Assessing different irrigation innovations for better climate resilience of olive farming systems in Morocco

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Morocco, Tensift basin

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This report presents the research activity carried out by the University Mohamed 6 Polytechnique (UM6P) in Morocco, member of the BRIDGE consortium (https://doi.org/10.23708/IY0MZY), as part of the Climate Smart Systemic Solutions and Scaling (C4S) innovation package led by ICARDA (Work package 3 cross-scale approaches).

Greater water efficiency of olive farms, a priority adaptation strategy for Morocco

Background

Food security and sustainable agriculture is rising as a global concern because of several factors such as population growth, socio-political issues, inadequate agricultural infrastructure, land degradation and low agricultural productivity exacerbated by climate change effects. Large arid and semi-arid areas in the world, particularly in Morocco and Africa, have high potential in terms of agricultural productivity, but water is the main limiting factor for production. As a result, one of the main challenges remains the improvement of agricultural water management, when the availability and quality of freshwater resources and the sustainable use of soil resources are under increasing pressure, which can lead to a global sustainable water resources management.

Long-term research for development partnership

In Tensift region (Morocco), a long-standing collaboration was initiated in early 2002 in the frame of SUDMED program and then the joint international laboratory (LMI TREMA: https://www.lmi-trema.ma), between researchers from Moroccan and French institutions and regional water and agriculture stakeholders (ORMVAH and ABHT), to address issues of the sustainable management of water resources in Haouz-Tensift basin, a typical catchment of the Southern Mediterranean region. In this context, the LMI TREMA studies the eco-hydrological functioning of semi-arid watersheds for a better understanding of the processes governing the redistribution of water at the catchment scale, based on the synergetic approach combining satellite remote sensing, process modelling and ground observations from the hydrometeorological observatory of Tensift basin, implemented gradually since 2002. One of the objectives of LMI TREMA is to co-develop with stakeholders operational tools that could help make wise decisions for water resources management and uses, in particular irrigated agriculture, to anticipate and develop adaptation measures to the global changes.

In the same vein, the collaboration initiated with regional water/agriculture stakeholders continued with ASSIWAT project, supported by OCP, which aims to co-develop and implement a decision support system (DSS) for water management in Tensift basin, based on an integrated eco-hydrological modelling combined with remote sensing and ground data.

Alignment with ClimBeR's theory of change

The work suggested by the University Mohamed 6 Polytechnique (UM6P) team as part of ClimBeR initiative pursue and build on the above-mentioned research projects and historical partnership with stakeholders to contribute to develop solutions, mainly around irrigation efficiency and deficit irrigation practices [1], that could influence policy pathways towards climate-resilient agriculture.

The objective is to assess the effectiveness of the irrigation policy, particularly the drip irrigation promotion program as part of the Moroccan Green Plan which continued with Green Generation strategy, in terms of water saving and its efficiency. In addition, the project will define the limits of the extension of the irrigated agriculture under global change impacts in semi-arid region in order to ensure an efficient and sustainable water resources management at regional scale.

One deliverable of this BRIDGE research activity is to co-develop a yield gap prediction tool to evaluate different irrigation practices at different scales, as part of the Climate Smart and Systemic Solutions and Scaling (C4S) decision-support innovation led by ICARDA.

As pointed out earlier, irrigated farming systems are undergoing climate change effects in Morocco (reduced irrigation water volumes, uneven rainfall, frequent droughts…). To improve climate resilience in water stressed growing areas, policy makers need guidance in both water planning (at irrigation perimeters and basin scales) and agricultural/irrigation extension service (at farm scale) especially during water scarcity periods. This guidance is supposed to drive current governmental plans for water and agriculture towards more inclusive and bottom-up transformation of irrigated farming systems.

The focus will be on olive trees to increase the climate resilience of this farming system through the efficient use of water and nutrients. In fact, Olive trees are cultivated on more than one million hectares in Morocco, representing 65% of the national arboreal soil, which points out the need for preserving the tree, considering its socio-economic and environmental importance.

Stakeholders involved in co-designing the irrigation decision tool

Since tackling the issue of water resources management involves the coordination and consultation between several stakeholders, several workshops were organized from the beginning, gathering the project team and the institutional partners in charge of the water management in the Tensift region (ABHT: Agence du bassin hydraulique du Tensift; ORMVAH: Office régional de mise en valeur agricole du Haouz) to discuss and identify the partners challenges, needs and scientific issues to be addressed (Table 1). The second workshop held at UM6P aimed to initiate the collaboration with the institutional partners of the project that are in charge of the water resources management and implementation of the water policy in the study area (Tensift basin). The main objective was to inform those stakeholders and operators about the goals and expected outcomes of the project, to present the last research results in the eco-hydrological modeling in the study area and to discuss the terms of the collaboration for the co-development and the implementation of the Decision support system for water management planned in Assiwat project. Then, another workshop was held at ABHT, as decided during the previous meeting, in order to further discuss and identify the partners challenges, needs and scientific issues relative to water resources management in the Tensift basin and starting the discussions on the models to be developed and gathering all the information and data needed for the implementation.

Date	Objective	Participants	Location
17/02/2022	- Presenting to partners (ORMVAH/ABHT) the project goal and the last research results in the eco-hydrological modeling in the study area, - Discussing the terms of the collaboration for the co-development and the implementation of the Decision support system.	- Researchers from IWRI/CRSA, LMI trema - ABHT, ORMVAH	UM6P
05/03/2022	- Identification of the partners challenges and needs relative to water resources management - Starting the discussion on the model development and the data needed	- Researchers from IWRI/CRSA, LMI trema - ABHT, ORMVAH	ABHT

Table 1: Recent workshops organized with stakeholders

Needs assessment

The consultations allowed the identification of partners needs as follows:

- The irrigation manager (ORMVAH) is more interested in leveraging on satellite remote sensing capabilities for monitoring spatial & temporal crop dynamics, improving methods for accurate estimation of crop water needs and monitoring agricultural water use at farm/perimeter scales to ensure optimal, equitable and sustainable agricultural water management in water scarcity context, and developing irrigation advisory services and tools to provide farmers with climate information and crop water needs as well as customized recommendations for optimal irrigation scheduling at their farms;

- The water agency (ABHT) is more concerned by implementing an information system for real-time monitoring of water resource status and uses at local and regional scales combining in-situ measurements and remote sensing products (climate data, piezometry/hydrometry, crop dynamic and evapotranspiration, …) and developing a decision support system for integrated water management at basin scale which could allow a better planning and allocation of available water resources to different users, particularly agriculture, considering the global changes.



Fig 1. Different stakeholder consultations held at UM6P and at the Tensift basin agency

Site selection and co-design of field experiments

Based on the exchanges with water managers in Tensift basin, taking into consideration their needs and also farmers lack of expertise in term of efficient and optimal irrigation water use, as an adaptation policy for sustainable water management in water scarce conditions, the field experiments described below were identified to assess irrigation efficiency, test and propose tools and guidelines for irrigation monitoring. We will focus on olive tree which have witnessed a great expansion the last decade in the region, thanks to the promotion supported by Moroccan Green Plan, increasing water demand and threatening the sustainability of the irrigated agriculture.

Comparative assessment of drip irrigation efficiency (site 1)

This first experimental site was identified at the Agdal domain (area of 275 ha) in the southeast of the city of Marrakech, Morocco (31°35’45’’N,7°58’37’’W). The site encompasses citrus and pomegranate trees but mainly olive orchards that were initially irrigated by gravity and converted to drip irrigation systems in the last decade. Two drip irrigation technologies are adopted, the surface and the subsurface drip systems. This experiment aims to understand the physical processes that govern energy and water exchanges at the Soil-Plant-Atmosphere interface and to quantify the different water and energy fluxes within the olive orchard in a semi-arid context. In addition, the objective is to evaluate the effectiveness of drip irrigation, both the surface and subsurface systems, in terms of water saving, crop productivity and contribution to groundwater recharge when compared to the flood irrigation system.

The measurements concern parameters necessary to compute the energy and water balance and derive the evapotranspiration (ET) and water flows within soil and plants. It encompasses meteorological data (temperature, wind speed, radiation, relative air humidity, precipitation), energy fluxes (radiative flux, sensible heat flux and latent heat flux and heat flux in the soil) by eddy covariance system, as well as water fluxes in the soil (by soil moisture sensors at different depths) and in the plant (by sapflow sensors). The resulting datasets collected will be used for the model calibration and validation. The experimental design is presented in figure 1.

The equipment necessary for the experiment have been installed in Agdal site as shown in figure 2. It consists in the installation of the two flux stations (eddy covariance EC) acquired within Assiwat project, one over the olive plot irrigated by surface drip system and the other one over the olive plot irrigated by subsurface drip system. The instrumentation is reinforced by a new scientific device (the optical microwave scintillometer), first time installed in Morocco, made of an emitter and a receiver to be installed along a transect of about 2.6 Km across the site which enable a direct characterization and quantification of sensible heat and latent heat fluxes (ET) over large heterogeneous surfaces. At the first stage, the emitter is installed over the surface drip irrigated field for validating the scintillometer signal, and then it will be transferred to the final location to cover the whole orchards after few months.

In addition, to better characterize and understand the signal/measurements made by the scintillometer over the heterogeneous landcover in the site, a third eddy covariance station is installed midway along the transect over a bare field. The scintillometer and the third EC devices are acquired by CRSA/UM6P and made available for the experiment. Furthermore, two lysimeters provided by the Cadi Ayyad University (faculty of Science and technique, Marrakesh) complement the whole instrumentation and were installed near the EC stations over subsurface and surface drip irrigated olive fields to allow measuring the water loss by percolation beneath the root zone.

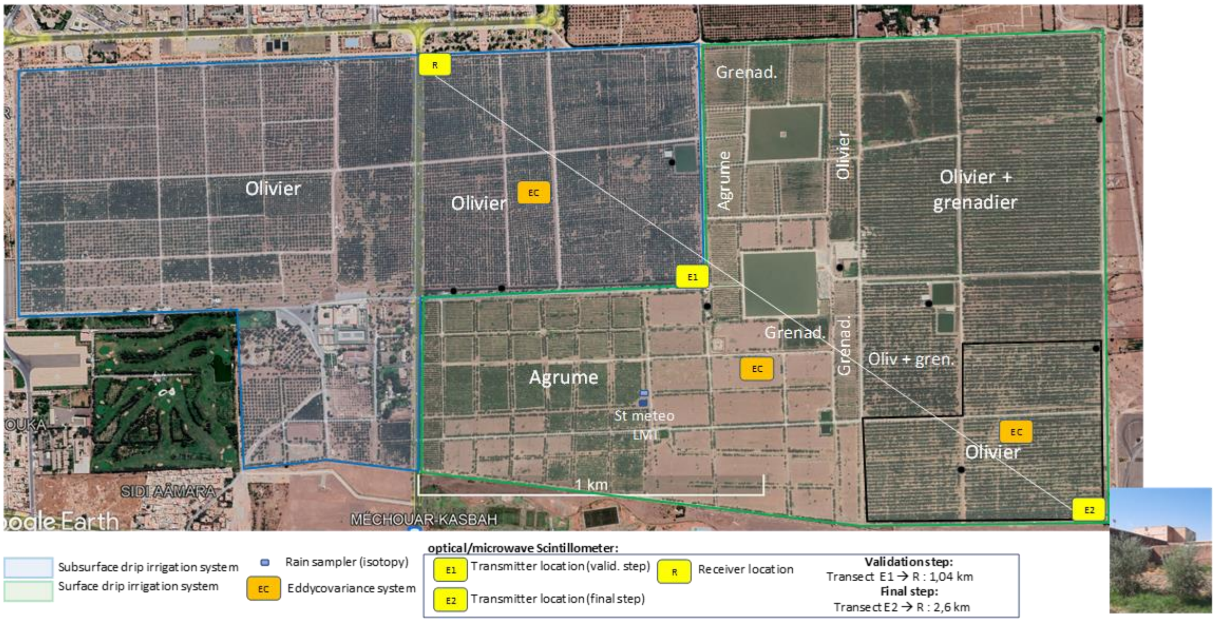

Figure 1: Experimental site 1 of Agdal domain over olive orchard.

a **b** **c** **d**

Figure 2: Equipment installed on the experimental site of Agdal: a) Scintillometer, b) EC stations, c) lysimeter and d) soil moisture &temperature sensors.

Combined effect of deficit irrigation & fertilizer on olive productivity (site 2)

The second experiment which was planned within ClimBeR project is located in center of Haouz plain (area of 13 ha), Morocco (31°39’46’’N,7°40’42’’W). The site encompasses some old trees but mainly young olive trees, concerned by the experiment, that are irrigated by drip irrigation system. This experiment aims to assess the combined effect of irrigation & fertilization on olive productivity, quality & water saving particularly the deficit irrigation practice that could be an effective adaptive response to climate change and water scarcity for olive farming.

The experimental design comprises: i) for irrigation application, a control treatment which is fully irrigated and three other treatments which are irrigated at reduced rates, ii) for the fertilizer application, an optimal rate as control and two other treatments. Two plots are considered to house the twelve treatments resulted from the combination of irrigation & fertilizer applications as shown in figure 3. In the control plot, hosting the combined full irrigation/optimal fertilizer treatment, an eddycovariance system was installed which allow estimating actual evapotranspiration of olive tree, that will serve to calculate the full irrigation needs and the reduced rates used for deficit irrigation treatments.

Figure 4 shows the typical experimental setup for an irrigation/fertilizer treatment. For each treatment, three successive olive trees by row will be monitored and equipped by dendrometers, sapflow devices and soil moisture sensors. Several variables will be measured comprising the water balance parameters (evapotranspiration, soil water content), physiological parameters (stomatal conductance, chlorophyll fluorescence, LAI…) and agronomic parameters (Shoot growth, fruit volume, yield, fruit oil content).

Figure 3: experimental site 2 in central Haouz with reference plot and treatments locations

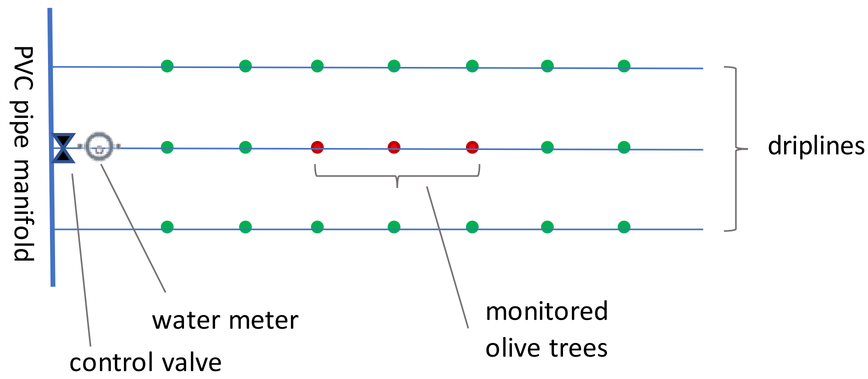

Figure 4: typical experimental setup for one irrigation/fertilizer treatment

This living lab experimental site will play a role of demonstration site for farmers, water/agriculture managers and students, hosting different field visits and training sessions for building capacities in efficient irrigation water management at different scales. The expected outputs include irrigation/nutrient monitoring guidelines for farmers & managers, for improved climate-smart agricultural water management.

Methodology and tools used to co-develop C4S olive system decision tool

The methodology adopted for this study comprises the following tasks:

- Collecting, quality test and pre-processing of raw data from the Eddy Covariance stations installed within the different plots in the experimental sites for calculating the surface energy fluxes (radiation, soil heat, sensible and latent heat fluxes). The evaluation of the energy balance closure using the different fluxes measured should be performed,
- Analysis of the water dynamic in the continuum sol-vegetation-atmosphere and the effects on crop growth and yield parameters, in the different treatments using the calculated evapotranspiration (ET), the measured soil moisture at different depths, the deep percolation, the measures from sapflows and dendrometers,
- Implementing models for ET and water productivity estimation, after calibration and validation using data collected from the experiments. A hybrid modelling framework will be adopted integrating different models or approaches such as TSEB, SimdualKc or developed machine learning models for yield prediction. The TSEB is a surface energy balance (SEB) model [2] forced by remotely sensed land surface temperature (LST) long considered a valuable tool for estimating ET at large scale without needing any information about rainfall, soil hydraulic properties or irrigation inputs compared to Soil Water Balance (SWB) models (e.g. simdualKc). SIMDualKc is a SWB model that uses the FAO56 dual crop coefficient approach for partitioning crop ET [3] and could be combined with a modified version of the water-yield model proposed by Paredes et al. [4] to assess the impacts of water deficits on yields. Also, an attempt to develop machine learning models to predict yields will be carried out, considering different factors (climatic, agronomic, …) influencing olive yield by exploring the

database of farms surveyed by AlMoutmir extension service that could be provided to the project team.

Targeted ClimBeR policy pathways

The research work described above, planned within the C4S innovation package of the ClimBeR initiative, aimed at assessing irrigation efficiency, developing tools for testing irrigation scenarios and providing guidelines for better irrigation scheduling. These products contribute to respond to stakeholders needs regarding water management and could influence their decision as follows:

End-users/stakeholders	Type of decision and/or changes, scale
Water managers: ABHT	- improving water planning & allocation for agriculture sector particularly in drought conditions by adopting irrigation efficiency and/or deficit irrigation scenarios (**basin scale**),
Agricultural managers: ORMVAH	- Enhancing equity/adequacy in water delivery to improve/stabilize productivity (**irrigation schemes level**)
-**Associations/cooperatives of farmers** - **Extension services**: Al moutmir (private), ONCA (public)	- adopting best practices of irrigation management to improve water productivity (**farm scale**)

The work is focusing on Tensift basin region, involving agricultural and water institutions thanks to the 20 year-long partnership.
The ClimBeR policy pathway is to provide guidance for the design and implementation of Green Generation Plan investments at subnational level, here at the catchment-level (Tensift) for both the water productivity and resilience pillars. This case study will be presented during INRA Maroc-led stakeholder consultations in 2023.

Important capacity building activities were also carried out in 2022, to raise awareness of the issue and showcase the importance of cross-scale water efficiency systemic analysis for olive farming systems to guide Morocco climate resilience strategies. The different capacity building events are presented in Annex 1.

Thanks to ClimBeR support, UM6P team was able also to submit a PhD thesis around the theme of irrigation and other farm management (fertilization) change and climate resilience of olive farm. This

PhD will look at semi-arid Haouz plain olive orchard-based farming systems. Description of the PhD thesis is given in Annex 2.

Finally, through the numerous research meetings carried out since 2021 with ICARDA and the BRIDGE consortium, the UM6P team is exploring different new interdisciplinary collaborations to shape more integrated solutions, in different contexts. For instance, how to integrate more socio-economic assessment evidence [link with Hatem Belhouchette / IAMM CIHEAM]; transfer Naila's orchard biodiversification pathway work to Tensift basin region and olive orchard system.

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