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

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**Deliverable:** 2.2 Report with the demand side of a Solar Powered Irrigation System for a community in Moamba, Mozambique

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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 demand side of a Solar Powered Irrigation System for a community in Moamba, Mozambique**

PRACTICA HUB

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Implemented by 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.

# Table of Contents

## Table of Figures



## List of Tables

# 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 and surface water as well as the possibility for rainwater harvesting. 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.

This deliverable aims to gather data to understand the demand side of the fit-for-purpose Solar Powered Irrigation System for the Pangalata association in Moamba. This includes the location, water source, weather, and insolation data, which will lead to the estimations of the crop water requirements. The collected information in this deliverable will be further used in the design of the fit-for-purpose solar irrigation system.

# 2. Methodology

To make a successful design of an irrigation system, there are several steps to take to select a solar irrigation system adapted to the farm situation:

1. Identify the water source and determine how much water is available during the driest season.
2. Determine how much water is needed to irrigate and the availability of sunshine hours.
3. Select the application and conveyance system and determine the required pump yield.
4. Calculate the friction losses and total head (Technical term that represents how much pressure the pump will need to provide).
5. Select the pump that fits the design needs and is available in the market.
6. Compare it with alternative pumps
7. Buy the correct pump and irrigation equipment.

This deliverable covers the first and second steps. Finishing with the estimation of the water needs and availability of sunshine hours according to the characteristics of the Pangalata association farming fields. Deliverables 2.3 and 2.4 will cover the next steps of designing irrigation systems.

# 3. Estimations of Technical information for the design of irrigation systems

## 3.1 Location, field size and slope of the Pangalata association field

As expressed in the previous deliverable, the selected area for implementing the Technical Assistance is the Pangalata Association in Moamba, Mozambique. The fields are approximately 25 km from the main town, with the farmland linked to the city by a dust road. GPS coordinates are shown in the table below.

*Table 1. GPS coordinates Pangalata association.*

| | |
|---|---|
| Latitude | -25.515326 |
| Longitude | 32.124129 |
| Altitude (m) | 91.5 |

The Pangalata association currently cultivate 3 hectares, see deliverable 2.1. However, smallholder farmers from the association express that agricultural land is available to expand up to 100 hectares. They state that the main limiting factor to expansion is the lack of irrigation[1].

The slope profile of the field does not represent a significant burden for the design of the solar irrigation system. To facilitate calculations, this will be considered flat, as it is not expected to affect the system's installation, operation and maintenance, see figure 1. The height difference between the place where the water will be taken and the agricultural fields will be considered during the calculations of the system's head. This difference has been estimated during the technical visits to the field and determined as 1m.


*Figure 1. Slope profile for the Pangalata field.*

## 3.2 Identification of water sources and their availability

Irrigation water can be sourced from groundwater reserves or rivers and stored surface water. The demand for irrigation water is characterized by its volume, location, timing, and quality. Irrigation typically requires a substantial amount of water, which may not always be of the highest quality. Regarding timing, the need for irrigation water can extend throughout the growing season and, where sufficient resources exist, continue into the dry season to support multiple crop cycles. Peak demand for irrigation water often doesn't align with the highest flows of surface water. This situation necessitates the use of storage capacity, which can be provided by natural water sources like lakes, wetlands, and aquifers or through the construction of purpose-built dams (FAO, 2014).

The specific location of the Pangalata association puts them in a privileged position, as they are located in the riverbed of the Incomati River, a perennial water source. Following the suggestions found in literature (FAO, 2014), a sustainable water flow rate for surface water can be fixed as 30

[1] It is questionable to the consortium to what extent the association has the financial means to cultivate 200 ha (mainly investments in seeds, fertilizers and pesticides) required to have a good harvest.

$m^3/h$,-this value will be used further in the design process. As referred by the smallholder farmers and the SDAE[2] extension worker, enough water is available even during the dry season to irrigate the surrounding fields. As problems stated by the farmers, the riverbank faces erosion each year, forcing the water to recede during the dry season. They managed to get water back to the pump's suction by digging a channel in the riverbed. The risk of sudden high-water levels is real during the rainy season. This is due to a dam in South Africa (upstream) which gets opened sometimes with only a one-hour notice. As information does not reach the technician quickly, this can be too late, and there is a risk for the pump to be lost in the strong current. Therefore, the farmers prefer an option where the pump is located in a safe place along the riverbed of the Incomati river.

There is a possibility to explore the construction of a borehole close to the farming area. The community expresses preference to drill it at a low zone next to the projected extended area, instead of the riverbank. This is because the flow of the water is more violent next to the stream. It also saves piping, which would need to be buried as the farm is ploughed by a tractor yearly (they propose a depth of 30-70 cm).

## 3.3 Weather Data

As expressed in deliverable 2.1, Moamba district is considered to have a semi-arid (BS) climate, following the Koppen classification. The software AQUASTAT, designed by FAO, was used to gather the climatic data from the closest climatic station to the project area. As there is no meteorological station in Moamba, the closest one is in Maputo, Mozambique and will thus be used for the design.

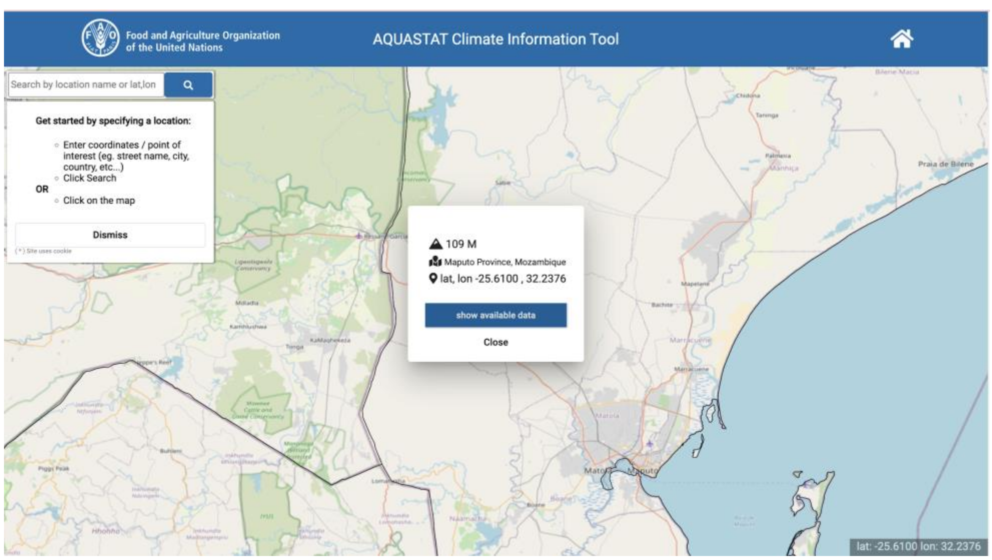
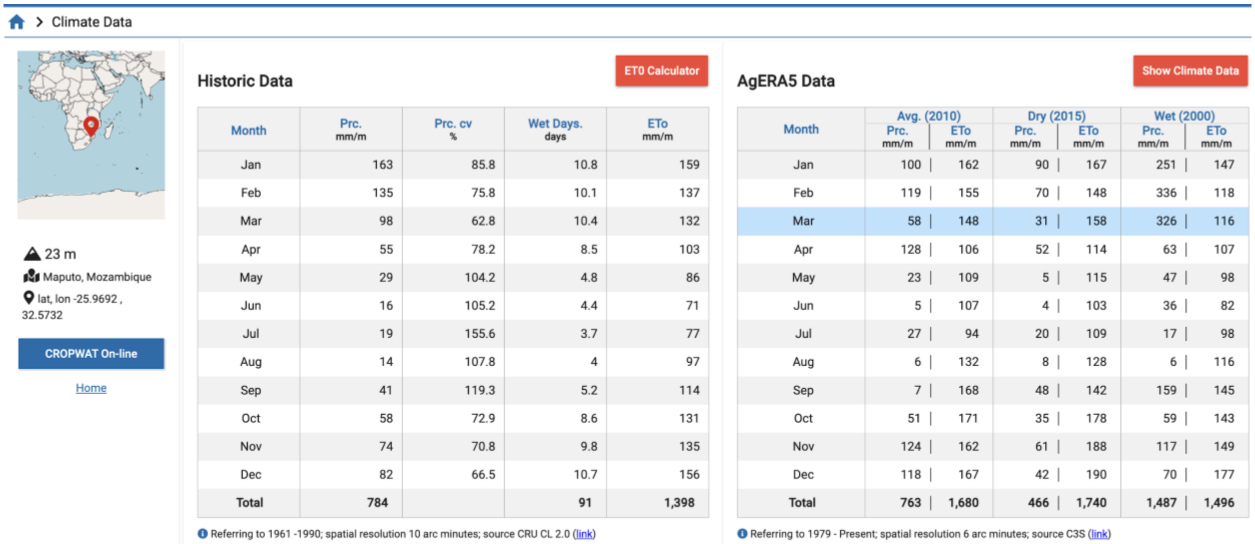



*Figure 2. Maputo meteorological station selected to gather weather data.*

[2] Serviço Distrital de Atividades Económicas

Once it has been selected, obtaining the climatic data is simple. The user must click on the red bottom on the right top of the screen to show climate data in more detail. After selecting the chosen year, the data will be displayed automatically.


Climate Data

Historic Data

ETO Calculator

| Month | Prc. mm/m | Prc. cv % | Wet Days. days | ETo mm/m |
|---|---|---|---|---|
| Jan | 163 | 85.8 | 10.8 | 159 |
| Feb | 135 | 75.8 | 10.1 | 137 |
| Mar | 98 | 62.8 | 10.4 | 132 |
| Apr | 55 | 78.2 | 8.5 | 103 |
| May | 29 | 104.2 | 4.8 | 86 |
| Jun | 16 | 105.2 | 4.4 | 71 |
| Jul | 19 | 155.6 | 3.7 | 77 |
| Aug | 14 | 107.8 | 4 | 97 |
| Sep | 41 | 119.3 | 5.2 | 114 |
| Oct | 58 | 72.9 | 8.6 | 131 |
| Nov | 74 | 70.8 | 9.8 | 135 |
| Dec | 82 | 66.5 | 10.7 | 156 |
| Total | 784 | | 91 | 1,398 |

Referring to 1961 -1990; spatial resolution 10 arc minutes; source CRU CL 2.0 (link)

AgERA5 Data

Show Climate Data

| Month | Avg. (2010) | | Dry (2015) | | Wet (2000) | |
|---|---|---|---|---|---|---|
| | Prc. mm/m | ETo mm/m | Prc. mm/m | ETo mm/m | Prc. mm/m | ETo mm/m |
| Jan | 100 | 162 | 90 | 167 | 251 | 147 |
| Feb | 119 | 155 | 70 | 148 | 336 | 118 |
| Mar | 58 | 148 | 31 | 158 | 326 | 116 |
| Apr | 128 | 106 | 52 | 114 | 63 | 107 |
| May | 23 | 109 | 5 | 115 | 47 | 98 |
| Jun | 5 | 107 | 4 | 103 | 36 | 82 |
| Jul | 27 | 94 | 20 | 109 | 17 | 98 |
| Aug | 6 | 132 | 8 | 128 | 6 | 116 |
| Sep | 7 | 168 | 48 | 142 | 159 | 145 |
| Oct | 51 | 171 | 35 | 178 | 59 | 143 |
| Nov | 124 | 162 | 61 | 188 | 117 | 149 |
| Dec | 118 | 167 | 42 | 190 | 70 | 177 |
| Total | 763 | 1,680 | 466 | 1,740 | 1,487 | 1,496 |

Referring to 1979 - Present; spatial resolution 6 arc minutes; source C3S (link)



*Figure 3. Historical data for the Maputo climatic station in AQUASTAT.*

The climatic data will then be used to calculate the water requirements in the field. The process is described in chapter 3.4

*Table 2. Maputo climatic conditions, obtained from AQUASTAT.*

| Month | Prc. mm/m | Tmp. min. ℃ | Tmp. max. ℃ | Tmp. Mean ℃ | Rel. Hum. % | Sunshine KJ $m^{-2}$ $day^{-1}$ | Wind (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 | | | | | | |

## 3.4 Determination of water needs for irrigation

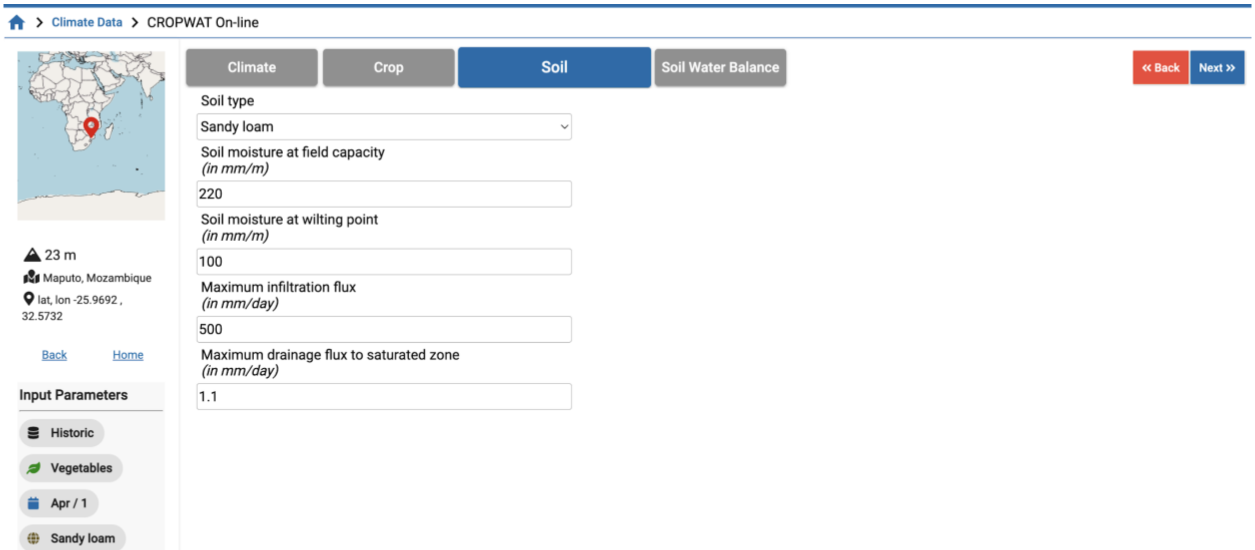
The agronomic design is a fundamental component in any irrigation project, and solar irrigation is no exception. This is the part in which mistakes can pose serious consequences. Hydraulic calculations are of no use if these are built over the wrong base. A bad agronomic design can lead to soil salinization due to a lack of soil washing or insufficient water volume during the dry season, decreasing crop yields.

Different methods for the prediction of crop water needs exist. Due in large part to the fact that procedures for directly measuring water used by crops are complex, laborious and expensive. The choice of method for estimating water needs will be determined essentially by the type of information available in the area where the irrigation project will be established. For this particular technical assistance, we will use FAO software to calculate the Reference Evapotranspiration (Eto), which uses the Penman-Monteith model developed in 1948[3].

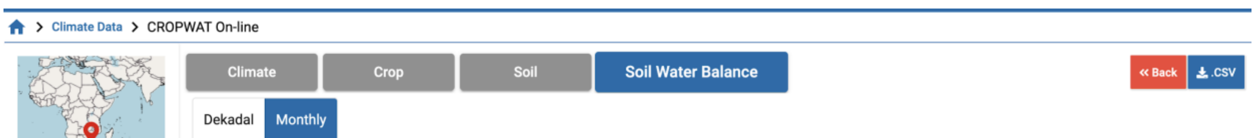
Once the climatic data is preloaded, see above. The next step is to select the crop and the planting/sowing date. For this case, as the community will be growing different kinds of vegetables, we choose the option 'vegetables', and the sowing date according to the SDAE extensionists can be determined as 1st of April, see figure below.


The second step is to select the type of soil found in the farming area. For this case, sandy loam is set; see below.

[3] For more detail on the Penman-Monteith equation visit https://www.fao.org/3/X0490E/x0490e06.htm




Finally, the software calculates the crop water requirements (ETcrop) (including supplementary and obligatory irrigation) and displays the monthly values by clicking the soil water balance button.




Crop Water Requirement (Monthly Aggregate) - Sample Type: - Year:

| Month | Prc. mm | Wet Days days | ETo mm | ETa mm | Crop Days days | ETc-Crop mm | Crop Deficit mm | GW Recharge mm | Drain mm | Soil Water mm |
|---|---|---|---|---|---|---|---|---|---|---|
| Jan | 49 | 6 | 159 | 33 | 0 | 0 | 0 | 3 | 0 | 114 |
| Feb | 29 | 4 | 137 | 32 | 0 | 0 | 0 | 2 | 0 | 109 |
| Mar | 28 | 5 | 132 | 33 | 0 | 0 | 0 | 2 | 0 | 102 |
| Apr | 209 | 12 | 103 | 74 | 30 | 74 | 0 | 32 | 78 | 236 |
| May | 61 | 5 | 86 | 71 | 31 | 81 | 10 | 28 | 0 | 198 |
| Jun | 143 | 12 | 71 | 71 | 30 | 71 | 0 | 25 | 9 | 237 |
| Jul | 43 | 5 | 77 | 48 | 9 | 21 | 0 | 28 | 7 | 195 |
| Aug | 58 | 8 | 97 | 48 | 0 | 0 | 0 | 20 | 0 | 185 |
| Sep | 16 | 4 | 114 | 53 | 0 | 0 | 0 | 14 | 0 | 133 |
| Oct | 5 | 3 | 131 | 14 | 0 | 0 | 0 | 10 | 0 | 114 |
| Nov | 21 | 8 | 135 | 17 | 0 | 0 | 0 | 7 | 0 | 112 |
| Dec | 3 | 4 | 156 | 9 | 0 | 0 | 0 | 5 | 0 | 101 |
| **Total** | **663** | **76** | **1,398** | **504** | **100** | **247** | **10** | **175** | **94** | |

*Table 3. Evapotranspiration values for the Pangalata association.*

| Month | ETo (mm) | ETc (mm) |
|---|---|---|
| Jan | 159 | 0 |
| Feb | 137 | 0 |
| Mar | 132 | 0 |
| Apr | 103 | 74 |
| May | 86 | 81 |
| Jun | 71 | 71 |

| | | |
|---|---|---|
| Jul | 77 | 21 |
| Aug | 97 | 70 |
| Sep | 114 | 108 |
| **Oct** | **131** | **131** |
| Nov | 135 | 34 |
| Dec | 156 | 0 |
| Total | 1398 | 0 |

It is crucial to consider the complete irrigation season during the calculations of the ETc. In the case of Mozambique, it runs from April until the beginning of October each year. For this case, the maximum value is found in October with a monthly ETc of 131 mm/month. Divided into 31 average monthly days, it gives a value of daily ETc= 4.2 mm/day. This value will be used to design the irrigation system in further steps in this technical assistance.

As we have determined the ETc, the next step is determining the water volume required to irrigate (in $m^3$/day). The reference area is usually one hectare. This step is important to select the right pump size. If the pump is too small, there will not be enough water to irrigate all the land.

First, we calculate the water requirements per ha:

$$Water\ requirement\ \left(\frac{m^3}{day}\right) = \ ETc\ \left(\frac{m}{day}\right) * Area\ (m^2)$$

$$Water\ requirement\ \left(\frac{m^3}{day}\right) = \ 0.00437\ \left(\frac{m}{day}\right) * 10{,}000\ (m^2) = 43.7 = 44\ \frac{m^3}{day}/ha$$

## 3.5 Determination of sunshine hours availability

The first thing that needs to be understood is how the sun works. Using the sun as a power source will let the system 'behave' in a certain way. Understanding this behaviour leads to the choice of the (number of) solar panels and the pump, the diameter of the distribution pipes, the selection of the well or water source, and the selection of the application systems.

### 3.5.1 Irradiation

When the sunlight enters the earth's atmosphere, some is absorbed, some is scattered, and some part is reflected back by clouds. The rest of the sunbeams pass through unaffectedly in the atmosphere. The absorbed part does not reach the surface but raises the temperature of particles in the air. The scattered part turns into diffuse radiation, and the part which passes unaffectedly is called direct beam radiation.

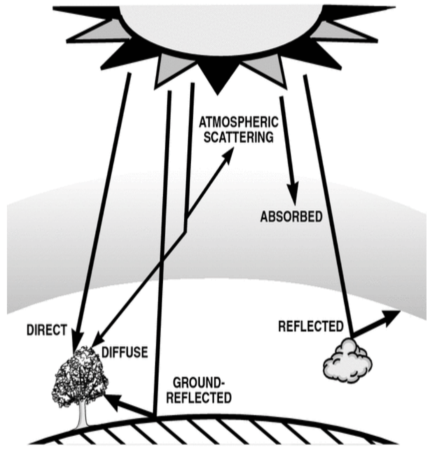



*Figure 4. Different types of radiation.*

**Irradiance** is the measure of the power density of sunlight at a particular moment. In other words, it is the power of the sunlight measured in Watt per $m^2$. When entering the atmosphere, the irradiance level is around 1350 $W/m^2$. After passing the atmosphere at sea level, the irradiance is approximately 1000 $W/m^2$, or 1 $kW/m^{2,}$ at noon at the equator. This represents a combination of direct beam and diffuse radiation.

**Irradiation** is the total amount of energy received on the earth's surface during a specific period on one square meter of horizontal surface. Usually, the time frame for measurement is one day. It is usually expressed in $kWh/m^2$. The following map shows the daily average horizontal irradiation[4].

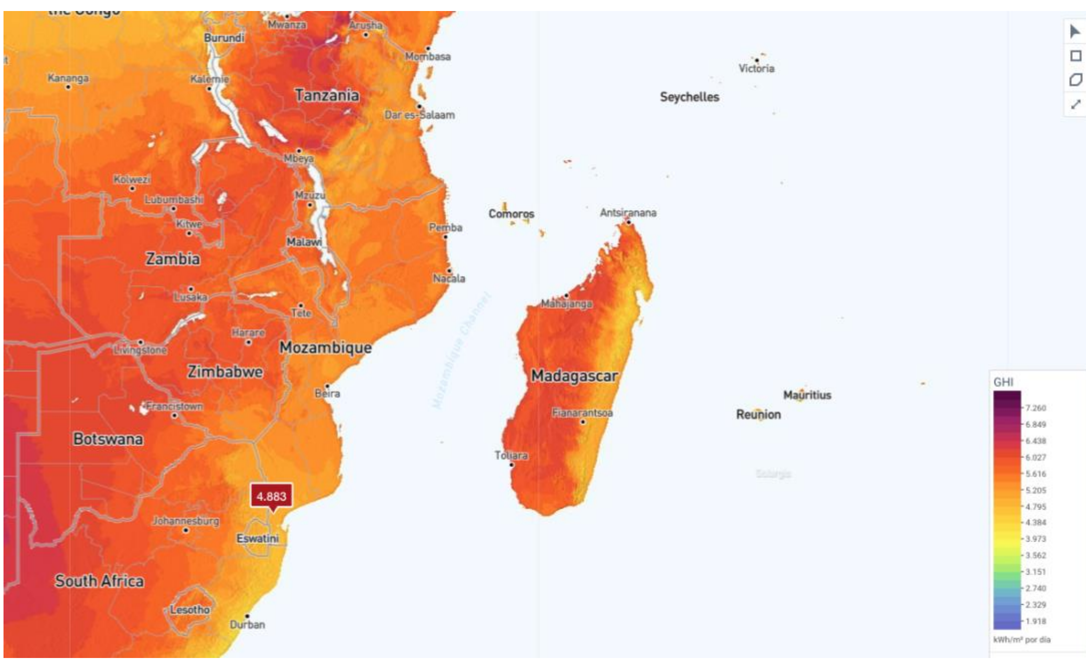



*Figure 5. Daily average horizontal irradiation (kWh/m2) (Solargis,2023).*

4 Solar GIS (www.solargis.com)

It is important to know that the data is the average horizontal irradiation. However, the irradiation will change during the day. A second effect that needs to be considered is the influence of seasons.

### 3.5.2 The critical month

The solar irrigation system should ideally produce sufficient water to meet the crop demands throughout the year. For dimensioning the system, the crux is to find the month having the most unfavorable combination of water demand and sunshine conditions.

As described above, average insolation varies between the different months of the year. In the month with the lowest insolation, the system should still produce sufficient energy to meet the power demand. Figure 6 presents the insolation on a horizontal surface for Maputo, Mozambique.

These irradiation figures have been obtained from the Solargis website (www.solargis.com).

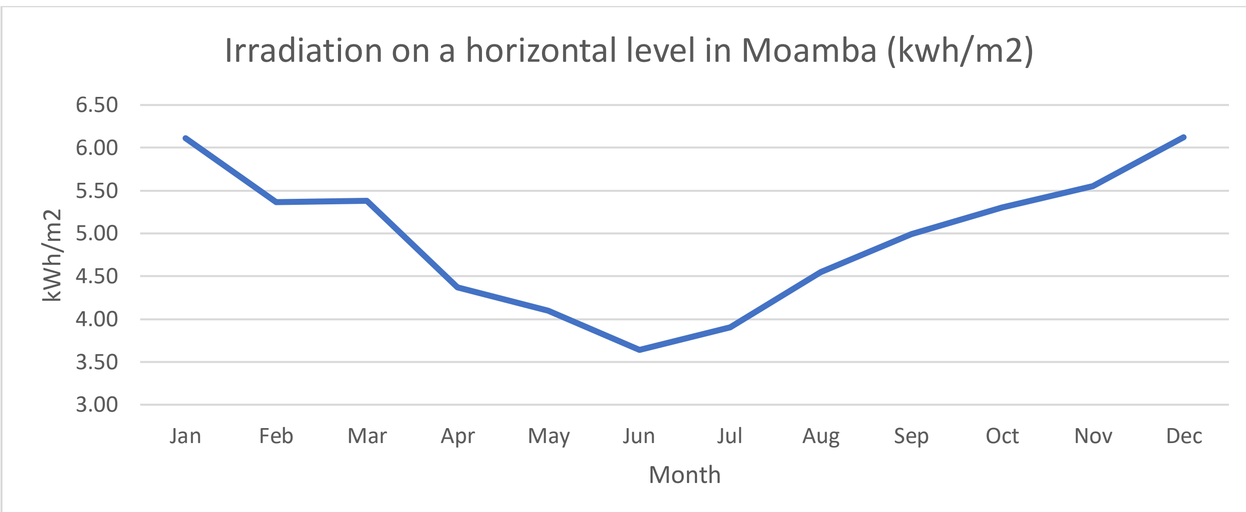



*Figure 6. Average daily irradiation in Moamba, Mozambique (Own elaboration with www.solargis.com data).*

It can be concluded that the month with the last favorable sunshine conditions in Moamba is June, when the average irradiation per day drops to 3.6 kWh per $m^2$ and during the water peak month (October) it raises up to 5.1 kWh.

In many calculations about water demand for irrigation, it is assumed that the demand is constant throughout the year. In reality, however, this is not the case. It is important to look at the hours of sunshine during the critical period for irrigation. In Mozambique, the irrigation season is during 'winter' when the days are shorter. So, in June and July, the sunshine available is about 5 hours/day. But the most critical period in terms of water needed by the plant and thus irrigation is during September and October (see figure below), when the days are longer. The average during this period is slightly above 5 h/day. We consider 5 hours of daily irradiance.

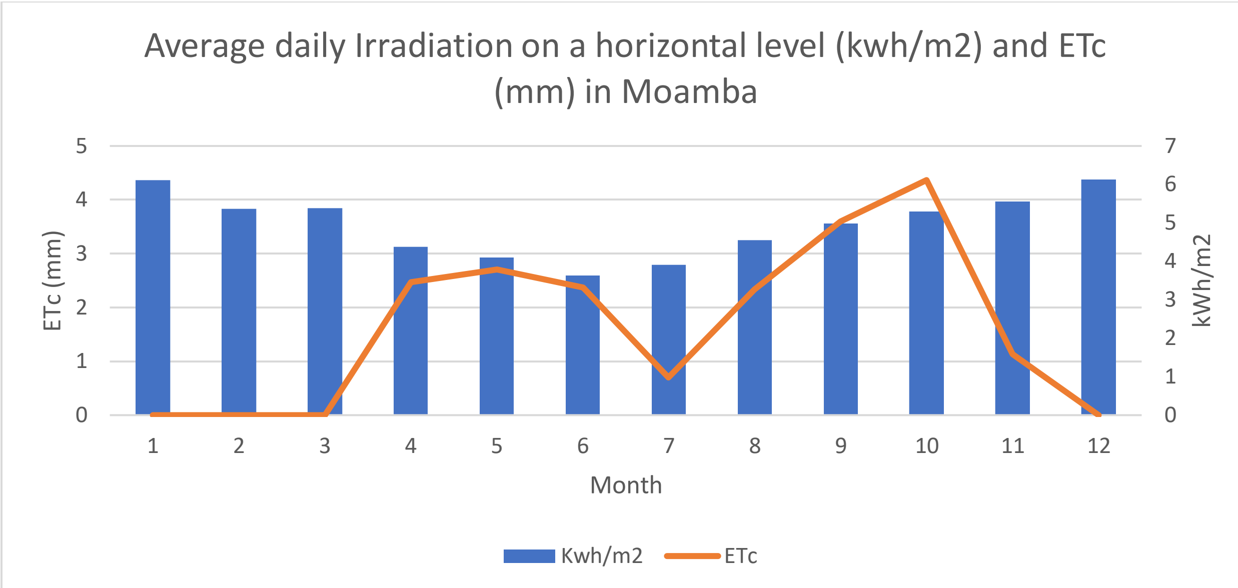



*Figure 7. Average Daily Irradiation on a horizontal level (kWh/m2) and ETc (mm) in Moamba (Own elaboration with the POWER project data[5]).*

## 4. Summary Table

This chapter summarizes the data gathered and calculated regarding the first and second steps of designing a solar-powered irrigation system. This data will be used in deliverable 2.3 to finalize the design.

*Table 4. Summary of information for the SPIS design.*

| | |
|---|---|
| **Currently cultivated area (ha)** | 3 |
| **Expected area to be irrigated with SPIS (ha)** | 5 |
| **Water source** | Surface water (Incomati River) |
| **Water source flow rate ($m^3$/h)** | 30 |
| **Critical Evapotranspiration (ETc) (mm/day)** | 4.2 |
| **Daily water requirement per ha ($m^3$/ha)** | 42 |
| **Average daily Irradiation on a horizontal level (kWh/m2), during critical month** | 3.6 |
| **Daily Average available hours for critical month (hours)** | 5 |

[5] https://power.larc.nasa.gov/data-access-viewer

## 5. Sources

FAO, 2014. Economic valuation of water resources in agriculture. From the sectoral to a functional perspective of a natural resource management. Available at: https://www.fao.org/3/y5582e/y5582e00.htm#Contents

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