GUIDELINES ON DEVELOPMENT AND MANAGEMENT OF PRECISION IRRIGATION/FERTILISATION SYSTEMS

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GUIDELINES ON PRECISION IRRIGATION / FERTIGATION SYSTEMS

Noureddine Mokhtari, ENAM

nmokhtari@enameknes.ac.ma

Food Hub: Ait Ouallal Bittit / Ait Yazem (MA)

1. Introduction

1.1 Precision irrigation/fertilisation systems

The precision agriculture appears as a technology tool that promote the optimization of agriculture inputs aiming at reducing adverse impacts on the environmental, ensuring the increase of the productivity, and protecting the environmental.

Precision farming (PF) simply means the information technology applied to agriculture. It aims to optimize yields and investments by automating and real-time monitoring of site specific environmental conditions such as moisture and soil conditions (e.g. soil type, fertility levels, etc.) using four technologies: remote sensing (RS), geographical information systems (GIS), positioning systems (GPS) and process control (sensors). Precision farming technique is sufficient for small-scale farms; it deals with dataset coming from sensors, GPS, GIS limited to a few hundred meters for a specific crop land area. This type of network is composed of a large number of spatially distributed sensor nodes, able to cooperate with each other using wireless or GPRS communication. Regarding sensing, computing, processing and communication capabilities, it's possible to continuously sense and transmit agricultural data to a base station where data can be stored, analysed and observed in real time.

Smart farming through the application of information and communication technologies including IoT (Internet of Things) is expected to revolutionize the global agricultural landscape, making it more resource-efficient and productive.

Smart farming solutions would enable users to monitor and control their irrigation equipment, manage farms more efficiently in terms of usage of resources like fertilizers, seeds, pests, and water, and monitor farm conditions in real time. This will help the small farmers to detect inconsistencies, reduce operational challenges and to be more cost effective. Precision agriculture employs technologies like sensors, GPS, GIS, and drones to measure spatial variability, communicate farm conditions, plan irrigation and harvesting, and thus eliminate human intervention to a large extent.

The collected data from the sensors can be shared with the stakeholders either through local server or the cloud, depending on the reliability of the communication network and internet availability. This data is accessed via smart phones, and user-friendly apps can be used to represent it in a simple and clear format. However, to encourage adoption suppliers we may have to work on the high initial purchase cost in order to encourage small farmers to access to those news technologies.

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According to the World Bank, about 80 percent of the agriculture produce consumed by developing regions comes from smallholder farmers, and most of these farmers base their decisions on experience and guesswork rather than on any scientific guidance. This approach is not reliable in monitoring and predicting critical variables like the water quality, soil condition, ambient temperature and moisture, irrigation and so forth, which impacts the crop quality, yield, and thus the returns.

Food Hub: Ait Ouallal Bittit (MA) | Food Product: Fresh vegetables

National context:

In Morocco, more than 70% of farmers work fewer than five hectares, but this accounts for only a quarter of the total land under cultivation: the large farms dominate the arable areas. Inevitably, the large farms have a more substantial income, earning than the average family farm. Many small farms face problems that make it difficult to increase their earnings, including ambiguous land ownership, a lack of infrastructure or access to credit, and poor technical and marketing support. Without registered land, small farmers cannot benefit from government programs, and even with registered land, many programs favour larger farms.

In the arid regions of Morocco, the use of precision irrigation (PI) is the forthcoming for the development of sustainable agriculture, in a future scenario of water scarcity due to a growing population and industry that compete for hydric resources. The benefits of PI can be optimized by incorporating efficient technologies into agriculture

To modernize irrigated agriculture in Morocco, the country has implemented the Green Morocco Plan (PMV), which aims to modernize agriculture and improve farmers' incomes. A main component of the PMV is the National Irrigation Water Saving Program (PNEEI), which consists of the conversion of 550.000 ha by 2022 of gravity and spraying irrigation systems to drip irrigation (DIAEA, 2015). Also, subsidies of up to 100% have been provided to encourage farmers to adopt drip irrigation. The PNEEI provides for two types of conversion. On the one hand, individual conversion, over an area of 330.000 ha, through the granting of individual subsidies to farmers and individual management of their drip irrigation projects and, on the other hand, by collective conversion for an area of 220.000 ha (on irrigated areas under community management).

In recent years, and especially since the entry into force of the Green Morocco Plan (PMV), many investments have been made to modernize irrigation systems. Many perimeters have been equipped with drip irrigation to save water. Now the areas equipped with localized irrigation have more than tripled, from 160.000 ha to nearly 520.000 ha in 2018.

Experiments on water saving carried out through the drip irrigation system show a decrease in water supply to the field from 14% to 50% (depending on the crops practiced). But more detailed studies in several areas of Morocco and especially in the Saïs plain have revealed that the dominance of over-irrigation, with parcel-based irrigation efficiencies between 15% and 90%. Indeed, in the absence of constraints on the resource and because of its relative low cost, farmers prefer to bring excess water in order to avoid any stress and potential yield losses. Thus, used to gravity irrigation, they irrigate by drip until water visibly accumulates in the basins. This results in significant losses of resources and implies a low level of technical knowledge in drip irrigation.

1.2 Objectives and description of the innovation

Objectives: The aim of this subtask is to find the best technological solutions by using precision technology in order to save water consumption of vegetables crops without reducing production quantity and quality.

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The purpose of our work is to relate the use of the precision irrigation management tools in order to help local and small farmers to be more proactive in the field by not only reducing water consumption but also by improving crop health and production.

In parallel, field trial was conduct in order to validate the scientific algorithm incorporated within the app. These trials have the objectives also to determine the scheduling irrigation parameters for some specific crops that are dominated in the region.

A crop coefficient “Kc” model is assigned using data from FAO 66 or adjusted crop coefficient based on experimentation result from the second activity. The third component of the continuum consists on the soil role as a water reservoir for the plant. The fourth component defining the irrigation duration is the system characteristics in order to determine the flow rate.

The second activity is to conduct agronomic experimentation on deficit irrigation and on the development of irrigation scheduling parameters (verification of crop coefficient, irrigation frequency, irrigation rate…) for specific crops dominated in the area (potatoes, onion, carrots).

Two trail were installed during the first year of the project, on an area of 0.5 ha each one respecting a DBAC experimentation design with four repetitions.

Innovation: To set up a digital solution allowing small farmers to schedule irrigation based on the monitoring of the continuous Soil, Plant climate using sensors and a smartphone app. All the information will be gathered through data collected by sensors installed in the field, processed and distributed by a Big Data service.

The digital platform (monitoring centre & mobile apps) will allow the small farmers to directly and efficiently monitor drip irrigation according to vegetation development stages based on the information provided by their smart phones through data collected by sensors installed in the field, processed and distributed by a Big Data service.

With agricultural IoT sensors installed at field monitoring stations, small farmers can have a powerful dashboard with analytical capabilities and integrated drip irrigation monitoring functions. This tool can be used both for agricultural advice in general and for specific crop monitoring and inputs reasoning. It is an open and scalable solution that can be extended to the entire agricultural production system in relation to farmers' needs and resource saving opportunities.

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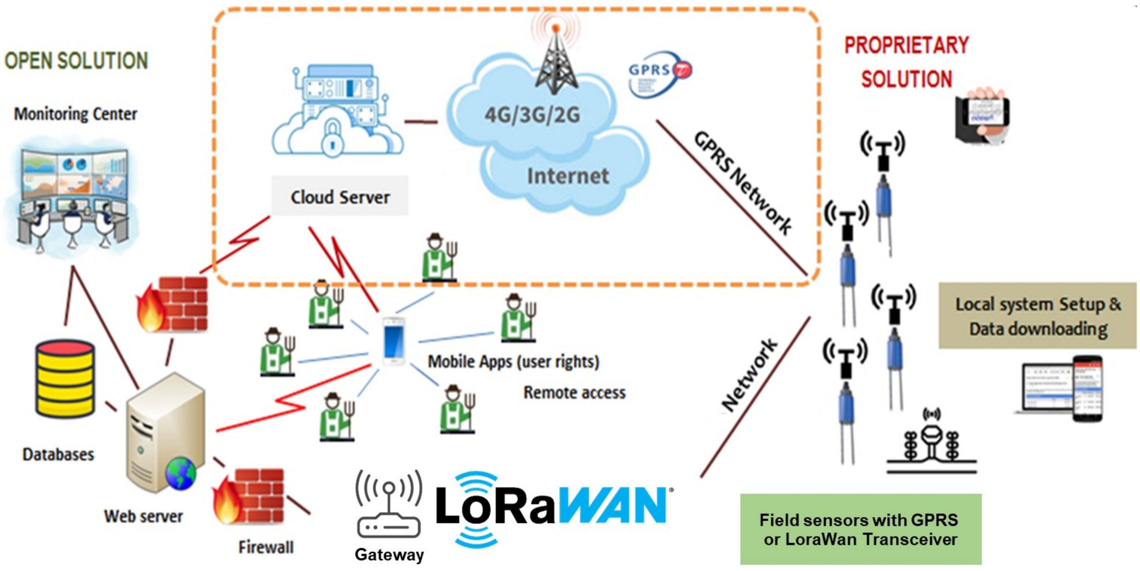

Figure 1: Global management system architecture of community precision irrigation.

2. Description of trials, prototype and results

2.1 Operative procedure

2.1.1 General indications to be considered for vegetables crops water requirements

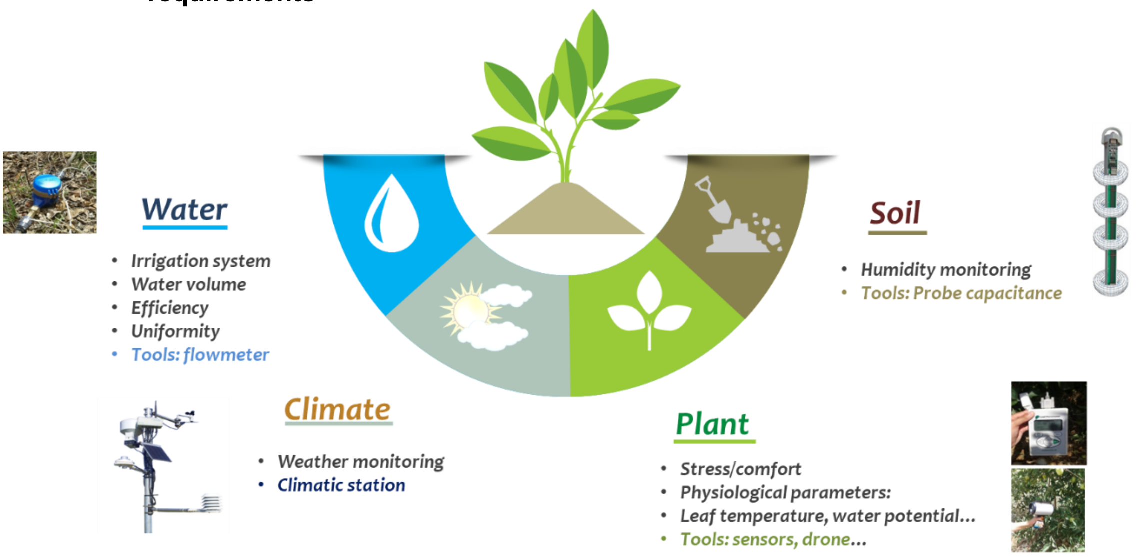

Figure 2: Global crops irrigation system measurements

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2.1.2 Specific prototype and procedure for data collecting by IoT

The entire system will integrate data from weather stations, field sensors and historical data on crop needs and yields to produce highly accurate forecasts of irrigation rates and frequencies. Models adapted to the different types of soils will make it possible to adapt the recommended water supplies to obtain interactive results for large areas, thus improving the predictive accuracy of the system.

The communes of Ait Ouallal Bittit and Ait Yazem represent the two agricultural production systems, namely the community system composed of farmers who manage a small hydraulic perimeter based on an irrigation network and the system of small private farms that are often based on irrigation based on wells and boreholes.

The two management methods will make possible to accurately monitor crop irrigation strategies and propose appropriate water saving solutions. Farmers who benefit from almost free irrigation water in the community system where most of the investment is supported by the State (irrigation network) will not have the same strategic visions for water saving as small private farms where water pumping charges are very high.

Stakeholders and regional partners:

- National School of Agriculture of Meknes (ENAM);
- Provincial Directorate of Agriculture (DPA El Hajeb);
- Association of irrigation water users Ait Ouallal Bittit (AUEI);
- National Office of the Agricultural Council (ONCA).

The tasks focus on four main pillars namely:

1. Conduct agronomic experimentation on deficit irrigation and on the development of irrigation scheduling parameters for specific crops
2. Development and implementation of a solution for parcel-based irrigation consulting using precision farming tools, a web service and a mobile application on smart phones,
3. Support and training of farmers on the installation, maintenance of sensors and use of the mobile application designed for irrigation reasoning at the field level;
4. Setting up a demonstration essays in best precision irrigations practices for fresh vegetables.

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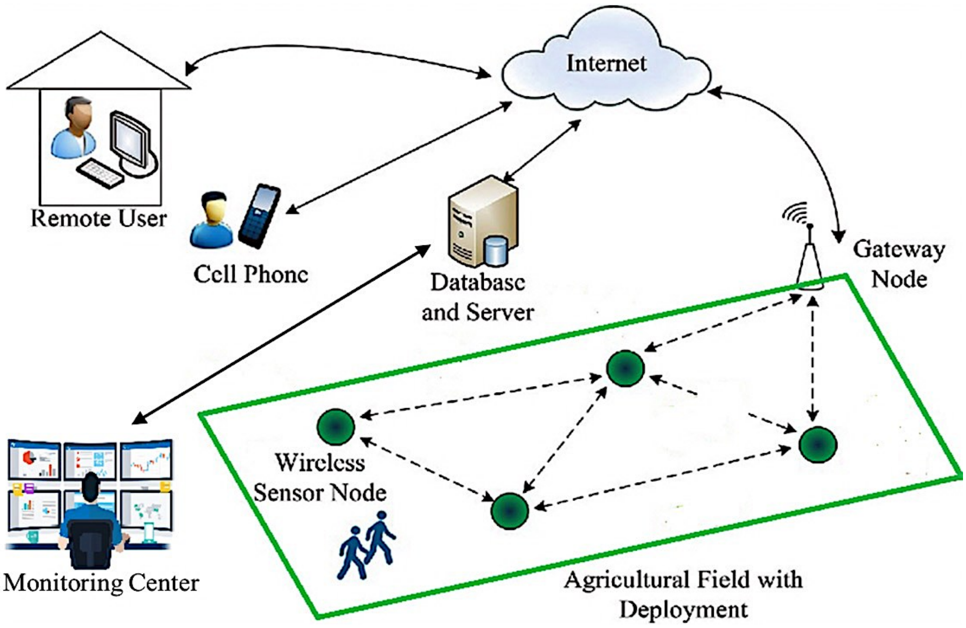

Figure 3: Conceptual design of the proposed precision agriculture connectivity model

In order to disseminate the technological innovation to small farmers who do not have the means to purchase capacitive probes connected to the local LoraWan network, it is planned to provide 4 farmers, well distributed in the area, with connected probes for the entire duration of the project to be able to disseminate useful and precise information on the irrigation doses to be recommended for each crop according to the stages of development throughout the community of farmers.

In addition, a connected weather station and the necessary equipment for data transmission over the Internet will be installed in the area (Gateway). This will allow data to be collected directly from the control plots and on the atmospheric conditions of the studied area.

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2.2 Results

2.2.1 Trials on potatoes

The plant material used for this study is potato (Solanum tuberosum) of the 'desirée' variety imported from the Netherlands. Seeding was carried out in the field at a depth of 10 cm, on rows spaced at 80 cm apart and 30 cm tuber spacing.

The experimental design adopted is a complete randomized block design (DBAC), with a single source of heterogeneity with four repetitions and three water regimes. The three water regimes are as follows:

Figure 4: Potatoes trail field at 8 weeks.

- Control T1: is a comfort irrigation with 100% crop evapotranspiration ETc throughout the whole cycle;
- Treatment T2: corresponds to sustainable deficit irrigation with an application of 75% ETc during the whole cycle; (i.e., a 25% of water restriction).
- Treatment T3: sustainable deficit irrigation with 50% ETc applied throughout the cycle; (i.e.,50% of water restriction).

A localized irrigation was provided by a drip system, including drippers each supplying 1.6 l/h, spaced at a distance of 0.4 m from each other.

As this study focused on water supply, the crop was conducted in a non-limiting manner concerning the other factors (tillage, density, fertilization, weeding, etc.)

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Results:

The highest marketable tuber yield was recorded by the T1 treatment (dose =100% ETc) which is 42.51 Tones/ha, and the lowest yield was that recorded by the T3 treatment (dose =50%) which is 20.96 Tones/ha. Analysis of variance showed a highly significant effect of irrigation rate on final potato yield. Treatment T2 (dose=75%) gave almost equal yield (41.17 T/ha) to control T1 (dose=100%), but a 50% restriction of ETc resulted in a 49% yield loss. The effect of applying a water restriction of about 25% compared to comfort irrigation (100% ETc) resulted in water savings of about 77mm while maintaining a high yield.

In fact, the good water use efficiency was recorded in the plants irrigated at 75% of the crop water requirements.

Figure 5: Harvesting potatoes on the trial field

It is therefore possible to strongly recommend the 75% water deficit and therefore apply 75% of the initial Kc as shown in the table below:

Table 1: Potato irrigation recommendations (Kc) for different development stages

Stages	Kc (FAO)	Recommended Kc
Initial	0.45	0.34
Development	0.75	0.56
Mid-season	1.15	0.86
Maturity	0.45	0.56

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2.2.2 Trials on onion

This trail addressed onion crop responses to continuous deficit irrigation with trigging thresholds of readily available water content. The experiment was conducted on an experimental plot in open field. Three water regimes were applied T1 control (100%), T2 (75%) and T3 (50%) of crop evapotranspiration ETc combined with two trigging thresholds (10% and 5%). This is a complete random block device with four repetitions.

The measurements concerned the monitoring of vegetative, eco-physiological and yield parameters

Figure 6: Global parameters measurement in trial onion field

Results

The results obtained show that: (i) 100% ETc irrigation at a threshold of 5% of RAW recorded the maximum bulb diameter and weight, thus achieving the best marketable bulb yields. However, in terms of yields, this treatment is not significantly different from the other irrigation regimes with the exception of the irrigated treatment at 50% daily ETc and at a threshold of 10% RAW. The latter recorded the lowest values in terms of production parameters.

(ii) For the eco-physiological parameters, significant effects of irrigation dose were observed for proline content, stomatal conductance and leaf temperature, and the effect of the trigging threshold was clearly observed for the moisture content of the leaves. (iii) Water restrictions have minimized the rate of premature run and population density of Thrips tabaci in the onion. (iv) Finally, the best agronomic efficiencies in the use of irrigation water were recorded in treatments with a water restriction of 50%.

According to this trial, it is advisable to apply 100 % of water requirements with a trigging threshold of the readily available water content of 5%, if water is not a limiting factor. But, if water is rare, it could be better to apply 75 % of water requirements, saving 25% of irrigation water without having a significant effect on production and quality. Reducing the FAO Kc with 25% is recommended with the condition of a well irrigation scheduling base on the monitoring of soil humidity.

2.2.3 Trials on carrots

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In the present study, five treatments were implemented with only one factor considered (crop evapotranspiration "ETc") and an additional 6th treatment to model Kc. It should be mentioned that all treatments received 100% irrigation from transplanting to the one leaf stage. The treatments are as follows:

- Treatment T1: Luxury irrigation with a dose of 125% ETc from the one-leaf stage;

- Treatment T2: Comfort irrigation with 100% ETc throughout the cycle;

- Treatment T3: Continuous deficit irrigation with an application of 85% ETc from the one-leaf stage;

- Treatment T4: Continuous deficit irrigation with an application of 75% ETc from the one leaf stage;

- Treatment T5: Continuous deficit irrigation with an application of 66% ETc from the one-leaf stage;

- The 6th treatment concerns the monitoring of the Kc with water probes in order to adjust the Kc of the FAO to accommodate the Saïs area.

Figure 7: Carrots trail field at 8 weeks (drip irrigation system between the twin seed rows)

The study was conducted using a randomized complete block design (RCBD), with one source of heterogeneity being the gradient and 4 repetitions.

Results:

The results obtained concerning the total yield show that this parameter is also strongly dependent on the applied water regime. The highest total yield per hectare was recorded in treatment T1 (125%) which was 59.595 T/ha, while the lowest was in treatment T5 (66%) which was 32.417 T/ha.

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However, by reducing the water rate by 25%, we still obtained a good yield of 48.7 T/ha, which was not significantly different from the yield of treatment T1. This leads us to say that by saving 25% of the water, we did not affect the yield.

2.3 Solution implementation tests

The installation and testing of the connected sensors in the field was carried out on the experimental trials conducted in spring and summer 2022. (probes, water counter, weather stations, etc.)

The data transmission, through a Gateway installed nearby, was made to the Cloud server of the equipment provider and the information is available on a dedicated proprietary app.

All the data collected in the field can be retrieved and loaded on our local server on the basis of an API (Application Programming Interface).

The next objective is to develop an own interface to receive data from the connected sensors without going through the service of the equipment provider in order to appropriate the data and to manage the raw data collected (raw data from the sensors) in a free and more flexible way. This will allow as to develop own applications and processing algorithms more adapted to the local agricultural context.

The main objective is to develop specific decision making management platform that offer to the local famers proof solutions for sustainable irrigation management, based on standard wireless IoT technology under LoraWan. By using the soil moisture probes and weather station in the specific area, the daily irrigation can be adapted to current weather and evapotranspiration (ET) data and localized soil moisture data, to fine-tune and optimize the water use to exactly what crops needs during all the development season.

2.4 Expected results

a. Reduction of crop irrigation water consumption in the area by less than 30% in relation to the results obtained from the deficit irrigation trials and considering the possibilities of reducing the doses based on the real needs of the crops (farmers tend to bring much higher irrigation doses than the real needs of crops).
.
b. Cost reduction of the production and more sustainability of regional agriculture considering water scarcity and climate changes effects. Increase of farmer’s income.

3. Guidelines for the Development and Management

3.1 System Development

3.1.1 Assessing Water Needs and Crop Requirements

- Identify crop-specific water requirements using evapotranspiration (ETc) rates and soil characteristics.
- Utilize FAO Kc values or locally calibrated crop coefficients for accurate irrigation planning.

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- Validate irrigation strategies through agronomic trials.

3.1.2 Selecting Suitable Irrigation Technologies

- Implement IoT-based precision irrigation using soil moisture sensors, weather stations, and remote monitoring.
- Utilize LoRaWAN networks for efficient data transmission.
- Opt for appropriate irrigation methods like drip irrigation based on soil and crop conditions.

3.1.3 Integrating Digital Platforms

- Develop a user-friendly mobile application providing real-time irrigation recommendations.
- Ensure data integration through cloud-based platforms or local servers via API connections.
- Offer free irrigation advice to farmers without sensors using regional sensor data.

3.2. System Management

3.2.1 Data Collection and Analysis

- Deploy soil moisture sensors and weather stations to monitor field conditions.
- Use predictive models to optimize irrigation schedules based on historical and real-time data.
- Provide farmers with actionable insights through mobile alerts and dashboards.

3.2.2 Irrigation Scheduling and Decision-Making

- Implement deficit irrigation (e.g., 75% ETc) to balance water savings and yield.
- Schedule irrigation based on soil moisture thresholds and crop development stages.
- Focus on participatory solutions by sharing irrigation recommendations with smallholder farmers.

3.2.3 Training and Farmer Engagement

- Conduct practical training on sensor installation, maintenance, and data interpretation.
- Develop participatory approaches involving farmers in decision-making.
- Provide continuous technical support and educational resources.

3.2.4 Risk Management and Sustainability

- Address digital literacy challenges by developing intuitive and local language user interfaces.
- Ensure equitable access to shared irrigation resources for all farmers.
- Promote low-cost sensor solutions for smallholder farmers.
- Foster collaborations with agricultural institutions and policymakers for long-term impact.

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4. Technology and production key performance indicators

The guidelines presented here and the work carried out so far contribute to the achievement of the following key performance indicators, foreseen in the project grant agreement:

- Reduction in the range of 10% to 30% of irrigation water consumption by crops and reduction of irrigation costs for farmers: with regard to the applied technology, it is expected that there will be an improvement in the knowledge and capacity of farmers to assess the real needs of crops in relation to the use of the mobile application. Improvement of farmers' profits (while contributing to the conservation of the water resource).

On a global scale in the region, it is expected that the sustainability of agriculture will be improved given the water scarcity and the effects of climate change. In addition, with regard to the availability of products for final consumers, a slight increase in yields and therefore production is expected, which should translate into better availability of final products on the market.

- IPT-ST: 10% reduction in crop water consumption and 5% reduction in production costs (pumping, labor) through efficient reasoning of crop irrigation (better valorisation): in relation with the use of useful information from the mobile application by farmers and the improvement of their know-how.

- PPI-LT: 10% increase of small farmers and SMEs' income through reduced production costs and improved product quality (average).

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EMPOWERING SMALLHOLDERS: A STEP-BY-STEP GUIDE FOR THE INSTALLATION OF THE OPEN SMART IRRIGATION PLATFORM

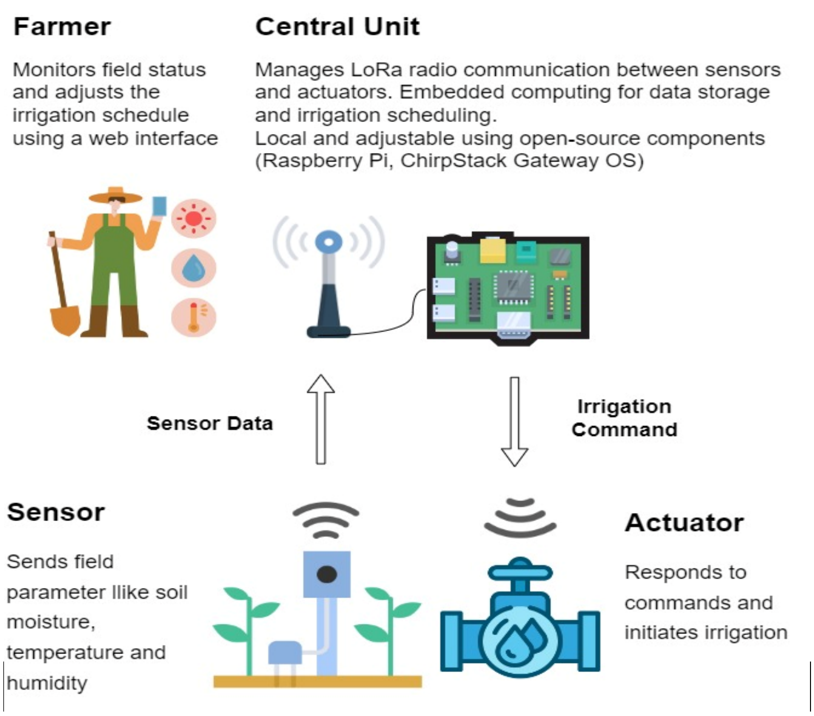
Thomas Anken, Andreas Bühlmann, Philippe Hess, Agroscope,

philippe.hess@opensmartirrigation.org

Food Hub: Nakaseke (UG)

1. Introduction

With agriculture accounting for 70% of global freshwater withdrawal(World Bank, 2021), improving water use efficiency is essential for sustainable food production, especially in regions vulnerable to climate change. Smart irrigation systems offer a promising solution by integrating modern technology to optimize water use while boosting crop productivity. Agroscope conducted field trials in Uganda using smart irrigation components, combined with nationwide farm surveys. The trials demonstrated a potential 30% productivity increase compared to conventional methods but also highlighted key challenges to adopting complex technologies in resource-constrained farming contexts. These insights led to the development of a requirement catalogue tailored to smallholders' needs, emphasizing accessibility and robustness. Building on this foundation, Agroscope introduced the “Open Smart Irrigation” platform to provide affordable, practical solutions for farmers in emerging economies. The platform includes both software and educational resources, supporting the setup of smart irrigation systems adaptable to diverse environments. The system architecture (Figure 1) uses LoRa radio technology to establish a low-power wide-area network (LPWAN) that connects sensors and actuators. At its core is a “Raspberry Pi” central unit running open-source software (Customized Chirpstack Gateway OS), which handles local data storage, LoRa communication, and irrigation scheduling. Designed to operate offline and with minimal power consumption, it addresses rural challenges like unreliable



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electricity and internet access.

The present manual provides step-by-step instructions for installing the central unit and setting up a sample smart irrigation system using a tested smart valve and soil moisture sensor. For guidance on additional components, updated training materials, and the required software, please visit the project website.

2. Installation manual

2.1. Required Hardware Components

Component	Description	Purpose	Advice & Tested Example
Raspberry Pi	A small computer serving as the system's central unit.	Runs the irrigation software, stores data, and manages LoRa communication.	**Tested Example:** Raspberry Pi 4 Model B (2GB RAM) **Advice:** Supported models include Raspberry Pi 3, 4, and Compute Module versions. More RAM improves performance for larger systems.
MicroSD Card	Memory card for the Raspberry Pi.	Stores the operating system, software, and data.	**Tested Example:** Samsung Pro Endurance 16GB **Advice:** Use “Endurance” cards for reliability, e.g., Samsung Pro Endurance, SanDisk Max Endurance, Transcend High Endurance. Larger sizes offer greater durability.
LoRa Gateway Module	Device enabling long-range wireless communication between sensors and the central unit.	Facilitates long-range communication (LPWAN).	**Tested Example:** Seeed WM1302 LoRaWAN Gateway Module + WM1301 Raspberry Pi LoRa HAT **Advice:** Supported gateways include models like WM1302. Ensure compatibility with Raspberry Pi and ChirpStack.
Power Supply for Raspberry Pi	Power adapter for the Raspberry Pi.	Ensures continuous power to the central unit.	**Tested Example:** Official Raspberry Pi Power Supply (5V/3A) **Advice:** For added reliability, use an optional UPS HAT (Uninterruptible Power Supply) with 2x 18650 batteries to protect against power outages. A PV module can be integrated for solar, off-grid power supply

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Component	Description	Purpose	Advice & Tested Example
LoRa Antenna	Antenna for long-range wireless communication.	Improves LoRa communication range and signal strength.	**Tested Example:** 3 dBi antenna for testing **Advice:** For longer ranges, use antennas with 5 dBi or higher. Ensure the LoRa module and antenna match the frequency (e.g., 868 MHz). A U.FL to SMA connector is required.
Soil Moisture and Environmental Sensor	Monitors soil moisture, temperature, humidity, and light conditions.	Provides environmental data to optimize irrigation decisions.	**Tested Example:** TEKTELIC KIWI Agriculture Sensor (868 MHz) **Advice:** Connect up to 2 external Watermark sensors and thermistors. The KIWI sensor integrates seamlessly into LoRaWAN networks and provides robust field performance.
Smart Valve	Valve that automatically opens or closes based on irrigation needs.	Controls the flow of water to the field.	**Tested Example:** STREGA Smart Valve (Solenoid Version, 868 MHz) **Advice:** Select a valve that matches the system's frequency and supports low-power operation. STREGA valves are ideal for long-range control via LoRa.
Tools for Setup	Basic tools required to install and secure components.	Helps connect, mount, and prepare the system for operation.	**Required:** Philips T10 screwdriver and, if needed, a wire cutter for cable preparation and sensor installation.
Protective Casing	Enclosure for protecting sensitive hardware.	Protects the Raspberry Pi, LoRa HAT, and other components from dust and unintended user interference.	**Tested Example:** HighPi Pro Case **Advice:** Choose a case with enough clearance for the LoRa HAT and good ventilation. The **HighPi Pro Case** fits the Raspberry Pi 4 with HAT attachments while ensuring proper airflow.

3. Software Requirements

1. **ChirpStack Gateway OS:** Full installation required. Select the version corresponding to your Raspberry Pi model.
    - **Resource:** ChirpStack Gateway OS Install Guide
2. **SD Card Flashing Utility:** For flashing the ChirpStack Gateway OS.

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- **Recommended for Windows:** Win32 Disk Imager

3. **Open Smart Irrigation Software:**
   - **Resource:** Open Smart Irrigation
4. **STREGA Smart Valve SV_SE Reader:** For configuring the valve.
   - **Resource:** STREGA Utilities
5. **Video Tutorials:** Recommended for new users and updated regularly to new versions of the system.
   - **Resource:** Video Series

4. Step-by-Step Installation Guide

Step 1: Central Unit Setup

1. **Connect the Hardware:**
   - Attach the LoRa Gateway Module to the HAT and to the Raspberry Pi using the 40-pin connector.
   - Connect the LoRa antenna to the HAT.
2. **Flash the Gateway OS:**
   - Use Win32 Disk Imager (or your preferred utility) to flash the ChirpStack Gateway OS onto the SD card.
3. **Power Up the Central Unit:**
   - Insert the SD card into the Raspberry Pi and connect the power supply.
   - Refer to the ChirpStack Getting Started Guide for first-time setup.
4. **Initial Wi-Fi Setup:**
   - Connect your computer to the Wi-Fi network **ChirpStackAP-XXXXXX** (default password: ChirpStackAP).
   - Open a web browser and enter the IP address (e.g., http://192.168.0.1).
   - **Default Login:**
     - Username: root
     - Password: (leave blank)
5. **Configure the LoRaWAN Concentrator:**
   - Navigate to **ChirpStack > Concentratord**.
   - Set the chipset (e.g., **SX1302**), antenna gain (e.g., 3 dBi), and channel plan (e.g., **EU868**).
   - Save and apply settings.
6. **Configure the LoRaWAN Network Server:**
   - Open the ChirpStack web interface.

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- Navigate to **Gateways > Add Gateway**, provide a name, and enter the Gateway ID.

Step 2: Smart Valve Configuration

1. **Install the Valve:**
   - Follow the STREGA manual (STREGA Smart Valve Manual) and installation video.
2. **Connect the Valve to the computer (Video)**
   - Use a USB cable to connect the valve.
   - Open the STREGA SV SE Reader and read the **Device EUI**, **APPEUI**, and **APPKEY**.
   - Save these values for later use.

Step 3: Sensor Configuration

1. **Connect Watermark and Thermistor Sensors:**
   - Refer to the TEKTELIC KIWI Manual (pages 17-20).
   - Open the case and pass the sensor wires through the cable gland.
   - Connect the wires as follows (for one watermark):
     - **Thermistor:** White wire (3A), Black wire (4A)
     - **Watermark:** Green wire (3B), Green-white wire (4B)
   - Close the case securely.
2. **Record Sensor Identifiers:**
   - Locate the **Device EUI**, **APPEUI**, and **APPKEY** on the device.

Step 4: Adding Devices to ChirpStack

1. **Create Device Profiles:**
   - Go to **Device Profiles** and add profiles for both the sensor (TEKTELIC) and valve (STREGA).
   - Set the region to **EU868** and adjust for the KIWI sensor the MAC versions to LoRaWAN 1.02.
2. **Register Devices:**
   - Add a new application with a suitable name, e.g. open smart irrigation
   - Add the devices under the application in ChirpStack.
   - Enter the **Device EUI**, **APPEUI**, and **APPKEY**.
3. **Wait for Activation:**

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o It may take time for devices to be recognized. Monitor uplink events under **LoRaWAN Frames**.

Step 5: Configure Open Smart Irrigation Software

1. **Open Node-RED:**
    - Access Node-RED from the ChirpStack Gateway OS interface.
    - Import the Open Smart Irrigation software by clicking on "Import Code" and selecting the downloaded JSON file.
2. **Install Additional Packages:**
    - Go to the **Manage Palette** section within Node-RED.
    - Search for **node-red-dashboard** and install it.
    - Repeat the process for other required packages, such as **node-red-contrib-cron-plus**.
3. **Configure the Node-RED Flow:**
    - Link the nodes within the imported irrigation flow to match your devices.
    - Set the input nodes to connect to the MQTT broker using the device IDs from the LoRaWAN frames.
4. **Adjust MQTT Settings:**
    - Ensure that the application and device IDs are correctly configured in the Node-RED flow, a green "Online" label must show.
    - Double-check that the uplink and downlink messages are properly routed in the Debug monitor.
5. **Training Material and Troubleshooting:**
    - Consult the comprehensive Open Smart Irrigation Training for additional instructions.
    - For new users, refer to Node-RED Beginner Guides to familiarize yourself with adjusting the system.

References

World Bank, 2021. World Development Report 2021: Data for Better Lives [WWW Document]. URL https://wdr2021.worldbank.org (accessed 6.22.24).

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