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

Diagnostic of the current irrigation system in the commune of Mubobo, Mozambique

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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.

Table of Contents

List of Tables

List of Figures

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 overall objective of the project is to identify the best Solar Powered Irrigation System (SPIS) for the Pangalata association in Moamba that could be deployed using groundwater, and surface water as well as the possibility for rainwater harvesting. The design of the system will be reinforced by the definition of a clear *pay-as-you-irrigate* business model that will be customized for the lowest-income farmers. The objective of this deliverable is to present a diagnosis of the current irrigation system and practices in the Pangalata association in Moamba district.

2. Methodology

A desk review of existing international and national data, including maps, regulations, laws, policies, reports and studies, was conducted to grasp the different types of crops and irrigation practices used in Mozambique; including their failures, bottlenecks, opportunities and limitations. The desk review was complemented by a field visit to the area, which included a series of semi-structured interviews with different stakeholders in the irrigation sector in Mozambique and in the area of Moamba, including NGOs, farmers, the private sector, academia, and farming cooperatives. As part of the diagnostic, a financial analysis, including (CAPEX and OPEX costs) was conducted to reflect on the current irrigation practices within the association.

3. General Data and Technical characterization of the project area

3.1 Geographical characterization of Moamba

Moamba is a district located within the Maputo Province in the southern part of Mozambique. This particular area is intersected by the Incomati River, which holds significant importance for smallholder agriculture in this region, deriving its name from the surrounding basin. The river experiences a substantial increase during the rainy season, spanning from December to April, and experiences shortage during the dry months. The area of the district is 4628 km[21]

[1] Mindú, A.J.; Capece, J.A.; Araújo, R.E.; Oliveira, A.C. Feasibility of Utilizing Photovoltaics for Irrigation Purposes in Moamba, Mozambique. Sustainability 2021, 13, 10998. https://doi.org/10.3390/ su131910998

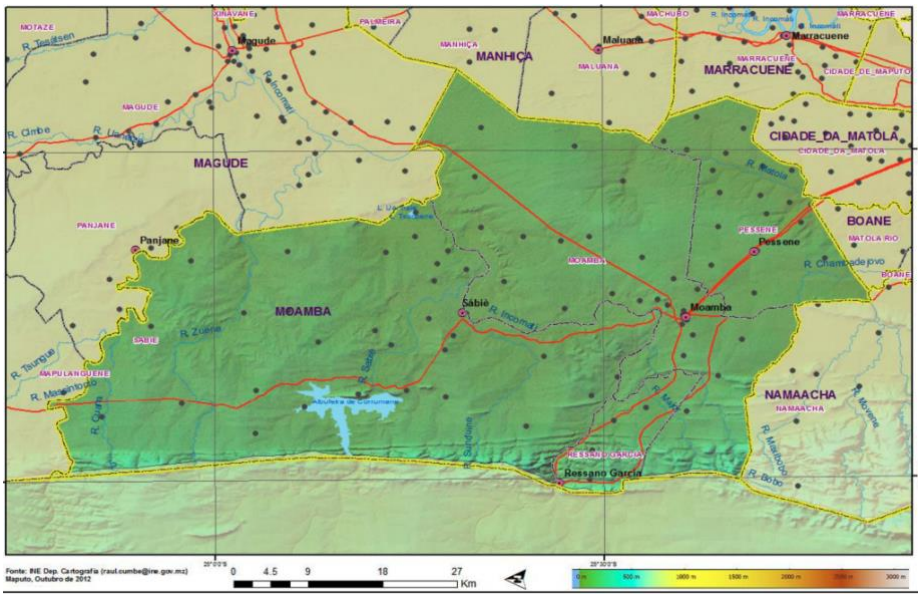

Figure 1. Moamba district map, including its boundaries (Mindú et al., 2021, p.5).

3.2 Climate

From a climatic point of view, the district of Moamba is classified as a semi-arid type (BS) following the Koppen classification. Characterized by tropical temperatures with little annual precipitation, as a result of the hot and dry weather, evaporation often exceeds precipitation. With an annual average temperature between 23 and 24 degrees and annual rainfall between 580 and 590 mm. The district has two main seasons, the first with higher temperatures and more pluviosity from October until March, and one with slightly lower temperatures running from April until September (Ministério de Administração Estatal, 2005).

Table 1. Maputo climatic conditions, obtained from AQUASTAT[2].

Month	Prc. mm/m	Tmp. min. ℃	Tmp. max. ℃	Tmp. Mean ℃	Relative Humidity %	Sun shine KJ m^{-2} day^{-1}	Wind speed at (2m) m/s
Jan	84	22.3	31.1	26.7	58.3	20811	3.5
Feb	32	22.0	33.2	27.6	48.9	21978	3.7
Mar	38	21.2	31.5	26.3	49.9	18404	3.3
Apr	110	19.0	28.2	23.6	57.3	14847	3.8
May	81	16.4	26.2	21.3	57.5	13457	2.8
Jun	11	12.7	23.4	18.0	51.9	12557	2.9
Jul	9	13.9	25.5	19.7	51.4	13276	2.7
Aug	5	14.9	27.2	21.0	43.9	16014	3.6
Sep	28	17.3	30.3	23.8	43.8	18664	3.9
Oct	54	20.2	31.8	26.0	48.8	19234	3.9
Nov	82	20.4	30.6	25.5	50.7	20298	3.8
Dec	148	21.6	31.6	26.6	52.3	20491	3.7
Total	682						

[2] https://aquastat.fao.org/climate-information-tool/

3.3 Geology and Soils

In general, the predominant soils in the district of Moamba, are those of alluvial and basaltic origin, with plains of medium texture and depths that vary from marginal to good. The soils of the Incomati valley are alluvial and have medium to high fertility with good agricultural aptitude. The red soils of Moamba, are characterized by having a superficial layer, reddish brown, sometimes very dark, clayey and with a granulose structure. The thickness varies from 10 to 25 cm and gradually transitions to red earth, chocolate color, strong clayey, compact to very compact, with calcareous nodules and generally with medium thickness (Ministério de Administração Estatal, 2005).

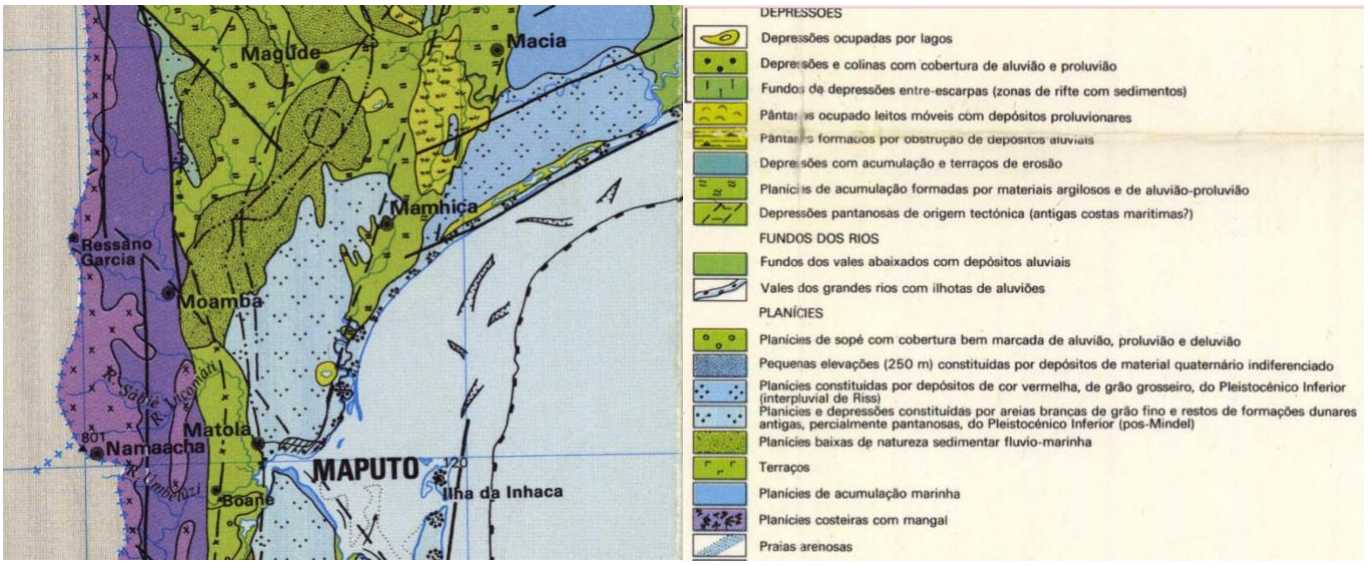

Figure 2. Geomorphologic map from Mozambique, National Soil Maps (EUDASM) 1983[3].

3.4 Land and Water rights

The existing governing land law in Mozambique was published in 1997 and meant to facilitate equitable and sustainable rural development, allowing negotiated private sector access to customarily acquired land, resulting in agreements benefiting local people (Tanner, 2010). The law recognizes three ways through which land uses can be obtained: i) through 'occupation, according to customary norms and practices'; ii) through 'good faith' occupation of land previously used by others, and iii) through a formal request to the State by investors and other externals. (Veldwisch et al., 2014). Regarding local rights, the production systems and livelihoods are protected by the DUAT[4] (Land Use Rights), which can be obtained individually or as a community in order to be able to exploit the land (Tanner, 2010).

A grouping of families and individuals living in a circumscribed territorial area at the level of a locality (the lowest official unit of local government in Mozambique) or below, which has as its objective the safeguarding of common interests through the protection of areas of habitation,

[3] https://esdac.jrc.ec.europa.eu/content/carta-geomorfol%C3%B3gica-mozambique
[4] Direito do Uso e Aproveitmento da Terra (DUAT)

agricultural areas, whether cultivated or in fallow, forests, sites of socio-cultural importance, grazing lands, water sources and areas for expansion (Law 19/97, Article 1, Number 1)

Regarding water rights, the governing water law was approved in 1991 and is the most important legal document concerning water resource management in Mozambique. It stipulates that water of the public domain comprises all inland water (including lakes and reservoirs), surface water, groundwater, and all existing hydraulic works, equipment and dependencies. The law considers that users of water for irrigation must make intensive use of that water, taking adequate and economically justifiable measures to reduce water losses by infiltration, evaporation and drainage. (FAO, 2004).

For the implementation of this technical assistance, the Pangalata agricultural association has recently applied for the actualization of their DUAT[5].

4. Description of Pangalata association

The selected association has a total number of 25 farmers, of which 15 are women and 10 are men. The group's history goes back up to 1993 when the President's father began farming in the area. In the past years, the group started to get assistance from SDAE[6] to formalize their farming group into an official association, with the common goal to be able to participate in projects. The president of the association is Mr. Elias Alberto Chirinza (phone number: +258 847687191).

[5] Information provided by the president of the farmer association during the semi-structured interviews.
[6] Serviço Distrital de Atividades Económicas

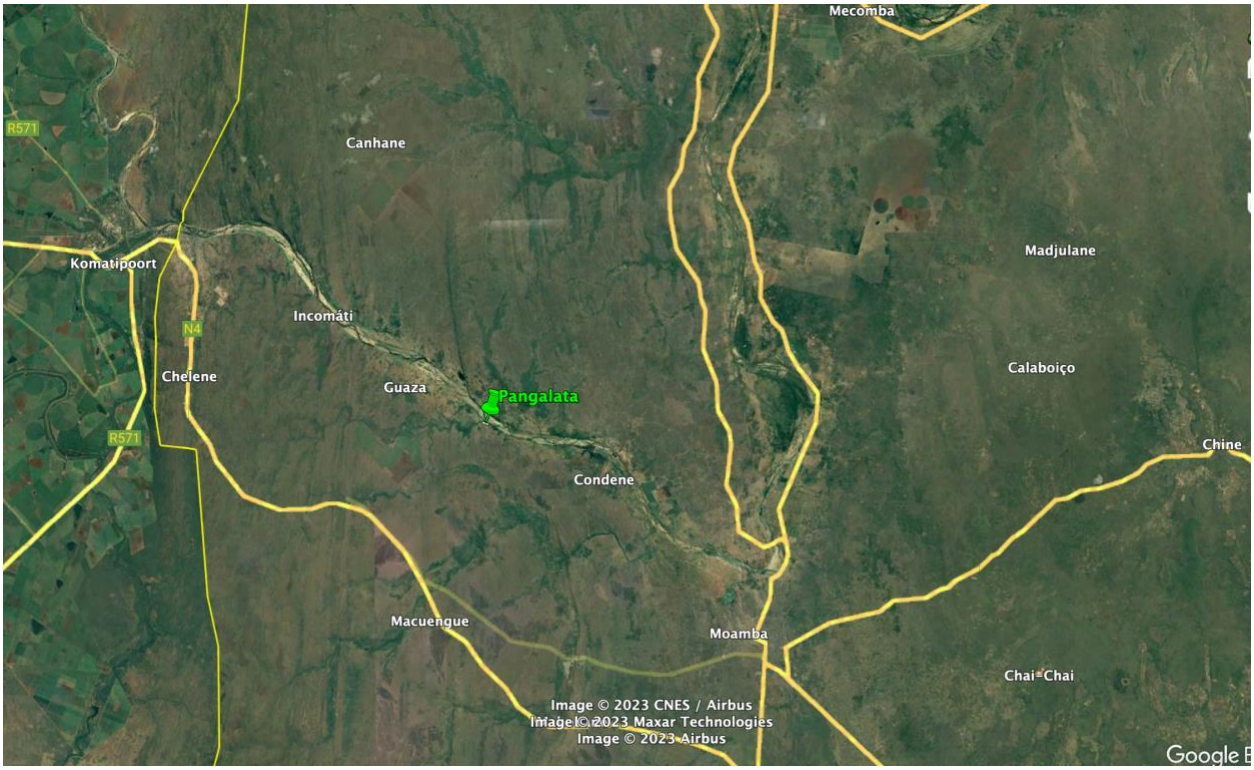

Figure 3. Location of Pangalata Association in the Moamba District, Google Earth, 2023.

The farmland is located approximately 25 km from Moamba city, linked by a dust road, which is vulnerable to inundation during peak flood seasons which the farmers indicated as happening every other 2-3 years. In a good year, the road does not get flooded. GPS coordinates are shown in the table below.

Table 2. GPS coordinates Pangalata association.

Latitude	-25.515326
Longitude	32.124129
Altitude (m)	91.5

3. Diagnosis

3.1 Technical

The Pangalata association currently cultivates 3 ha: 2 ha of cabbage and potatoes, 0.5 ha of tomatoes and 0.5 ha of capsicums on a loamy clay soil. The field is situated right next to the Incomati river. In the past they tried to irrigate from a side stream which is even closer to some of the fields (see image) but they discarded it due to perceived salinity problems. Farmers are currently using water from the Incomati river, we can assume water salinity does not represent a threat for the project, farmers report good water quality. A 3” -6.5HP petrol pump is installed at a simple wooden construction at the river bank, about 1 meter above the water table. The elevation of the nearest field is about three meters above the water table. The pump was bought

in September 2021 for 43,000 MZN. It has not required any repairs so far[7]. The previous pump, which was a diesel pump, has only been used for 7 months, after which it broke down and was abandoned.

Figure 4. Layout of the current irrigation system in Pangalata association.

The pump connects to a lay-flat hose to transport the water to the capsicum field (starting 80m away from the pump) and the tomato field (another 40m away), both of which are irrigated through furrows. On the cabbage and potato field next to the river, a 2-ha drip system is installed at the moment. The drip system of the Italian brand irritec was bought at Tecap in Maputo for about 100,000 MZN (1400 EUR)[8]. It was purchased completely with the money of the association; no external support or credit was required. The drip system was chosen to reduce the need for labor. Irrigation is done by the association members, as they only hire external people during seeding and harvesting. Yet, the members of the association also need to dedicate time to other activities, as they need to earn money during the cropping season. They are not in the financial position to wait for the harvest. This is the first year of working together, so the benefits are not known yet.

[7] During a second visit in October 2023, the petrol pump has been replaced for a diesel pump.
[8] Filter: 10,000 Mt, piping 24,000 Mt, dripline 7 rolls of 8000 = 56,000 Mt, joints 3 x 700 = 2100 Mt, and valves.

Figure 5: Lay flat hose used to pump water into the field from pump.

Figure 6: Field with green pepper and tomatoes under gravity irrigation.

The president is installing the system himself with help of the members, and he knows how to do the maintenance as he has worked with drip irrigation before. He also knows how to perform the pump maintenance, as he has ten years of experience in vegetable production. In 2014 he did a course on irrigation and the correct use of inputs. From 2015-2017 he worked on his own using a motor pump, drip and micro sprinklers, which he purchased bit by bit. He created the association last year, because the government only supports associations and not individual farmers. This support includes funding to purchase fertilizer and the purchase of a multi-cultivator, a sort of mini tractor. He recently followed a two-week seminar offered by the PROCAVA project on technologies and irrigation systems, and one on micro finance through iDE.

The irrigation system of the association is functional throughout the year. The pump capacity is a limiting factor: it can irrigate 4ha in the cold season but only 2ha in the hot season. They irrigate daily from 7.00-16.00 with a break from 12.00-14.00 so that the pump and the people can rest. According to the president this is necessary as the pump becomes very warm. The pump uses 12 liter of petrol per day. If the next harvest goes well he will buy a bigger pump with 3 cylinders, as he wants to expand. The measured flow rate at the pipe outlet in the cabbage field was 3-4 L/s.

Figure 7. From left to right: the petrol pump, drip system and filter.

The technical feasibility for a solar-powered system is very positive. The recommended option is to install a solar suction or submersible pump directly in the river, which has water all year round. It could directly feed into the drip system, and the pump specifications could be defined following the characteristics of this drip system, taking into account the need to expand it from 2ha to 5ha. The only downside is that solar panels may take up space from the irrigable field, as they cannot be installed right next to the pump because the river and fields are lined with trees. The feasibility of this needs to be checked when presenting the draft to the association.

Manual drilling of a borehole in the field could be an alternative option, however the advantage is limited because of the proximity to the river. Next to this, stones and some rock outcrops visible on the currently uncultivated area moving away from the river, indicate a higher chance of failure when trying to drill a borehole. Hence, manual drilling can be tried, but it is not the preferred option for this site.

Table 3. Summary of the existing irrigation system in Pangalata association.

Water source	Incomati river
Pumping system	3” petrol pump (6.5HP)
Application system	Drip irrigation system from Ritec and furrow irrigation using lay flat
Storage system	Non-existent
Total agricultural area	Currently 3 ha. Farmers refer land availability up to 100 ha

Area covered by the irrigation system	• Drip irrigation: 2 ha • Furrow irrigation: 1 ha

3.2 Business Model

The Pangalata association was established by the president in order to get access to external support. He is the only member who dedicates all his time to the functioning of the association and takes the initiative in discussing what to plant, purchase and how to distribute the revenue. However, the association functions as a working group, where the revenue and the responsibilities[9] are shared among the participants. For example, if the association makes a revenue of 2M MZN, he will put 1M aside for savings. The savings can be used in case of emergency, including emergencies faced by members that are not related to the production system. From the remaining 1M he will roughly use half of it to buy inputs and prepare the new land, and distribute the other half equally amongst the members as profit. To sell the capsicums he already has an agreement with the supermarket, who will come to the farm to pick it up. For the other vegetables he will hire a truck for 8000 meticais to sell in Maputo. While Moamba is relatively far, the highway to Maputo is 7km away. The association is also located close to the train station (3km) which is the cheapest option to transport vegetables to Maputo. For large volumes a truck is the preferred however, to avoid difficulties in moving the production around Maputo city.

The association is interested to invest in a solar-powered irrigation system as it will reduce the running costs of the system, and it fits well with the drip system, with which they already have hands-on experience. The business case of the current petrol-powered irrigation system looks positive, although some confusion exists on the expected market price. Based on the production of 2ha of potatoes, a net profit of 437,000 MZN (6300 EUR) is expected to be attained, or 17,500 MZN per member (250 EUR), after a 3-month season. The profit margin excluding unpaid labor by the association members is 79%, which is lower than the production systems of the other associations due to the high investment in agricultural inputs. Yet, the net profit and profit per member are the highest, in the expected price scenario of 50 MZN/kg. Though generating the highest profit, this high input strategy brings in a higher risk, as the low-price scenario (10 MZN/kg) would lead to a major loss of 363,000 MZN (5200 EUR). The return on investment for the petrol pump and drip system is 0.3 seasons or 1 month. It is expected that with the investment of a solar powered irrigation system, the operation costs (mainly petrol) will be reduced drastically (a detailed financial assessment will be presented in future deliverables).

3.3. Upscaling potential

The upscaling potential of the current agricultural initiative within the Pangalata association is a topic to be considered. Members of the association have expressed the availability of 100 ha of

[9] New investments such as the expected in SPIS will be done as a group.

land to expand the operations. While the exact location and condition of this available land requires further exploration, the very notion of such expansion holds promise of bolstering agricultural productivity in the area.

Moreover, in terms of water resources, the irrigation system is favorably positioned. The nearby river consistently maintains a year-round flow, ensuring a reliable source of water for agricultural needs. This, in turn, minimizes concerns related to water scarcity and offers a distinct advantage in supporting the envisioned upscaling of agricultural activities.

The upscaling potential within the Pangalata association represents a promising avenue for enhanced agricultural production, improved livelihoods, and the facilitation of economic growth. Further assessments and detailed plans will be essential to unlock the full potential of this expansion opportunity, ensuring that it aligns with the broader goals of the association and its stakeholders.

3.4 Local supply chain

Moamba is the nearest town with agricultural inputs, basic hardware including pipes, and small construction companies with access to different solar pump suppliers in Maputo and South Africa. Different agricultural organisations were visited and interviewed by the consortium to understand the supply chain regarding irrigation equipment. Some of these organisations are: AQUI, Premier, sete agrarian, Tecap, Bluezone, and others[10]. For more details on the solar pump market, see the solar irrigation market study for Mozambique performed by Practica in 2021.

3.5 SWOT Analysis of the existing irrigation system in the Pangalata association

Based on the information gathered from the field visits, the semi-structured interviews with the NGOs, smallholder farmers, academia and the private sector. The main bottleneck, opportunities and advantages analysis of the existing irrigation system in the Pangalata association, are presented in Table 4.

Table 4. SWOT analysis Pangalata irrigation system.

Strenghts	**Weaknesses**
• **Local knowledge and Expertise:** The presence of experienced individuals within the association who possess knowledge about local soils and crop characteristics, as well as traditional irrigation practices. • **Community Cohesion:** Strong community engagement and collaboration, fostering a	• **Limited Financing:** Financial constraints and the lack of funds for infrastructure upgrades and regular maintenance. • **Lack of Infrastructure:** Aging infrastructure (when existing), pipes, pumps and canals, may result in water losses and inefficiencies.

[10] The updated supplier survey's results can be found in the following online document : https://docs.google.com/spreadsheets/d/19YEgqx3ZJXHO94c4nwq2QdF_-ibA0OEh/edit?usp=sharing&ouid=112789746957537703336&rtpof=true&sd=true

sense of ownership and collective responsibility for the irrigation system's maintenance and success. • **Agricultural Diversity:** A variety of crops grown using the irrigation system, diversifying agricultural output and potentially increasing market access.	• **Seasonal Dependence:** Reliance on the seasonal rainfall (water flowing through the Incomati river) for supplemental irrigation, may be unreliable.
Opportunities	**Threats**
• **Modernization:** The potential to upgrade infrastructure with modern (solar) technology and efficient irrigation systems, such as automated drip irrigation. • **Partnerships:** Collaboration with NGOs, academia, and private sector entities for funding, technical assistance, and knowledge exchange. • **Market expansion:** Enhanced production capabilities, leading to increased market access and potentially higher profits to smallholder farmers in the association. • **Water Resource Enhancement:** If done correctly, new ways to improve water sourcing and storage can be explored, such as rainwater harvesting or reservoir development. • **Capacity Building:** Providing training to farmers on advanced irrigation techniques and water conservation methods.	• **Poor Water Management:** Inadequate water management practices, leading to uneven distribution and potential water wastage. • **Theft:** Theft of irrigation equipment will disrupt the operations and lead to financial losses. • **Climate Variability:** Increased climate variability, leading to shifts in precipitation patterns and potentially exacerbating water scarcity in the region. • **Regulatory Changes:** Modifications in water-use regulations or land-use policies that may affect the irrigation system's operation. • **Market Competition:** Competition from larger agricultural operations or imports that may affect local produce prices and market access. • **Resource Conflicts:** Competition for water resources from other sectors such as industry or municipal water supply. • **Economic Uncertainty:** Economic downturns or unforeseen economic challenges that could impact investment in irrigation/agricultural improvements.

4. Estimation of production costs and revenues of one plot

The presented financial analysis is based on semi-structured interviews and visits to the Pangalata association field. The objective was to understand what are the costs related to irrigation activities, investments in agricultural inputs (seeds, fertilizers, pesticides, etc., and expected revenue. Results for the 2-ha irrigated plot are shown in Table 5.

Table 5. Financial analysis of one plot of the Pangalata association (CAPEX/OPEX costs).

Association Pangalata					
Crop	Potato				
Area	2 ha				
Period	3 months				
Number of members	25				
	Unit	**Unit cost**	**Amount**	**total MZN**	**€ (1€ =69.5 MZN)**
(A) Irrigation cost					
Petrol	liter	85,34	540	46083,6	663
Lubricant	liter	300	3	900	13
Maintenance	Year	2000	0,25	500	7
				SUBTOTAL	683
(B) Production cost					
Seed	kg	68	4000	272000	3914
Transport seed + fertilizer	lump sum	8000	1	8000	115
Fertilizer	50 kg	4000	7	28000	403
Pesticides	lump sum	118000	1	118000	1698
Labour seeding	mday	250	80	20000	288
Labour harvest	mday	250	160	40000	576
Transport to Maputo	return	11000	2	22000	317
Market fee	sales	100	2	200	3
				SUBTOTAL	7312
			(A+B) Total Production costs	**555684**	**7995**
(C) Income from sales					
Revenue (50 MZN/kg)	kg	50	20000	**1000000**	**14388**
			D=(C-(A+B)) Gross profit	**444316**	**6393**
(E) Depreciation					
Depreciation pump	5 year	43000		2150	31
Depreciation drip system	5 year	100000		5000	72
			(D-E) Nett profit	**437166**	**6290**
Nett profit per person*	25 people			**17487**	**252**
Profit margin excl labour					79%
Nett profit low price scenario (10 Mt/kg)				-362833,6	-5221

Nett profit per 8 hours worked (estimate)			36	486	7,0
Return on investment Petrol pump + drip	MZN per season	143000		**0,3**	
Irrigation cost per ha (excl labour)				**23742**	**342**

5. Reflection on different types of pumps and irrigation systems

Table 6 reflects the categorization of different irrigation systems available in Mozambique. Highlighting their distinctive attributes and operational principles. This analysis is pivotal in not only recognizing the existing practices but also in assessing their effectiveness and potential areas for enhancement.

Table 6. Comparison matrix on solar, fuel and human-powered pumps.

Description/Type of pump	**Solar Pumps**	**Fuel Pumps**	**Human powered pumps[11]**
Investment	Expensive	Less Expensive	Cheapest
Running costs	Very cheap	Expensive	Very cheap
Labour	Time consuming with most application methods	Limited	Physical energy and time consuming
Maintenance	Little	More often	Little
Lifetime *depends on the type of pump and use	3-10 years*	3-5 years*	3-5 years*
Water depth	Depending on the pump	Less than 8-6 m	Depending on the pump
Average plot size	Generally, less than 1 acre (4000sqm)	More than 2 acres (>8000 sqm)	Up to 0.1 acre (<400 sqm)
Pumping time	Daytime only	No restriction	No restriction
Power, pressure, flow	Low	High	Very low
Typical use	Optimized systems pump the entire day	Pump for a short time, linked to fuel input	Pump for a short time, linked to labour input

[11] Even though human powered pumps were not identified in the Pangalata association, based on previous experiences from the consortium, it is important to include them in the comparison matrix for guiding future interventions.

Table 7 is designed to reflect on the interplay between irrigation pumps, application systems and key performance factors. By categorizing and evaluating these variables, we provide an insightful overview of how different methods impact irrigation outcomes.

Table 7. Comparison matrix for different application systems.

Performance factors/Application systems	**Drip kit**	**Misters & spray tubes**	**Low pressure sprinkler kit**	**Hose or pipe**	**Furrow/ Basin**	**Bucket/spray can**
Water saving	Very high	High	Medium	High	Low	High
Labour time needed	Very low	Low	Medium	Very high	Very high	Very high
Price	Very high	High	Medium	Low	Low	Low
Lifetime	2-3 years	4 years	5 years	5-8 years	N/A	N/A
Pressure needed	2 m	5 m	10 m	2 m	0 m	0 m
Water efficiency[12]	90%	75%	70%	75%	50%	75%
Complexity	High	Medium	Medium	Low	Low	Low

Both matrixes aim to provide a foundation for informed decision-making, encouraging the adoption of sustainable and efficient practices that can ultimately contribute to increased agricultural productivity and improved livelihoods for the Pangalata farming association.

[12] Highly dependable on the actual conditions in which the irrigation systems is installed and operated but in the table the most commonly agreed water efficiency in the sector % are shown.

6. Sources

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