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Solar-based irrigation business model 'pay as you irrigate' for women empowerment, water management and food security in Mozambique

Report with the revised architecture of the solar-powered irrigation system for Pangalata association in Mozambique, including the Internet of Things.

PRACTICA HUB

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Disclaimer:
This document is an output of the Technical Assistance Response in Mozambique. The present report is the output of the project 'Solar based irrigation business model 'pay as you irrigate' for women empowerment, water management and food security in Mozambique. The views and information contained herein are a product of the international TA implementation team led by PRACTICA & HUB.

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1. Introduction

This report is part of the deliverables for the project *Solar-based irrigation business model' pay as you irrigate' for women empowerment, water management and food security in Mozambique* implemented by the consortium PRACTICA and HUB. The project's overall objective is to identify the best Solar Powered Irrigation System (SPIS) for the Pangalata association in Moamba that could be deployed using groundwater. The system's design will be reinforced by the definition of a clear *pay-as-you-irrigate* business model that will be customized for the lowest-income farmers.

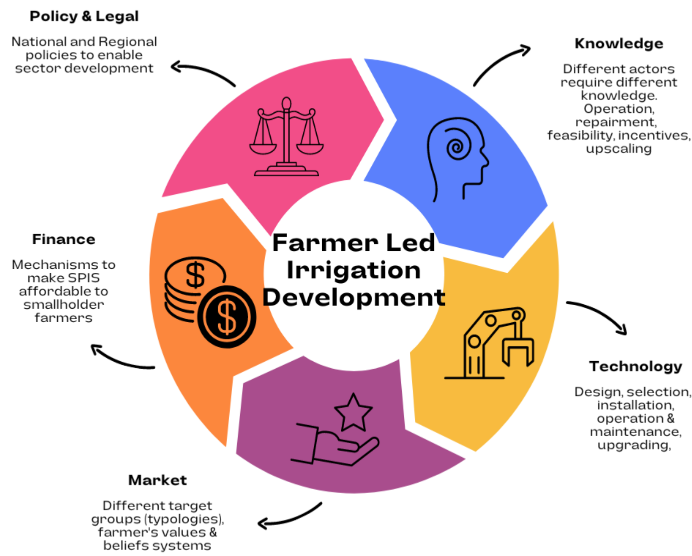

Figure 1. Five enabling factors to catalyse Farmer Led Irrigation Development (Practica, 2023).

This deliverable aims to use the inputs received from future users and stakeholders towards improving the draft architecture of the solar-powered irrigation system, including any Internet of Things components that are relevant to be used to ensure effective and easy use of the system by the targeted smallholder farmers in the Pangalata association.

2. Methodology

The first stakeholder consultation took place during the 20th of February of 2024 at the SDAE offices in Moamba with the presence of 23 participants representing different stakeholders such as Pangalata association smallholder farmers, Directorate district of agriculture (SDAE), District Service for Education, Youth and Technology (SDEJT), District Service for Health, Women and Social Action (SDSMAS), District Service for Planning and Infrastructure (SDPI), Head of Chanculo Locality; see deliverable 3.1 for the workshop minute. During this workshop, the draft architecture of the solar-powered irrigation system was presented by the solar irrigation expert of the consortium, and a round of discussion was held to receive feedback from future users and assess their readiness to test the technologies. Special attention was given to understanding the barriers (technical and social) that can impact the deployment of the technology.

This technical assistance follows a Human-Centered Design[1] process in line with the Farmer-Led Irrigation Development (FLID) framework introduced by the World Bank in 2021. FLID emerges as a transformative force for improving the production system for smallholder farmers by

[1] Human-Centered Design is a methodology that puts people at the center of the design process to solve complex problems.

empowering their local knowledge and ownership. Enabling them to plan and manage irrigation systems tailored to their unique needs, see figure 1 (Izzi et al., 2021). In this sense, the feedback collected in the workshop has been used by the consortium to improve the design presented in this report.

3. Improved design of the solar powered irrigation system

3.1 Basic information

Table 1 presents the summary of initial setting data required for the design of the solar-powered irrigation system for Pangalata association fields; this includes the assumptions on the water flow rate and dynamic level expected in the wells that should be constructed in the field as part of the system.

Table 1. Summary of initial setting data for the SPIS design.

Project data[2]	Plot 1	Plot 2
Country	Mozambique	Mozambique
Location climate data	Maputo	Maputo
Type of crops	Vegetable	Vegetable
Depth borehole (m)	35	35
Water flow rate (m^3/h)	22.0	22.0
Dynamic level	25.0	25.0
Irrigation method	Drip	Drip
Pumping method	Solar submersible pump	Solar submersible pump

3.2 Revised geometry of the irrigation system

The proposed geometry of the solar-powered irrigation system has been detailed. As shown in table 2, each subplot of 2.5 ha will be irrigated by a separate pump and different pipe system.

Table 2. Projected irrigated area.

Projected irrigated area	Plot 1	Plot 2
Gross water requirements (m^3/ha)	44	44
Maxi irrigable surface (ha/day)	3	3
Projected surface (ha)	2.5	2.5
Projected flow (m^3/h)	22	22

[2] The design is valid with the assumption of 22m^3/h and 25 m dynamic head from what can be expected from the boreholes that will be constructed. Once boreholes are built and flow test needs to be conducted to double check the design before the irrigation system is tendered and procured.

The location of the pump(s), the solar panel(s), the main pipe and the subplots to be irrigated are shown below in figure 2[3].

Figure 2. Geometry of the revised irrigation system in the Pangalata association.

The specifications of the water application system equipment (drip irrigation for this case) are presented in table 3.

Table 3. Drip design parameters.

Drip irrigation	**Plot 1**	**Plot 2**
Soil type	Heavy soil (clay dominant)	Heavy soil (clay dominant)
Spacing drip lines (m)	0.5	0.5
Irrigated plot configuration	mirror	mirror
Emiter flow (liters/h)	1	1
Operating pressure (m)	10	10
Equipment specifications		
Spacing emitter (m)	0.3	0.3

[3] The irrigation geometrical design can be found in the following link: https://www.google.com/maps/d/u/0/viewer?mid=1OUWw41EGfcyeOSp4IfKh4KmbfsxE2LE&ll=-25.516603715448035%2C32.122826986397804&z=18

Dripper line lenght(m)	100	100
Total drip line length (m)	50,000	50,000
Irrigated area width (m)	33	33
Total length of manifold (m)	264	264
Diameter of manifold (mm)	50	50
Irrigation management		
Number of lines used per irrigation cycle	66	66
Duration of an irrigation cycle (min)	0 h 40 min	0 h 40 min
Irrigated area of one irrigation cycle (m^2)	3,300	3,300

The design of the pumping system considers aspects such as the crops, production practices, and plot characteristics. For the Pangalata drip irrigation system, the maximum total head required is 44 m. See table 4 for more details.

Table 4. Pumping parameters design.

Specifications	Plot 1	Plot 2
Total head		
Water flow rate (m^3/h)	22.0	22.0
Geometric height (m)	**2**	**2**
Main pipe lenght	**120**	**230**
Commercial pipe diameter (mm)	90	90
Total head	41	44.0
Generator (Solar)		
Mini pump power (kW)	4.10	4.40
Minimal solar panel efficiency (kW)	8.20	8.80

3.3 Details on the irrigation system

The drip irrigation subunits[4] will be operated by a valve control unit, which is composed of different valves that will allow water to flow directly into the supply pipes and later to the driplines in the irrigated area (see figure 3).

[4] A water meter is proposed at the head of the irrigation system. Another option would be to include a water meter for each irrigated area (after the valve control). In the expert's experience, it is better to have a single water meter (for monitoring) and charge a fee based on irrigated area.

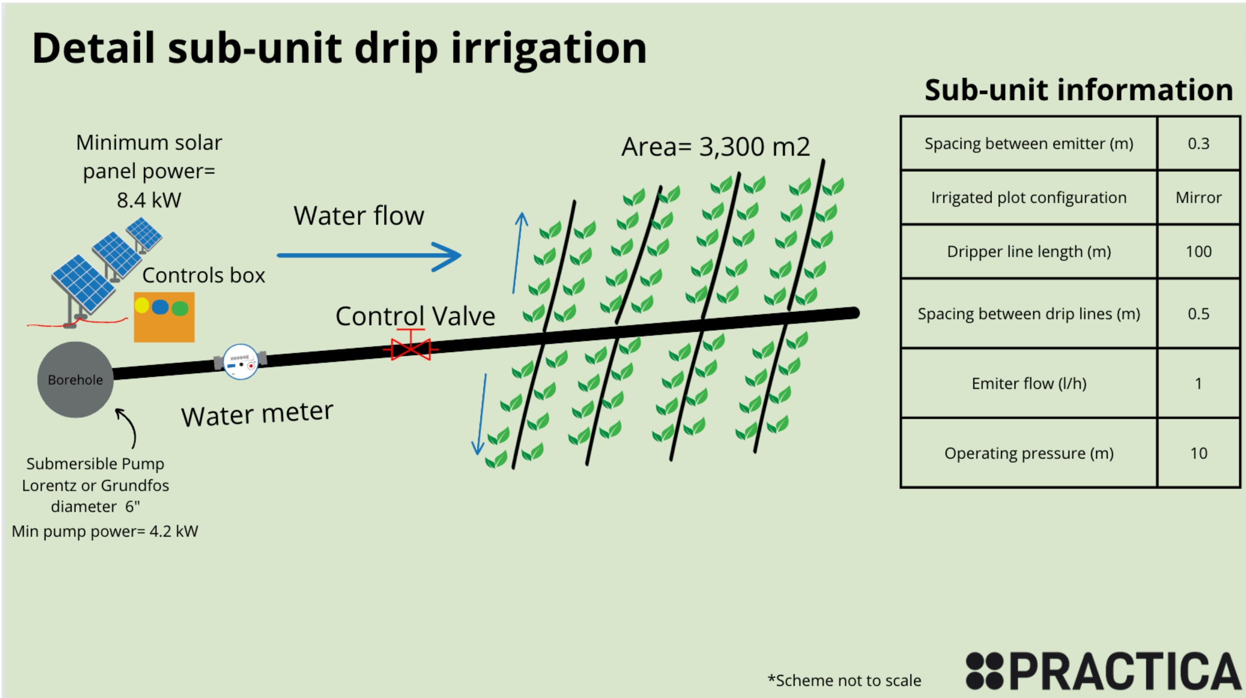

Figure 3. Detail sub-unit drip irrigation.

Details on the valve control can be found in Figure 4. The main pipe (90mm) conveys the water from the pump into the fields and is later divided into the different sub-units[5]. One extra outlet has been included in the design as requested by the smallholder farmers, and this can be used for multiple purposes.

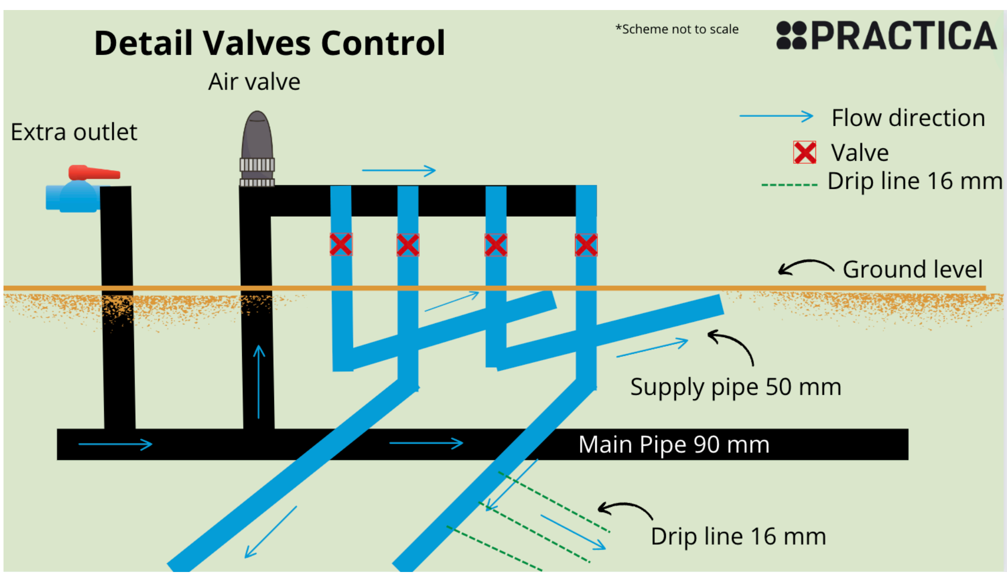

Figure 4. Details valve control.

[5] In the design, the irrigation manifold is buried below the ground (50cm). However, it can be installed on the surface of the association fields.

3.4 Bill of quantities

A detailed bill of quantities, including specifications, unit and quantity, is provided per component of the solar irrigation system and per plot. See table 5 for plot 1 and table 6 for plot 2.

Table 5. Bill of quantities for plot 1.

N°	Specifications	Unit	Quantity	Remarks
1	**Borehole**			
1.1	Borehole using rotary method, and supply and installation of 8-inch casing, including flow rate testing.	meter	35	Minimum yield 22 m3/h, max dynamic level 25 m
2	**Solar pumping equipement**			
2.1	Supply, and installation of a submersible pump 22 m3/h at 41 m (TDH), 6-inch diameter, including pipes and accessories.	unit	1	Lorentz PSk2-7 C-SJ30-6 or Grundfos SPE 30-5. Diameter not more than 6 - inch
2.2	Supply, and installation of a solar generator, including electrical accessories for regulation and protection, wiring, and panel support.	kW	8.2	Around 26 panels (320 Wp 2m x 1m) = 52 m2 = 13m x 4m (2 lines)
3	**Irrigation equipment**			
3.1	Supply, and installation of a header station: connection accessories, valves, 130-micron filtration, pressure gauge, water meter.	unit	1	Fertilizer injector is excluded
3.2	Supply, and underground installation of main PVC pressure pipe with a diameter of 90 mm, including connection accessories	m	120	
3.3	Supply, and underground installation of manifold diameter 50 mm, including regulation unit and accessories	m	264	underground or surface with PE flat pipe
3.4	Supply and surface installation of integrated drip line diameter 16 mm, 1 L/h at 10 m, spacing 0.3 m, including connection accessories	m	50,000	Netafim streamlineX or Irritec P0

4	**Internet of things devices**[6]			
4.1	Soil moisture sensor	Unit	4	To be installed one per side of the control valve (4 in total)
4.2	pH sensor	Unit	4	To be installed one per side of the control valve (4 in total)
4.3	Light sensor	Unit	4	To be installed one per side of the control valve (4 in total)
4.4	Weather station[7]	Unit	1	One for the whole design
4.5	Hydraulic sensors	Unit	4	To be installed one per side of the control valve (4 in total)

Table 6. Bill of quantities for plot 2.

n°	Specifications	Unit	Quantity	Remarks
1	**Borehole**			
1.1	Borehole using rotary method, and supply and installation of 8-inch casing, including flow rate testing.	meter	35	Minimum yield 22 m3/h, max dynamic level 25 m
2	**Solar pumping equipement**			
2.1	Supply, and installation of a submersible pump 22 m3/h at 44 m (TDH), 6-inch diameter, including pipes and accessories.	unit	1	Lorentz PSk2-7 C-SJ30-6 or Grundfos SPE 30-5. Diameter not more than 6 -inch !
2.2	Supply, and installation of a solar generator, including electrical accessories for regulation and protection, wiring, and panel support.	kW	8.8	Around 28 panels (320 Wp 2m x 1m) = 56 m2 = 14m x 4m (2 lines)
3	**Irrigation equipment**			
3.1	Supply, and installation of a header station: connection accessories, valves, 130-micron filtration, pressure gauge, water meter.	unit	1	fertilizer injector is excluded
3.2	Supply, and underground installation of main PVC pressure pipe with a diameter of 90 mm, including connection accessories	m	230	
3.3	Supply, and underground installation of manifold diameter 50 mm, including regulation unit and accessories	m	264	underground or surface with PE flat pipe
3.4	Supply and surface installation of integrated drip line diameter 16 mm, 1	m	50,000	Netafim streamlineX or Irritec P0

[6] These devices should only be procured if previously agreed with the smallholder farmers who will be operating the irrigation system.
[7] Only one weather station is required for the whole Pangalata association.

	L/h at 10 m, spacing 0.3 m, including connection accessories			
4	**Internet of things devices[8]**			
4.1	Soil moisture sensor	Unit	4	To be installed one per side of the control valve (4 in total)
4.2	pH sensor	Unit	4	To be installed one per side of the control valve (4 in total)
4.3	Light sensor	Unit	4	To be installed one per side of the control valve (4 in total)
4.4	Hydraulic sensors	Unit	4	To be installed one per side of the control valve (4 in total)

3.5 Specifications

For the preparation of the tender documents, it is important to have specifications of the materials and the installation. These are provided for plots 1 and 2 in tables 7 and 8 correspondingly.

Table 7. Specifications for Plot 1.

N°	Materials	Installation
2	**Solar pump equipment**	
2.1.1	Electric submersible pump with brushless motor, 22 m3/h at 41 HMT m, including pipe connection accessories (sleeve). Indicative rated power of the pump is 4,1 kW. The supplier will provide the pump curve and its technical data: brand, model, maximum flow rate, maximum head, rated power.	The pump is suspended from a stainless steel cable (minimum diameter 5 mm). It is positioned 2 m below the dynamic water level.
2.1.2	Polyethylene discharge pipe 10 bars, length 27 m, with a diameter equal to or greater than the discharge diameter of the pump, including connection accessories.	The pump is connected to the pipe using threaded fittings all the way to the surface.
2.1.3	Drilling head with a 2.5 mm thick steel plate measuring 0.4 m x 0.4 m, with three openings fitted with galvanized sleeves: 1 hole with a diameter equal to the discharge pipe, and 2 holes of 1" (25 mm) for cable passage and water level measurement.	The drilling head is fixed above the opening by 4 bolts secured into the concrete anchorage of the opening.

[8] These smart devices should only be procured if previously agreed with the smallholder farmers who will be operating the irrigation system.

2.2.1	Monocrystalline or polycrystalline solar panels wired with a name plate indicating: name, manufacturer's brand, model reference, serial number, peak power, short-circuit current (A), open-circuit voltage (Voc). Indicative power of solar panels 8,2 kW. The supplier will indicate the total peak power of the panels based on the characteristics of the proposed pump.	The panels are connected in series, parallel, or a combination using MC4 connectors to reach the voltage and current required by the pump. The tilt angle of the panels is set to 25 degrees from horizontal, and the orientation is north.
2.2.2	Stainless steel solar panel support fixed to the ground, resistant to winds of 200 km/h.	The support is placed as close as possible (less than 20 m) to the pumping location (without shadow) and anchored in a concrete base with a depth of 0.4 m. The bottom part of the support is at a minimum height of 1,5 m (flooding prevention) and follows the inclination of the panels. An anti-theft device protects the panels: either anti-theft nuts or a protective angle welded onto the frame of the support without covering the cells.
2.2.3	Controller matching pump specifications: MPTT, overcurrent/short-circuit/surge protection, automatic shutdown in case of dry running. On/off switch and lightning protection. Variable frequency solar inverter (25 to 50 Hz) if the pump operates on alternating current (AC). The supplier will provide the technical specifications of the controller and the inverter	The controller, inverter, and on/off switch are positioned under the solar panels (protected against rain and sunlight), at a height of 1.5m from the ground. They must be easily accessible. All equipment is connected to an earthing rod: a 16 mm2 cable for the panel supports and surge protector, and a cable of identical section to the power cable for the controller and pump.
2.2.4	Water shortage sensor connected and wired to the control box	The sensor is attached to the pipe with a hose clamp at a maximum of 0.1 m above the pump outlet, with the electrical cable at intervals of 2 m along the pipe
2.2.5	Wiring type HO7RNF for pump/panels and MC4 parallel and series connections of the panels. The supplier will provide the cable section calculated based on cable length (50 m), voltage drop (less than 2%), and current (1.25 times the short-circuit current)	All surface cable are buried under ICTA conduit until reaching the controller. Every 2 m, the cables are attached to the discharge pipe with hose clamps , including on the panel supports. Cable connections are made with waterproof joints (resin).
3	**Irrigation equipment**	

3.1.1	Head station accessories in PVC PN10 (valve, elbow, tee). Water meter suitable for the projected flow rate 22 m3/h. Manual screen filter from 130 suitable for the projected flow (22 m3/h) rate and pressure (41 m). 2 dry pressure gauges from 0 to 6 bars	The installation order on the PVC PN10 pipe is as follows: water meter, pressure control valve, pressure gauge, screen filter, pressure gauge.
3.2.1	120 m of main pipe PVC PN10 pipe, diameter 90 mm, including connection accessories (elbow, tee, valve).	The pipe connected to the head station is buried at a depth of 0.5 m. The pipes and accessories are glued together.
3.3.1	8 irrigation areas regulated by 2 control units, and connection accessories in PVC PN10 diameter 50 mm.	A control unit consists of 4 valves, an air valve, and an extra outlet for different water use. It is above ground and connected to the main pipeline supplying 4 irrigation manifolds. The pipes and accessories are glued together.
3.3.2	8 irrigation manifolds in PVC PN6 diameter 50 mm, each 250 m total length, including connection accessories.	The 33 m irrigation manifold is buried and connected to the control unit. The pipes and accessories are glued together
3.4.1	50 000 m of self-regulating integrated dripline, diameter 16 mm, 1 l/h at 10 m, dripper spacing 0.3 m, including connectors and connection accessories	For each manifold, 66 lines of drippers, each 100 m long, are installed on the ground with a spacing of 0.5 m between the lines. They are directly connected to the irrigation manifold by perforation with connectors

Table 8. Specifications for plot 2.

N°	Materials	Installation
2	**Solar pump equipment**	
2.1.1	Electric submersible pump with brushless motor, 22 m3/h at 44 HMT m, including pipe connection accessories (sleeve). Indicative rated power of the pump is 4,4 kW. The supplier will provide the pump curve and its technical data: brand, model, maximum flow rate, maximum head, rated power.	The pump is suspended from a stainless steel cable (minimum diameter 5 mm). It is positioned 2 m below the dynamic water level.
2.1.2	Polyethylene discharge pipe 10 bars, length 27 m, with a diameter equal to or greater than the discharge diameter of the pump, including connection accessories.	The pump is connected to the pipe using threaded fittings all the way to the surface.

2.1.3	Drilling head with a 2.5 mm thick steel plate measuring 0.4 m x 0.4 m, with three openings fitted with galvanized sleeves: 1 hole with a diameter equal to the discharge pipe, and 2 holes of 1" (25 mm) for cable passage and water level measurement	The drilling head is fixed above the opening by 4 bolts secured into the concrete anchorage of the opening.
2.2.1	Monocrystalline or polycrystalline solar panels wired with a name plate indicating: name, manufacturer's brand, model reference, serial number, peak power, short-circuit current (A), open-circuit voltage (Voc). Indicative power of solar panels 8,8 kW. The supplier will indicate the total peak power of the panels based on the characteristics of the proposed pump.	The panels are connected in series, parallel, or a combination using MC4 connectors to reach the voltage and current required by the pump. The tilt angle of the panels is set to 25 degrees from horizontal, and the orientation is north.
2.2.2	Stainless steel solar panel support fixed to the ground, resistant to winds of 200 km/h.	The support is placed as close as possible (less than 20 m) to the pumping location (without shadow) and anchored in a concrete base with a depth of 0.4 m. The bottom part of the support is at a minimum height of 1,5 m (flooding prevention) and follows the inclination of the panels. An anti-theft device protects the panels: either anti-theft nuts or a protective angle welded onto the frame of the support without covering the cells.
2.2.3	Controller matching pump specifications: MPTT, overcurrent/short-circuit/surge protection, automatic shutdown in case of dry running. On/off switch and lightning protection. Variable frequency solar inverter (25 to 50 Hz) if the pump operates on alternating current (AC). The supplier will provide the technical specifications of the controller and the inverter	The controller, inverter, and on/off switch are positioned under the solar panels (protected against rain and sunlight), at a height of 1.5m from the ground. They must be easily accessible. All equipment is connected to an earthing rod: a 16 mm2 cable for the panel supports and surge protector, and a cable of identical section to the power cable for the controller and pump.
2.2.4	Water shortage sensor connected and wired to the control box	The sensor is attached to the pipe with a hose clamp at a maximum of 0.1 m above the pump outlet, with the electrical cable at intervals of 2 m along the pipe.
2.2.5	Wiring type HO7RNF for pump/panels and MC4 parallel and series connections of the panels. The supplier will provide the cable section calculated based on cable length (50 m), voltage drop (less than 2%), and current (1.25 times the short-circuit current)	All surface cable are buried under ICTA conduit until reaching the controller. Every 2 m, the cables are attached to the discharge pipe with hose clamps , including on the panel supports. Cable connections are made with waterproof joints (resin).

3	**Irrigation equipment**	
3.1.1	Head station accessories in PVC PN10 (valve, elbow, tee). Water meter suitable for the projected flow rate (22 m3/h). Manual screen filter from 130 microns suitable for the projected flow (22 m3/h) rate and pressure (41 m). 2 dry pressure gauges from 0 to 6 bars	The installation order on the PVC PN10 pipe is as follows: water meter, pressure control valve, pressure gauge, screen filter, pressure gauge.
3.2.1	230 m of main pipe PVC PN10 `, diameter 90 mm, including connection accessories (elbow, tee, valve).	The pipe connected to the head station is buried at a depth of 0.5 m. The pipes and accessories are glued together.
3.3.1	8 irrigation areas regulated by 2 control units, and connection accessories in PVC PN10 diameter 50 mm.	A control unit consists of 4 valves, an air valve, and an extra outlet for different water use. It is above ground and connected to the main pipeline supplying 4 irrigation manifolds. The pipes and accessories are glued together.
3.3.2	8 irrigation manifolds in PVC PN6 diameter 50 mm, each 250 m total lenght, including connection accessories.	The 33 m irrigation manifold is buried and connected to the control unit. The pipes and accessories are glued together
3.4.1	50 000 m of self-regulating integrated dripline, diameter 16 mm, 1 l/h at 10 m, dripper spacing 0.3 m, including connectors and connection accessories	For each manifold, 66 lines of drippers, each 100 m long, are installed on the ground with a spacing of 0.5 m between the lines. They are directly connected to the irrigation manifold by perforation with connectors.

4. Internet of Things for smart solar irrigation systems

The Internet of Things (IoT) is a structure that provides an exclusive identity and the ability to relocate data over a network without requiring two-way handshaking from human to human. It enables the path to connect anytime, anywhere, with anything and anyone ideally using a network typology with a specific service (Vaishnavi et al., 2023). When adapting this concept to smart irrigation systems, it inherently enhances the performance and is an emerging technique that allows for automatization of the operation of the systems. A central feature of the IoT when related to agriculture is the use of sensors to better understand the crops, reduce climate change impacts and save resources (Obaideen et al., 2022).

Obaideen et al. (2022) present a clear diagram (figure 6) with the main components to be considered for a smart irrigation system using the IOT. Exemplifying the interconnections between the different components and how these interact within the whole system.

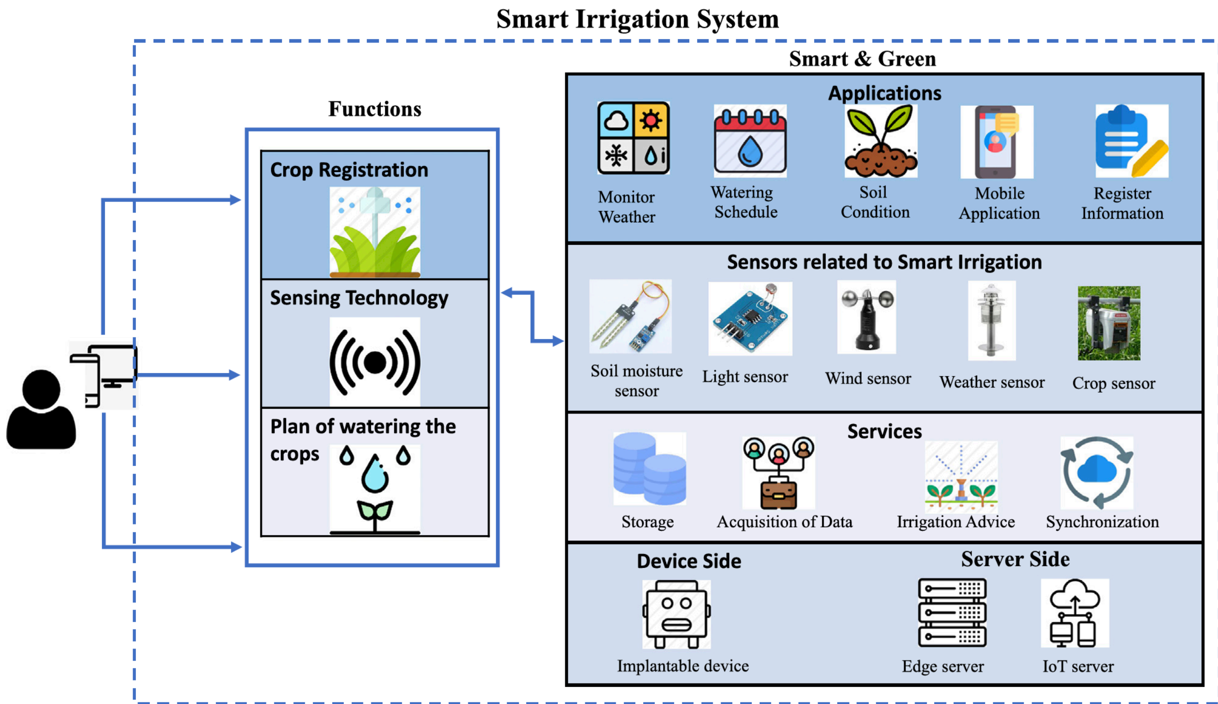

Figure 5. Block diagram of a smart irrigation system using IoT (Obaideen et al., 2022, pp. 7).

The consortium aims to have a simple configuration of the SPIS, and emphasizes redundantly to avoid using complicated technological components as much as possible.
As stated by Obaideen et al. (2022) the barriers for smart irrigation can be described as: high power consumption of devices, hardware equipment is exposed to harsh environment conditions, weak communication signals, reliable internet connection is not available in all locations, lack of IoT knowledge and applications to farmers, low privacy and security on devices and servers and short battery life of equipment.

In line with these thoughts and with the FLID framework, for successful adoption of the technology, this needs to be inserted in the values and beliefs system of the smallholder farmers and thus be in line with the available resources and knowledge to which the smallholder farmers can access easily and in an affordable way. Different experiences of complex and expensive to replace technologies have proven to only lead to the deterioration and thus abandonment of the technologies once a simple component breaks down. However, in the following chapter, the main components presented in figure 5 will be presented for documentation purposes.

4.1 Agricultural sensors

4.1.1 Soil moisture sensor

A soil moisture sensor is a device for monitoring the moisture levels in the soul. Integrating this tool into the irrigation system allows for more precise watering scheduling. These usually transmit data wirelessly and are deployed at varying depths through the soil layers, eliminating the need for manual data collection.

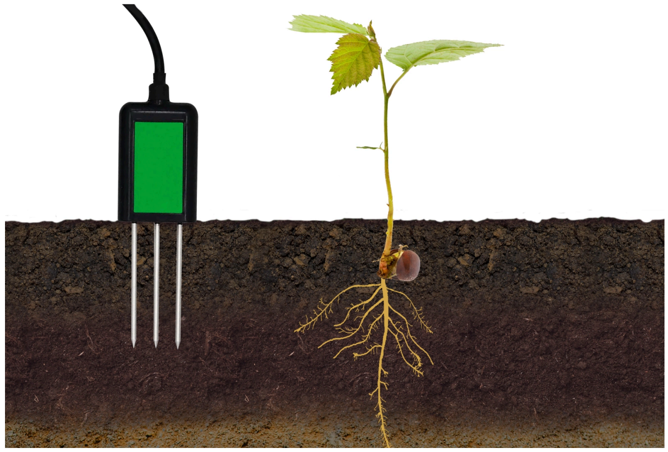

Figure 6. soil moisture sensor, Modernagritech.com

4.1.2 pH sensor

A pH sensor is a device that measures the acidity or alkalinity of the soil or water used for farming. pH is an important factor in agriculture as it affects nutrient availability to plans, soil microbial activity, and overall plant health. Maintaining proper soil pH is the basic requirement for normal crop growth. The pH sensors detect the current generated by the oxidation-reduction reaction, and the current value will drive the data of different pH value units.

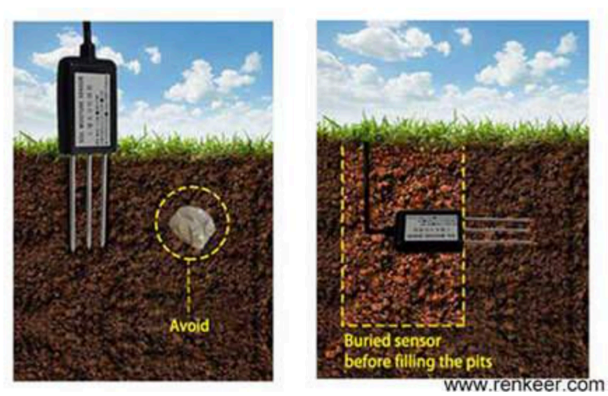

Figure 7.pH sensor buried in the ground, renkeer.com

4.1.3 light sensor

The light sensor helps farmers to accurately grasp the sunshine time duration, light saturation point, and light compensation point of plant growth, which allows them adjusting their light preferences by controlling and improving access to direct or indirect light.

Figure 8. Illuminance sensor, renker.com.

Agricultural sensors are mainly used in agricultural monitoring to facilitate the decision-making of farmers with real-time data-driven decision-making. However, to utilize the sensors, they need to be installed, calibrated and adjusted constantly. The manufacturer provides calibration functions that are typically refined in controlled laboratory settings. However, factors like soil temperature, texture, bulk density and soil salinization affect the soul sensor accuracy.

4.2 Weather station

A weather station's purpose is to collect meteorological data to make accurate weather predictions. The weather will determine how much water to use, what protection to implement, labour needs and crop health. The mentioned benefits for smallholder farmers are:

- Be prepared: Automatically receive notifications on a cellphone when a certain maximum or minimum temperature is going to be reached- preventing crop losses due to freezing or heat strikes.
- Save water: By monitoring rainfall and humidity, farmers can optimize irrigation techniques accordingly. Preventing overwatering.
- Temperature tracking: Being able to monitor the temperature in the future allows farmers to plan accurately for the labour required, the type of equipment to use, and measures of protection for the crops if required.

The constraints for installing a weather station are:

- **Cost:** Weather stations typically include multiple sensors and instruments that require installation, maintenance, and data processing. These costs may be burdensome for smallholder farmers in developing countries.
- **Technical requirements**: installing and operating a weather station requires technical knowledge and skills. For farmers who are unfamiliar or have no relevant expertise, additional training and support is required for the proper use and interpretation of the collected data.
- **Data analysis and utilization:** Meteorological data collected by the weather station is only relevant when analysed and utilized for decision-making agricultural purposes. This requires specialized data processing and decision support systems, as well as corresponding human resources.

- **Theft:** The fact that new technologies and innovations are implemented in the field can raise interest from the thieves who might steal or damage the recently installed technology.

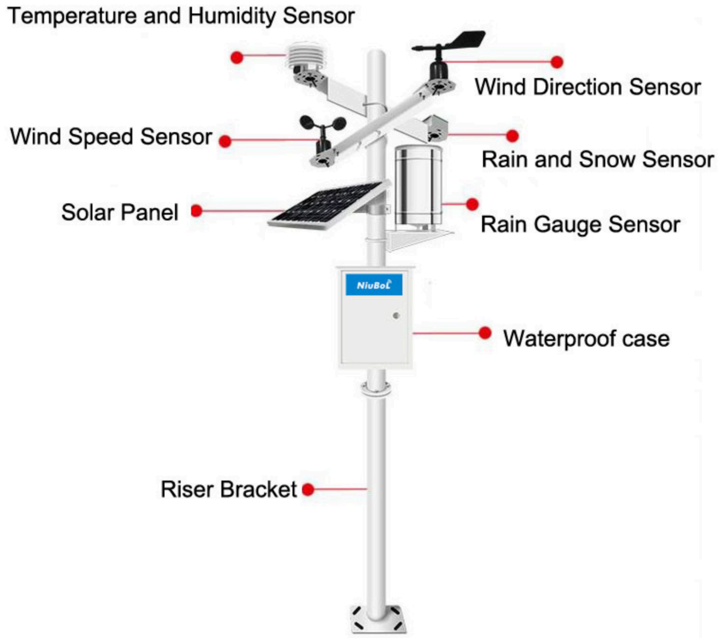

Figure 9. Diagram of a typical weather station for automated solar irrigation systems (NiuBoL, 2023).

4.3 Hydraulic Sensors

Hydraulic sensors provide instant confirmation that open or close certain valves according to the information provided.

The pressure meter is a device that measures the change in water pressure and provide real-time feedback on the irrigation system's hydraulic performance (Netafim, 2023). It is designed to enable real-time monitoring of the hydraulic function of the system and overall improve the management of the system and finally the system maintenance.

Figure 10. Pressure sensor installed in a greenhouse (Netafim, 2023).

The pressure switch is a device that operates an electrical contact either when pressure rises, or pressure falls from a preset fluid pressure level. This switch can be installed either at the irrigation head or on laterals, to indicate whether the irrigation is on or off.

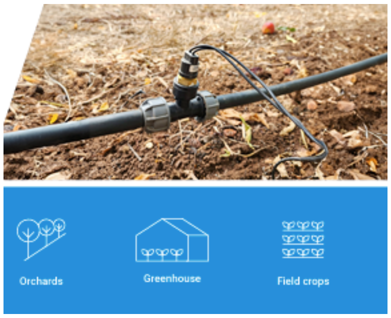

Figure 11. Pressure switch installed in the field (Netafim, 2023).

In general, the constraints for the hydraulic sensors are:

Cost: Hydraulic sensors can be expensive to provide, install and maintain. The initial cost and ongoing expenses associated with these sensors can be prohibitive.

Maintenance: Hydraulic sensors require regular maintenance and calibration to ensure accurate readings and proper functioning. However, access to skilled technicians and spare parts for repairs may be limited in rural areas, leading to challenges in maintaiing the sensors over time.

Accessibility to data: Even if hydraulic sensors are successfully deployed, accessing and utilizing the data they collect can be challenging in remote areas with limited connectivity and infrastructure.

4.4 Final Note on the Internet of Things for solar irrigation systems in Mozambique

Based on previous experiences and vast know-how on the practicalities of installing irrigation systems in rural context in developing countries. The consortium does not recommend the installation of smart devices, including hydraulic sensors due to the significant constraints posed by factors such as cost, limited technical expertise, harsh environmental conditions, and challenges in accessing and utilizing data. Instead the consortium suggest to keep the system as light as possible in terms of technologies to make it more suitable for the local context and resource constraints, ensuring sustainable and effective irrigation practices in the Pangalata association in Mozambique.

5. Sources

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