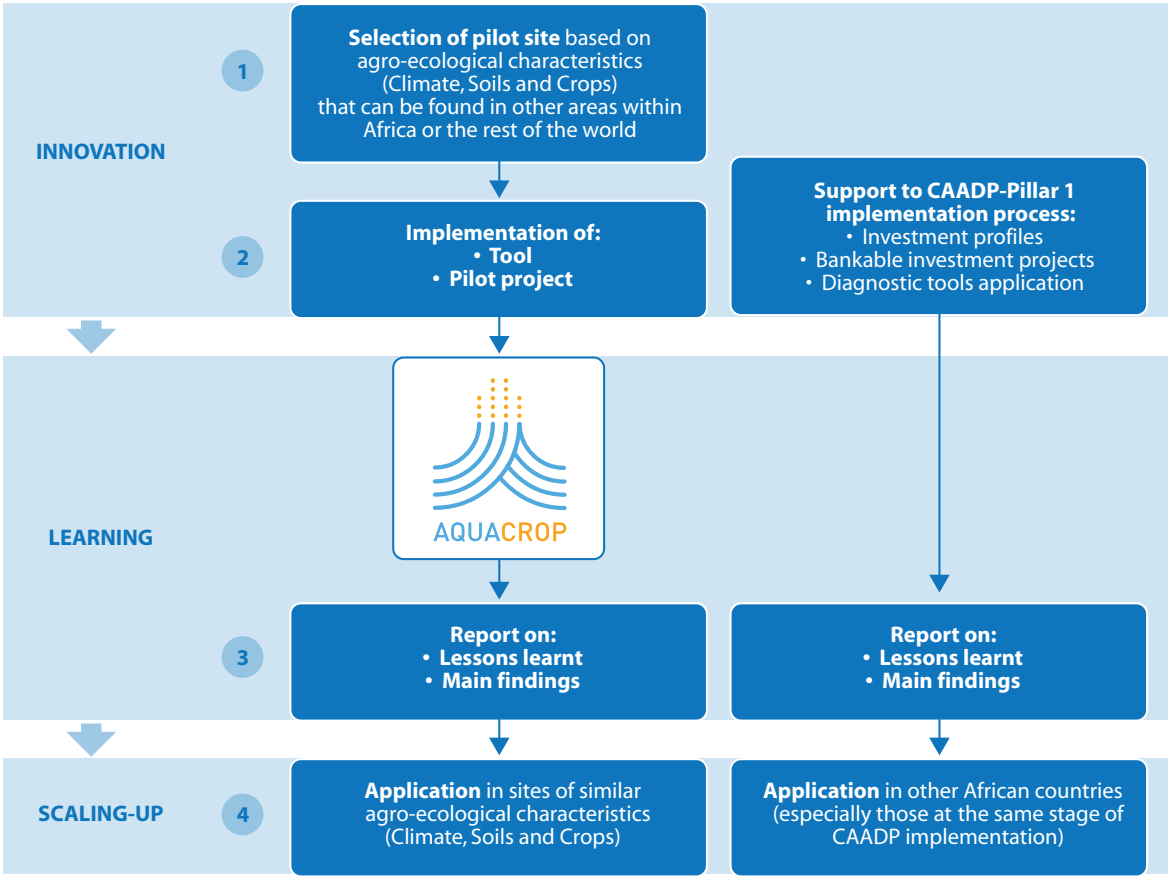
Scale-up

The long term vision of the project anticipates the opportunity to **bring results forward and scale them up** as well as practices of common nature to other countries, both in a regional (South-South) cooperation process and globally.

Furthermore, the **dissemination and promotion of good and context-tailored agricultural practices** represent a critical activity in the follow-up phase, relying on the full involvement of major stakeholders such as Water User Associations. Continuous efforts to ensure the **enhancement of capacities** at all levels are, therefore, of paramount importance.

Such an approach fosters an **increase of investment** in AWM, also through the **involvement of the private sector** to encourage **farmers' accessibility to agricultural inputs,** still a challenge for smallholders in most developing countries.

Moving forward: The scaling-up strategy



Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Agency for Development and Cooperation SDC

AgWA

Partnership for agricultural water for Africa

CA2371EN/1/11.18