Commissioned by: UN Environment, CTCN, Adaptation Fund

Project Title: Solar based irrigation business mode 'pay as you irrigate' for women empowerment, water management and food security in Mozambique

Implemented by: Practica Foundation & HUB

Country: Mozambique

Deliverable: 4.1 Comparative Analysis of appropriate technologies for the SPIS configuration defined for Pangalata association in Mozambique.

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

Comparative analysis of appropriate technologies for the SPIS configuration defined for the Pangalata association in Mozambique

PRACTICA HUB

July 2024

This project has been proposed by Universidade Pedagógica de Maputo

With the support of the Ministry of Science and Technology and High Education

Implemented by PRACTICA & HUB

Commissioned by UN Environment, CTCN, Adaptation Fund

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-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 customized for the lowest-income farmers.

At this step, the technical design has been approved by the working group, and this deliverable compares different technologies that respond to the requirements of the architecture designed and approved for the solar-powered irrigation system for the Pangalata association in Mozambique.

2. Methodology

This document presents the three leading technologies identified for installing the solar irrigation system: i) borehole construction; ii) solar pumping system, and iii) application system. Information has been synthesized into matrices that allow for comparing the presented technologies. A scoring system has been developed to compare the suitability of each technology based on how recommended or not each technology is compared to the conditions given in Pangalata. Scores have been assigned from one to five, begin not recommended equal to one, and highly recommended equal to five, see scoring system in Table 1.

Table 1.Scoring system for recommendation of technologies.

Scoring System				
1	2	3	4	5
Not recommended	Poor Recommended	Neutral Recommendation	Strongly recommended	Highly recommended

3. Comparative Analysis

3.1 Borehole drilling

In the context of water well drilling in sub-Saharan Africa, a prevailing concern revolves around the perceived high costs and compromised construction quality (Danert et al., 2009). However, recent developments in various African countries, including Mozambique, showcase a shift towards affordability and improved drilling services by adopting different techniques and focusing on professionalization. Historically, diverse drilling methods have been known, and their appropriateness is pivotal in enhancing water access. This subchapter presents a comparative analysis between manual and mechanical drilling. Critical considerations for understanding the differences are explored in detail. Factors such as the physical environment, geology, climate, regulatory structures, and availability of materials are analysed.

Table 1 presents a comparison matrix between manual boreholes and mechanized borehole drilling (based on the literature review and the consortium experiences in Sub-Saharan Africa)

Table 2. Comparison between manual and mechanized borehole drilling (based on Martinez-Santos et al., 2020 pp. 9-10).

Aspect	Manual Boreholes	Mechanized Boreholes
Drilling costs	Low- $5 to $25 per meter for a borehole equipped with grid, gravel pack and well-head protection.	High-$80 to $1000 per meter (in extreme cases) for a borehole equipped with grid, gravel pack and well-head protection.
Depth	The average depth usually ranges between 25 to 40 m	Up to several hundred meters deep. It may capture groundwater at great depths.
Accessibility of technology for users	Small-scale enterprises provide this service	Users always need to rely on professional drilling enterprises
Time and Labour	Under favourable conditions, boreholes can be drilled in one day and installed on the following. In most settings, boreholes may take one week to drill.	Typically quick. In some cases, boreholes can be drilled, equipped, and developed within two to three days. However, transporting a mechanized rig to the site may be time-consuming (even unfeasible).
Geological constraints	Typically suited to soft, unconsolidated sediments, but some methods (i.e., percussion) may traverse consolidated rocks of medium hardness. Can drill at any time of the year.	It is usable under most geological conditions at any time of the year.
Frequent hazards	Insufficient technical expertise leads to poor borehole consumption and the loss of the borehole during construction. Nearby contamination sources can compromise supplies.	Combed or inclined boreholes. A contractor with insufficient expertise leads to poor borehole construction.

The most relevant aspects from Table 2 to be considered for the selection of drilling method for the Pangalata association are:

- Geological constraints
- Drilling costs
- Accessibility of technology for users.

Geological constraints

Based on the results of deliverable 2.1 Diagnosis of the current irrigation system in the Pangalata association, Mozambique (page 7). *The predominant geology in the district of Moamba has alluvial and basaltic origins. Characterized by a superficial layer of reddish brown (10-25 cm) and gradually transitioning to red earth, strong clayey with calcareous nodules with medium thickness ((Ministério de Administração Estatal, 2005)'*. The characteristics of the soil have been revised during the field missions, the soil is composed of unconsolidated sediments, which allows for a manual drilling technique (rotary jetting) to be used and reach a borehole depth of up to 30 m.

Drilling costs

An 8-inch diameter borehole has been pre-designed for the solar-powered irrigation system, with a depth of 30 meters. Assuming it will be a rotary jetting kit, let's study two possible scenarios. Assuming it will be drilled by a small semi-manual drilling enterprise, that will represent a cost of 44 Euros per meter, a total cost of 1320 Euros for the well (including gravel pack and well-headed protection)[1]. Compared to the price offered by the machine drilling contractor, the total price for the well would be approximately 6000 Euros[2]. This represents approximately six times the costs when compared to manual drilling.

Accessibility of technology for users

As for the accessibility of technology users, mechanical and manual implementation is feasible in the Pangalata association. As it is close to the capital, several machine drilling companies can be contacted to provide the service, and these can easily transport themselves to the location where the well should be drilled. The same applies to the manual drilling.

An overall score of the recommended drilling technique is presented in Table 3.

Table 3. Scoring of borehole drilling techniques.

Technology	Manual Borehole	Mechanised borehole
Cost	4	2
Depth	4	4
Accessibility of technology to users	5	3
Geological constraints	3	3
Frequent hazards	3	4
Total	**19**	**16**

Based on the results of Table 3 and considering the 3 main constraints discussed above, the consortium recommends selecting **manual drilling: rotary jetting kit** as the most suitable drilling method.

3.2 Solar pumping system

The principle of solar pumping is to use photovoltaic (solar) panels to convert solar energy into electrical energy. This generated electrical energy then powers either surface or submersible electric pumps, driving a sustainable and efficient supply system. The pump uses external potential or kinetic energy to displace a fluid (typically water) under suction or discharge pressure.

[1] Prices based on the last price updated for the South of Mozambique.
[2] Price quoted by phone call.

Submersible pumps are typically used where water is available at a greater depth and open wells are unavailable. The hermetically sealed motor-pump assembly is wholly immersed in the water. Solar submersible pumping system operates directly off the solar panels as power source.

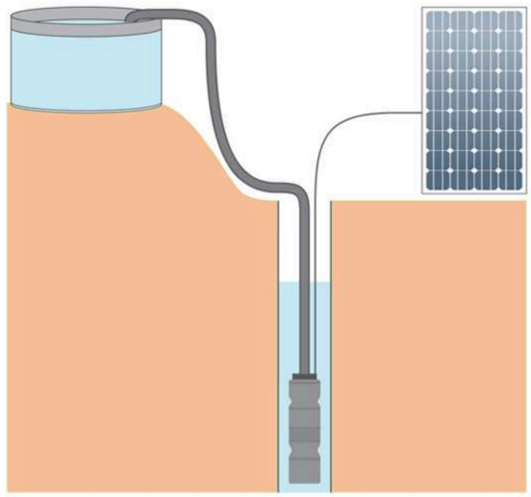

Figure 1. Submersible pump system. Water mission (2019).

For open source/surface water sources, **surface water pumps** are installed at ground level to lift water from shallow water sources such as shallow wells, ponds, streams, and storage tanks. These surface water pumps are also suitable for lifting and pumping water from a maximum depth of 7 meters.

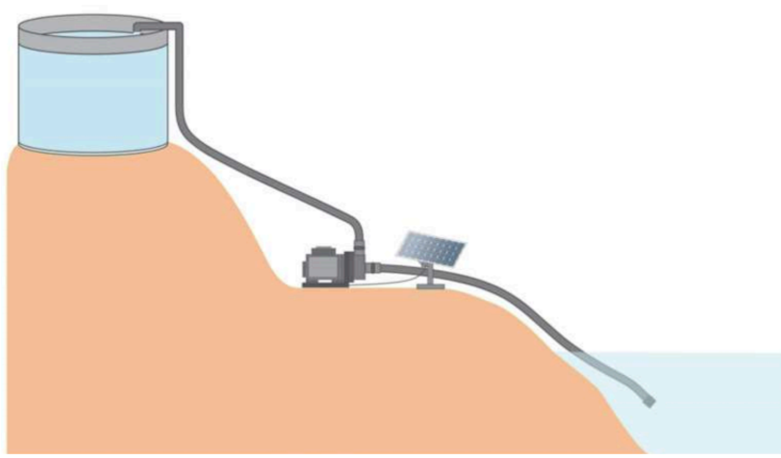

Figure 2. Solar surface pump system (Water mission, 2019).

Table 4 presents a comparison matrix between suction and submersible solar pumps (based on the literature review and the consortium experience)

Table 4. Comparison between surface and submersible solar pumping devices.

Aspects	Solar suction pump	Solar submersible pump
Location of the installation	They are installed above the ground, usually next to the water source they are pumping.	Installed below the water level, submerged in the fluid they are pumping.
Functionality	Draw water from the source and then pump it to the desired location. Suitable for shallow wells and surface water.	Operate by pushing the fluid to the surface. They are more efficient for deeper wells and can usually provide higher pressure.
Maximum water depth	7m **maximum**	Depending on the pump, it is installed below the static water level.
Size and Design	Usually, they take up more space as they are designed to sit above the ground. They typically have a more visible and accessible design.	Typically smaller in size and designed to be submerged. They are more compact and often quieter compared to surface pumps.
Cost	Usually, it is more affordable in terms of upfront costs, but operational costs may be higher.	Generally, they are more expensive to purchase and install, but their efficiency can lead to long-term cost savings.
Theft	They are more visible and accessible, potentially more susceptible to theft or vandalism. Security measures, such as fencing or locking mechanisms, may be necessary to prevent unauthorized access.	Generally, they are less vulnerable to theft due to their submerged nature. They are out of sight and more challenging to access without proper equipment and knowledge.
Usually applied to	River, stream, pond, hand dug well, borehole (water at less than 7m)	Hand dug well, borehole
Resistance to silt/sand in water	Usually more resistant	Usually more sensitive to clog when exposed to salty water.
Type of installation	Generally portable	Generally fixed

As presented above, different factors play a role in deciding what type of pumping should be installed in the field. Considering the field conditions at the Pangalata association, the relevant ones are:

- Location of installation
- Front cost
- Theft

Location of installation
During previous field activities, the smallholder farmers requested that the pump not be fitted directly into the river's margin. This is because they have prior experience with increasing water levels (see deliverable 2.2). Therefore, since the first design, it has been included that a borehole will be proposed to be constructed directly in the field to be used by the smallholder farmers. As water in the borehole might withdrawn more than 7 m, a submersible pump is therefore suggested to be installed in the field.

Maximum water depth
A surface pump cannot withdraw water from water deeper than 7 meters. As water will be pumped from a borehole, and the water table can withdraw in the coming years, it is advisable to install a submersible pump.

Theft

The submersible pump relies inside the well, with a metal cover that makes it less susceptible to theft. Also, chances for malfunctioning are less, as people are not supposed to have direct contact with the pump's moving parts (only when conducting maintenance). Meanwhile, surface pumps might need to be taken into a safe place every night and re-connected every morning.

Table 5 presents the scores regarding the suitability of both technologies.

Table 5. Scoring of the solar pumping device.

Technology	Surface pump	Submersible pump
Location of the installation	2	5
Functionality	3	4
Maximum water depth	3	5
Size and Design	2	4
Cost	4	3
Theft	2	4
Resistant to sand in water	2	4
Total	**18**	**29**

Considering the results of Table 5 and the three key points discussed above, the consortium recommends the adoption of **a solar submersible pump** for its installation in Pangalata association fields.

3.3 Application System

While drip irrigation is often considered the most efficient and optimal water application system for solar irrigation, there is not one ideal system for all situations. Besides water efficiency, the design of an irrigation application system involves factors such as crop choice, water quality, cost, availability, and farmers' preferences. Van de Zande et al. (2023) found that the preference for application methods for solar pumps differs amongst different types of farmers. For the Pangalata association, the smallholder farmers are already familiar with pressurized irrigation, specifically drip, and would like to continue using the same application technology. Therefore, a comparison between drip line and drip tape technologies will be made.

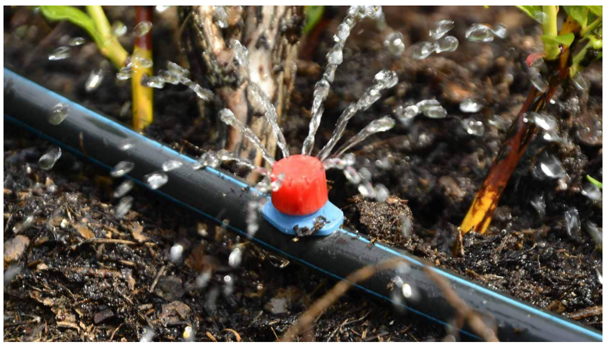

Figure 3. Drip line with dropper.

Drip line emerges as a robust and steadfast solution, embodying durability and longevity in agricultural irrigation. Crafted from resilient materials such as polyvinyl chloride (PVC) or high-density. It is a ticker, structured tubing similar to a hose. But unlike a hose, it has drip emitters along the length of the line. Unlike drip tape, which has smaller measurements, drip line has a wall thickness bigger.

Figure 4.Drip tape with the dropper installed directly in the hose.

Drip tape is a common drip irrigation component that is a long, thin-walled piece of tube. It lies flat until it is pressurized with water. Typically used in low-pressure situations (max 15 PSI). Installation is easier than drip lines, as they can easily be rolled up thousands of meters of line, whereas with drip line it can be frustrating to roll even a few hundred meters. Wall thickness is much less than with a drip line. The thickness varies from 5 to 15 millimeters. Emitter spacing varies depending on the drip tape you buy, it varies from 20 cm to 50 cm. Each emitter is optimal for different reasons, such as crop water needs, water availability, and seasonality. Drip tape is meant for long and straight applications, and it is not recommended when the design includes steep curves or other applications. Drip tape is also meant for short-term crops, as it typically lasts for a maximum of 5 years.

Table 6. Comparison between drip tape and drip line as application systems.

Aspects	Drip line	Drip tape
Material	Usually made of rigid materials like PVC or PE	Typically thinner, flexible, made of LDPE or PVC
Water distribution Uniformity	Generally provides more uniform water distribution due to emitter spacing	May have variations in water distribution due to emitter spacing and tape design
Installation and Layout	Requires more fixed installation due to rigidity. Suited for permanent installation	More flexible and adaptable to irregular layouts. Suitable for both temporary and permanent setups

Durability	Typically, it is more durable and resistant to wear and tear	Generally, it may have a shorter lifespan due to thinner materials.
Pressure Sensitivity	Less sensitive to pressure changes	More sensitive to pressure variations.
Cost	Often higher initial cost. However, it may have lower long-term maintenance and replacement costs.	Generally lower initial costs. It may require more frequent replacement (yearly).
Application suitability	Suitable for permanent crops and landscapes.	It is suited for row crop temporary installations. Ideal for seasonal use.

As presented in Table 6, there are different factors that play a role when deciding what type of drip application system to install in Pangalata. Considering conditions in the field, the most relevant ones are:

- Installation and Layout
- Durability
- Cost

Installation and Layout
Flexibility in installation is essential for smallholder farmers in Mozambique, as they often switch crops and fields with the seasons. The farmers from the Pangalata association have expressed their need for a highly adaptable system. Therefore, drip tape is recommended.

Durability
As the farmers are making a substantial investment in the application system, they requested to use high-quality materials installed in the field. Something that will allow them to share knowledge with partners around them

Cost
Aligned with the focus on durability, smallholder farmers are prepared and willing to invest in technology that offers the best cost-quality ratio. Therefore, ensuring the selected system provides long-term value and balancing upfront costs with reduced maintenance and increased productivity benefits. In this case, drip tape is cheaper than a drip line.

Table 7 provides an overview of the scoring obtained after comparing the drip line and the drip tape application systems.

Table 7. Scoring of application systems.

Technology	Drip line	Drip tape
Water distribution uniformity	3	2
Installation &. Layout	2	4
Durability	3	3
Pressure sensitivity	2	4
Cost	3	4

Total	13	17

Considering the results of Table 7 and the three key points discussed above, the consortium recommends the adoption of **a drip tape** for being installed in Pangalata association fields.

4. Summary

The comparative analysis has allowed for determining the most suitable drilling technique, pumping system, and application system to be installed in the field. The technical package shown in Figure 5 consists of a manually drilled borehole, a submersible solar pump and a drip tape.

Figure 5. Selected technologies for the Pangalata association.

In Deliverable 4.2, the consortium will provide a cost estimation for the prioritized technologies.

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