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

Africa is a rural continent, with agricultural production accounting for 17 percent of the 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.


In particular, Output (2) of the project aims at “Enhanced capacity for increased water use efficiency (WUE) in small scale irrigation in Burkina Faso, Morocco and Uganda”, through:

- Conduct training programmes at regional and national levels targeted to agriculture water extension agents, water professionals and farmers’ representatives, including those responsible of the management of irrigation schemes, in the use of tools to analyse and evaluate the performance of small-scale irrigation systems;
- Develop and implement a rehabilitation/improvement plan for small scale irrigation for the selected pilot schemes in each of the three project countries;
- Develop and implement Flexible Water Service Management approach and conduct training programmes on its implementation for Water Users Associations and for farmers;
- Apply discharge measurement techniques and methods with data collection protocol and establish water discharge history;
- Undertake information campaigns to increase irrigation efficiency and WUE at small scale, and widely disseminate the results of the application of the MAISCODE for Small Scale Irrigation to users, including staff of authorities and farmers’ representatives responsible for the operation of irrigation systems.

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 commitment showed by national governments and the support of a relevant network of stakeholders ensure the project’s sustainability and the most effective dissemination of results. Furthermore, to achieve a long term impact of the project’s outcomes, the in-country findings and processes of common nature are synthesized in order to, on one side, scale them up at national level and, on the other, scale them out to other countries, in a regional (South-South) cooperation process.
The definition and the objectives

The rising competition over water resources is particularly affecting the agriculture sector and, in the specific, the irrigation domain, which currently represents the largest user of agricultural water resources.

The assessment of water resources employed for irrigation, and the evaluation of their economic productivity, is therefore a fundamental activity as it leads to the definition, both, of beneficial and/or potentially harmful effects of irrigation practices.

In this respect, Water Use Efficiency (WUE) represents a major component of agricultural water management and it supports crop water productivity by reducing water losses from drainage, seepage and non-productive evaporation. In practical terms, WUE indicates the ratio between effective water use and actual water withdrawal and it illustrates how effective is the use of water employed for irrigation purpose.

Improving WUE in agriculture is critical to enhance food production while using diminishing water resources. In a broader perspective, it should be highlighted the significant contribution that the enhanced efficiency of water resources brings to the achievement of a number of Sustainable Development Goals:

- SDG1: Build the resilience of the poor and reduce their vulnerability to climate-related events
- SDG2: Ensure sustainable food production systems and implement resilient agricultural practices
- SDG6: Sustainably increase water-use efficiency
The methodology: MASSCOTE approach

The MApping System and Services for Canal Operation TEchniques (MASSCOTE) is a method for evaluating different components of irrigation systems and auditing performance in order to develop a modernization plan. According to FAO definition (1997), modernization represents “a process of technical and managerial upgrading (as opposed to mere rehabilitation) of irrigation schemes with the objective to improve resource utilization (labor, water, economics, environmental) and water delivery services to farmers”.

The 11 activities composing the MASSCOTE approach, are grouped into 2 main parts:

1. Baseline information and analysis through a Rapid Appraisal Procedure (RAP)
2. A design of water services and modernization plan for canal operation

The iterative nature of MASSCOTE is a fundamental feature of the approach, as several rounds of analysis at different level of the systems might be required before reaching a consolidated evaluation. Furthermore, MASSCOTE introduces Service-Oriented Management (SOM) as standard practice and, in this respect, users are considered central actors in the overall process.

In order to adapt the tool to the case study approach of the project, and since MASSCOTE application is funded on rigorous on-site evaluations of the physical water infrastructures, a selection of one small scale irrigation system in each of the three countries was carried out prior to application.

The MASSCOTE project approach

- Assess the in-country status of water use efficiency
- Identify existing gaps
- Application of the tool to analyse and evaluate performance of small scale irrigation system
- Examine possible improvements in operation and management of irrigation systems at small scale
- Develop a modernization/improvement plan for small scale irrigation in each country pilot site
Discharge measurement techniques: Traditional and non-traditional

Discharge measurement is a **multi-objective activity** considering, in the specific:

1. The relation between water supply and demand.
2. Monitoring optimal water allocation to enhance water use efficiency.

Within the framework of the project, both **traditional (weir) and non-traditional (crowd-sensing) techniques** were applied on small- and medium-scale irrigation systems for open-channel flow measurement. In particular, the scalability of crowd-sensing technique was tested in Uganda.

**Weir measurement**
- 6 measurement sites
- 6 installed weirs
- 3 measurement campaigns
- 159.1 l/s annual mean discharge

**Crowd-sensing application**
- 13 measurement sites
- 6 relocated sites
- Real time measurement values
- 92.1 l/s annual mean discharge
- +/- 20% relative error range

It should be noted that **crowd-sensing technique required the application of another technology for validation**. Once the method is deployed and the rating curve is computed, the measurement can rely on the discharge app. Therefore, the non-conventional technology was not deployed as a stand-alone system at installation stage.
Flexible water resource allocation:  
An approach towards enhanced Water Use Efficiency

Although irrigation in Africa has the potential to boost agricultural productivities by at least 50 percent, food production on the continent is almost entirely rainfed and the area equipped for irrigation makes up just 6 percent of the total cultivated area. In this respect, improved Agricultural Water Management (AWM) has a pivotal role in increasing WUE.

In order to achieve the enhancement of production while reducing employed water, however, sufficient knowledge of irrigation schemes’ discharge data is required, together with a clear understanding of the potentiality to increase efficiency of those schemes and the mechanisms to do so. Accessible databases on historical water use thus represent useful decision-support tools that can facilitate the elaboration of tailored flow models for optimal water service.

At irrigation scheme level, the following indicators of water services should be established in a flexible manner in order to allocate sufficient water resources according to the most efficient and sustainable standards: 1. Adequate water rates; 2. Frequency; 3. Duration; 4. Control

**BURKINA FASO and UGANDA: 2 case studies of flexible water service**

<table>
<thead>
<tr>
<th>Application</th>
<th>Proposed options</th>
</tr>
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<tbody>
<tr>
<td>One responsible (&quot;aiguadier&quot;) for opening/closing of intake of primary canal</td>
<td>Adjust filling of primary/secondary canals to eliminate overflow</td>
</tr>
<tr>
<td>Leaders of tertiary canals only responsible for opening/closing outlet on secondary canals</td>
<td>Link irrigation time to operational management of network for energy distribution &gt; (i) incentive to irrigate during off-peak energy rate; (ii) re-schedule irrigation rotation to off-peak periods for all crops but rice, (iii) install capacitors to reduce energy costs</td>
</tr>
<tr>
<td>Tertiary canal leaders control water turns and five-day rotation to plot</td>
<td>Manage all canals to ensure farmers receive adequate flow for irrigation</td>
</tr>
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**Current water service**  
Proposed water service

| Water provided 4 times/week; blocks irrigated once at each 4th day | Apply elaborated modelling at quaternary level to allow water reaching farms |
| At tertiary level, 4 hrs of water availability; 60-80 l/s | At tertiary level, increase irrigation to 6hrs and allow 6hrs/day flexibility |
| Secondary canals provide water for 24 hrs (peak) | Three tertiaries planned for irrigation once per 4 days; discharge reduced to 30 l/s |
| All the six tertiaries of Division 8 are irrigated in a week and the 8th day is off irrigation. | Allow 24 hrs for on demand water service, of which 6 hrs free irrigation/day |
The country at a glance

Environmental characteristics

- Predominance of tropical sähelian climate, with three different AEZs and precipitation increasing from North to South.
- Average rainfall is 748 mm/year.
- Early droughts in humid regions (December/January) caused by (i) water stress due to competition; (ii) high evapotranspiration.
- Soil depletion and loss of fishing resources in the river basins.

Water resources

- Renewable water resources estimated around 12 500 million m³/year.
- Exploitable renewable water resources estimated around 4 750 km³/year, corresponding to 280 m³/person/year.
- Due to climatic changes aquifers are not recharged and exploitable resources are only freshwaters.

Water use

- Irrigation sector employs around 421 million m³/year of water resources, corresponding to about 51 percent of totally exploited resources.
- Low exploitation of hydraulic potential - only 4 percent of total renewable resources.
- Competition mainly between domestic and agricultural sectors.

Irrigation and drainage

- Estimated irrigable land is between 165 000 and 233 500 ha.
- Overall equipped agricultural land is around 290 730 ha, of which 25 389 ha with surface and 3 900 with sprinkling irrigation.
- Around 13 700 ha are dedicated to small scale agriculture (below 20 ha).
Pilot site - Ben Nafa Ka Cha

Pilot site – overview

- **Location and characteristics:** In the landlocked northwestern valley of Sourou, on the border with Mali, with 205 farmers, including 40 women. Farm sizes vary from 0.25 to 3 ha; average size is 1 ha.

- **Governance:** The Organisation des usagers de l'eau agricole (OUEA) is responsible for services and maintenance of infrastructures and equipment of irrigated scheme. OUEA is supervised by the Water Agency of Mouhon, which processes or procures to an audit of the OUEA leading to required improvements. At scheme scale, OUEA transmits irrigation schedule and cropping plan to the Autorité de Mise en Valeur de la Vallée du Sourou (AMVS) to estimate water demand.

- **Discharge and Water Service scheduling:** Currently, fixed and rigid. In case of excessive discharge, water is re-pumped into main stream and re-paid for by OUEA. Improving water service scheduling is essential for enhanced and more efficient water management at farm level.

Pilot site – recommendations

**Management level:**

- Strengthened commitment of Water User Association to pre-define irrigation schedule at weekly-step frequency.

- Follow-up of energy consumption and bill of energy according to the new scheduling, in coordination with WP line of activities and the association. New schedule should avoid peak hours for energy.

- Optional installation of capacitors to decrease energy bill

**Field level:**

- Include weed control in the rehabilitation plan to protect from further infection and prevent soil salinization

Rehabilitation of modules à masque and canals to reinforce equity and reliability of water distribution + More frequent definition of water requirement to establish optimal water supply and reduce water loss = Water in appropriate time and amount will increase crop water productivity and ensure farmers' commitment
Outcomes

Rehabilitation of water distribution infrastructures:

- Rehabilitation of main canal and modules à masques between primary and secondary canals.
- Rehabilitation of primary canal associated with realization of downstream drainage basin.
- Lining of tertiary canal.

On-field water control:

- Refurbishment of tertiary canals with on-field water control.

Improvement of measurement system:

- Calibration of modules à masques.
- Calibration and rehabilitation of water regulation structures.
- Establishment of discharge data collection protocol for the local WUA.

Training and knowledge sharing:

- Training on discharge measurement and Flexible Water Services.

Photos: CIHEAM Bari
The country at a glance

Climate and AEZs
- From semi-arid to arid climate with 2 main seasons: warm and dry summer and cold and humid winter.
- 2 main AEZs: (i) main plains and hills with average rainfall above 400 mm/year and large irrigated areas; (ii) arid and semi-arid cultivated plains, mountains and oasis.
- Rainfall varies from 25 mm/year in the South-East to 2 000 mm/year in the mountain areas, with an average of 346 mm/year.

Water resources
- Overall renewable water resources are estimated at around 29 km³/year, of which 22 from freshwater and 10 from groundwater (3 km³/year not exploited within country).
- Water resources distributed across 6 main hydrographic basins.
- Estimated exploitable resources are 22 km³/year (18 surface and 3 groundwater), of which 1 km³ from returned irrigation water.

Water use and gaps
- Overall water demand amounts to around 14 649 million m³/year, of which 13 225 millions for irrigation (above 90 percent).
- About 4 000 million m³ of water gaps in all sectors. Irrigation needs varies according to different basins and highly depend on groundwater (generally overexploited).

Irrigation and drainage
- Currently managed surface amounts to 1 458 160 ha, while potentially irrigable land amounts to 1 664 000 ha.
- Around 72 percent of lands are irrigated with surface water, around 9 percent with sprinklers and 19 percent with localized methods.
- Currently, around 45,4 percent of managed lands are equipped for drainage.

Standard irrigation scheme in Morocco

Source: CIHEAM Bari

Water use per sector

Source: FAO, 2018
Pilot site - R3P2 sector Al-Haouz

Overview

- **Location:** about 35 km at the north-east of Marrakech, Ras El Ain rural community. The R3P2 sector covers 1500 ha within the Al-Haouz plain and is part of the Tensift River basin.

- **WUE parameters:** (i) efficiency at plot level= 50-60 percent; (ii) distribution efficiency= 70-80 percent; (iii) transport efficiency= 80-90 percent > Average efficiency rate estimated between 40-45 percent.

- **Accounting:** validation of water quantity discharged to farmers at tertiary canals, after modules à masques, essential to ensure validity of efficiency rates.

- **Discharge:** Time and quantity of applied irrigation water registered for 3 plots. Average discharged water is 33.8 l/s.

**Low efficiency due to:**

1. Predominance of gravity irrigation, mainly at farm level.
2. Poor physical conditions of open flow canals.

Pilot site – considerations

- Implementation of WUE policies, taking into consideration water demand management in all sector.
- Need for efficiency plans and sustainable financing systems for irrigated agriculture.
- Regional cooperation to support transfer of knowledge, build capacities, exchange experiences and practices.
- Public-private partnership can allow optimal allocation of available resources with regards to employed economic instruments (tariffs, subsidies) and techniques (rehabilitation and modernization of transport and distribution infrastructures).

Source: CIHEAM Bari
Rehabilitation of water distribution infrastructures

Rehabilitation of conveyance to increase WUE (pipeline activity):

- fixing the negative consequences of vandalism.
- measuring water supply.
- increase the lifespan of conveyance structures at secondary

Improvement of measurement systems

- Calibrated modules à masques at secondary and tertiary level.
- Established rating curves at secondary level.

Training and capacity building

- Discharge measurement campaign and training for local professionals.
- Established data collection protocol to set-up discharge history.
The country at a glance

Climate and agriculture
- Equatorial climate with precipitation varying from 750 to 1500 mm/year.
- 23 percent of GDP originating from agriculture, in sharp decline in recent years.
- Cultivable area estimated at around 14 million ha, 9.15 percent of which is currently cultivated (6.75 million ha of arable land and 2.2 ha under permanent crop).

Water resources and management
- Internal renewable surface water resources estimated at around 39 km³/year, renewable groundwater resources around 29 km³/year.
- Groundwater represents main source of municipal water supply for rural population and for livestock use.
- About 278 “water for production” facilities under community management registered, with established water users’ committees.

Water Use and exploitation
- Total water withdrawal amounts to 637 million m³/year, out of which agriculture employs 259 million.
- Only 1 percent of total renewable resources (surface and groundwater) are withdrawn.
- Low extraction rates of groundwater, boreholes fitted with hand pumps.

Irrigation and drainage
- In terms of irrigation potential, 295,000 ha do not need storage facilities while 272,000 require storage to be developed.
- Formal irrigation limited both in extent and success due to top-down approach adopted in most schemes. The farmer-based (or self-help) scheme of Mubuku is considerably more successful.
- Around 36,000 ha of agricultural lands are drained, with the highest share (18,612 ha) in the East.
Pilot site - Mubuku irrigation scheme

Overview

Location: 10 km North East of Kasese town, western Rift Valley.

Bordered by River Sebwe and River Nyamwamba, the scheme covers an area of around 587 ha

Scheme organization: Overall area distributed amongst 56 farmers within Phase II (156 ha). Water diverted from River Sebwe to main canal, then to 5 secondary canals (Divisions). Water distributed to each holding through tertiary canals.

Irrigation and crops: Main crops cultivated in the area are maize, rice and onion. At farm level, water applied by furrows for maize and onion and by basin irrigation for rice.

Assessed gaps: (i) Inequity; (ii) Scarcity; (iii) Rehabilitation/Maintenance of infrastructures; (iv) Regulations.

Water distribution

Farmers' survey on irrigation management at farm level

<table>
<thead>
<tr>
<th>Access to information system on production and water use</th>
<th>80%        90%       100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequent experience of failing production</td>
<td>70%         80%        90%</td>
</tr>
<tr>
<td>Frequent experience of water shortage or waterlogging</td>
<td>60%         70%        80%</td>
</tr>
<tr>
<td>Attended in irrigation training/courses (yes/no)</td>
<td>50%         60%        70%</td>
</tr>
<tr>
<td>Membership of cooperative /WUA/extension service provider</td>
<td>40%         50%        60%</td>
</tr>
</tbody>
</table>

Source: FAO, 2018

Scope of the pilot

Training of water extension agents and water professionals, including those responsible for the management of irrigation schemes, on performance analysis tools (MASSCOTE)

Application and monitoring of traditional and non-traditional tools for discharge measurement (MASSCOTE/iMOMO)

Development of a rehabilitation plan for small scale irrigation

Elaboration of flexible water service model to increase efficiency at farm level

Source: CIHEAM Bari

Source: FAO, 2018

After every 4 days

After every 3 days

After every 2 days

Every other day

Duration (hours)

Farmers (%)

Source: FAO, 2018
Outcomes

**Rehabilitation of water distribution infrastructures**

- 15 tertiary canals repaired > Distribution efficiency improved to 60-75 percent > overall irrigation efficiency rate increased to 40 percent (+10%)
- 6 eroded field canal bed raised and reshaped for improved distribution efficiency

**Data monitoring at main and secondary canal level**

- 6 flumes (broad crested weirs) constructed along the main and 5 secondary canals; all equipped with staff gauges.
- Daily monitoring of flows at main and secondary canal.

**Calibration of measurement**

- Rating curves generated for each flow measuring structure.

**Capacity building of local technicians on discharge measurement tools**

**Knowledge sharing on water service**
Strengthening agricultural water efficiency and productivity on the African and global level

知识分享关于水资源服务