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Study of the Sizing of a Drip Irrigation System by Solar Photovoltaic Pumping at the National School of Agriculture and Livestock of Tolo, Mamou, Republic of Guinea

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ABSTRACT

Background and Aim: Drip irrigation or localized irrigation, is the provision of water localized near the roots of plants, with reduced doses but at high frequencies. This work aims to design a drip irrigation system by photovoltaic pumping at the National School of Agriculture and Livestock (ENAE) of Tolo in Mamou for the irrigation of market gardening crops (onion, cabbage, tomato and eggplant).
Method: The approach followed for this study consists of: field investigation (choice of site, types of soil and crops, water needs); the sizing of system parameters (drip irrigation and photovoltaic solar pumping).
Results: The main results of the work are: Evapotranspiration (8 mm/d); crop water requirements (2.5 mm/day); watering duration (3 h/d); number of gutters (125); Length of the ramp (50m); ramp diameter (16 m); ramp spacing (40 cm); boom flow rate (5 l/h); daily water requirements (30 m3); HMT (26m); daily energy (3000 Wh/d); field power (1200 Wp), number of panels (12, type 100Wp); Regulator (60 A); inverter (1400 W); number of batteries (8); hydraulic power of the pump (125 W); installation diagram and estimated cost of creating the system (200150000 GNF).
Conclusion: The results of this study will serve as a basis for the creation of a drip irrigation system using photovoltaic pumping for market gardening in the agricultural plains of ENAE from Tolo to Mamou.

Keywords: Drip irrigation, market gardening, photovoltaic pumping.

INTRODUCTION

Water management for agriculture is an ancient and contemporary concern in the world. Water management practices and technologies have developed in a context of sustainable management of natural resources [1]. Water and energy are important, essential and indispensable elements for life. Access to water resources and clean and sustainable energy constitutes one of the major challenges of the 21st century [2]. Galloping demographics, the search for well-being and economic development in sub-Saharan Africa imply an increase in water needs for domestic consumption, livestock breeding, agriculture and industry [3].
The use of renewable energies for pumping and irrigation makes it possible to reduce greenhouse gas emissions, limit the costs linked to the purchase of diesel while improving farmers' income.The development of Irrigated agriculture is essential to achieve the objectives of long-term food strategies. Irrigation improves agricultural yields by more than 50% [4]. Given the increase in the world population, water has become a limited factor for agriculture. About 70% of the world's water resources are used for agricultural irrigation.

The development of irrigation is linked both to the design and installation of large irrigation equipment (dams, hill lakes, basins, boreholes, collective distribution networks, etc.) and also to the management and valorization of irrigation water [5].

Drip irrigation or localized irrigation, also called micro-irrigation, is the provision of water localized near the roots of plants, with reduced doses but at high frequencies. In principle, localized irrigation is in fact only an improvement of traditional techniques [6]. Drip irrigation saves water by 50 to 70% compared to gravity and 30% compared to sprinkling. It contributes to an increase in yields, of the order of 20 to 40%, and to improving the quality of market garden products. Compared to other irrigation systems, drip irrigation allows a reduction in energy costs used in pumping, a reduction in the cost of labor involved in irrigation operations, and a reduction in costs. quantities of fertilizers used [7].

The implementation of irrigation methods such as drip irrigation saves water resources, provides a source of income and increases plant cover. It is in this context that drip irrigation by photovoltaic solar pumping remains one of the solutions for all areas with significant solar radiation [8].

The diversity of climatic conditions, hydraulic resources and soil fertility give Guinea an advantage in the production of a wide variety of products. On an area of 24.6 million hectares, Guinea has 6.2 million hectares of cultivable land, 50% of which is exploited, representing a cultivated area of 3.3 million hectares. Of the 364,000 ha of irrigable land, only 30,200 are currently developed [3].

Thus, meeting water needs within the framework of sustainable development requires mastering appropriate pumping technologies, judicious exploitation of resources and the use of renewable energy sources. It is with this in mind that this study is undertaken.

MATERIALS AND METHODS

Study area

The study area is the sub-prefecture of Tolo, created in 1977; it is one of the 13 sub-prefectures of Mamou located 23 km from the Urban commune. It has an area of 150 km2 and a population of 8718 people including 4798 women for an average density of 58.12 people/km2 (RPH, 2014).

With a climate characterized by the alternation of two seasons of the same duration, the dry season from November to April and the rainy season from May to October; precipitation ranges between 1600 mm and 2000 mm, with an average annual temperature of 25°C. The annual rainfall is around 1681 mm3. The average humidity varies between 65 and 67%. The dominant winds are the harmattan and the monsoon. The soils are varied, including ferralitic mountain soils, hydromorphic soils and skeletal soils. The rugged terrain is made up of plateaus forming the Fouta Djallon massif [9].

The sub-prefecture of Tolo has: Five (5) districts namely: Tolo center, Siminkhö, Soumbalako Tossokhéré, Gouba, Morhodhé; divided into seventeen (17) sectors (Figure 1). The National School of Agriculture and Livestock (ENAE) of Tolo was created in 1932 under the name "Ecole de Labor du Fouta" which is the oldest of the Agricultural Schools of Guinea and even of West Africa. The ENAE of Tolo has 239 ha of land of which 53 ha are developed (figure 2). All these areas are served by a hydro-agricultural dam with a capacity of 522,000 m3 of water allowing their exploitation in the dry season. The school currently operates four (4) vegetable gardens of 6 ha each (Figure 2).

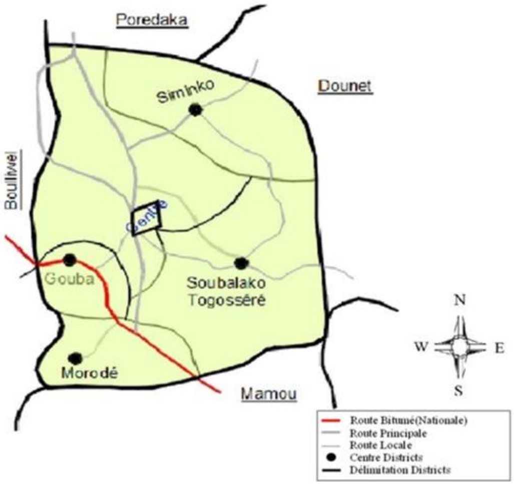

Figure 1. Map of the Tolo sub-prefecture

Figure 2. Market garden crops in a vegetable garden in the Tolo plain

METHODOLOGY

The methodology adopted for this study followed the following stages: field survey, sizing of the systems (drip irrigation, photovoltaic pumping, and photovoltaic field). For this, we used the following equipment: software (RETScrem, QGIS, AutoCAD); analytical formulas, charts and various tools (computer, GPS, tape measure, centimeter, string, rod and the level bezel).

As part of this study, we chose one hectare of plain used for market gardening (tomato, eggplant and pepper) at a time or in rotation. The water requirement for these types of crops is 60 m3/d.ha. The pumping system is with water storage; the pressure losses correspond to a maximum of 10% of the total geometric height [10].

Irrigation system

The determination of the parameters of the irrigation system takes into account the average water requirement for types of market gardening, i.e. 132mm per month, for an efficiency of the water distribution network which varies from 70 to 80% [11]. Thus, taking into account the hydrological characteristics and hydraulic equipment are necessary for this step, namely: specific flow, characteristic flow, flow of ramp doors, water storage, drip network, soil humidity level, frequency of watering, daily watering duration, pressure losses). The sizing of ramp holders is identical to that of ramps and the pressure variation conditions are identicalv [3, 11].

Solar pumping system

The determination of the characteristics of the solar pumping system takes into account the following elements: daily photovoltaic pumping capacity, Total Manometric Head, solar irradiation, hydraulic power, daily energy, peak power of the panels, type of panel, number of panels, battery capacity, accessory elements of the PV field (regulator, inverter, cable etc.) [12, 13].

The different sizing parameters of the drip irrigation system using the photovoltaic pumping system are given in (Table 1).

Table 1. Sizing parameters of the irrigation system [11, 12, 13, 14].

Parameters	Formula	Unit
Rainfall in drip irrigation	$P_l = \frac{q.n}{a.b}$	mm/h
Evapotranspiration	$E_{toj} = \frac{E_{to}.10^3}{10^4}$	mm/d
Irrigation time	$t_i = K_c.\frac{E_{toj}}{P_l}$	h/d
Water requirement of a crop	$E_{tc} = K_c.E_{toh}$ ou $B_{ec} = K_c.E_{tol}$	l/s
Continuous fictitious flow	$Q_{fc} = \left(\frac{B_{ec}}{24.3600.30}\right).S.10^4$	l/s
Effective flow	$Q_e = 3,462.Q_{fc}$	l/s
Daily water storage capacity	$C_{st} = \frac{Q_e.3600.t_i}{1000}$	m^3/d

Daily pumping capacity	$C_{jp} = \frac{C_{st}}{0.85}$	m^3/d
Parcel unit	$S_b = \frac{M}{Q_{fc}}$	ha
Number of parcel	$N_{pl} = \frac{S}{S_b}$	-
Unit storage capacity	$C_{ust} = \frac{C_{st}}{N_r}$	m^3/d
Dimensions of a tank	$V_r = L \times l \times h$	m^3
Daily capacity of a pumping station	$C_{jsp} = \frac{C_{jp}}{N_{sp}}$	m^3/d
Hourly capacity of a pumping station	$C_{hsp} = \frac{C_{jsp}}{t_{ens}}$	m^3/h
Calculation of the area of a plot	$S_b = \frac{M}{Q_{fc}}$	m^2
Length of a ramp	$L_{rp} = 1m/2$	-
Number of ramps per sector	$N_{r/s} = (1m/a) \times 2$	-
Total number of ramps	$N_{tr} = N_{r/s} \times N_s$	-
Number of drippers per boom	$N_{grp} = L_{rp/b}$	-
Number of dripper pairs per boom	$N_{pg} = N_{g/2}$	-
Total Head	$HMT = H_g + \Delta h$ $HMT = 1,1.(Hr + ha)$	m
Geometric height	$H_g = Hr + ha$	m
Hydraulic power required	$E_h = C_{jsp}.C_H.HMT$	Wh
Hydraulic constant	$C_H = 2,725.\frac{kg.s.h}{m^2}$	-
Electrical energy required for the motor pump	$E_{MP} = \frac{C_H}{\eta_p.\eta_{mot}}.C_{jsp}.HMT$	Wh
Controller peak power	$P_{Ccnt} = \frac{E_{MP}}{\eta_{cont}}$	W
Peak power of the photovoltaic generator	$P_c = \frac{P_{Ccnt}}{E_j.\eta_{PV}}$	Wc
Peak flow	$Q_c = \frac{P_C.E_j.\eta_P.\eta_{mot}.\eta_{PV}.\eta_{cont}}{HMT}.\frac{3600}{\rho.g}$	m^3/d
Maximum peak flow	$Q_{max} = \frac{P_C.\eta_P.\eta_{mot}.\eta_{PV}.\eta_{cont}}{HMT}.\frac{E_j}{E_{jréf}}.\frac{3600}{\rho.g}$	m^3/d
Number of panels associated in series	$N_{bs} = \frac{U_s}{U_m}$	-
Number of panels associated in parallel	$N_{bp} = \frac{P_C}{I_m \cdot U_s}$	-
Total number of panels	$N_P = N_{bp} \times N_{bs}$	
Peak power of the field to be installed	$P_{CI} = N_P \times U_m.I_m$	Wc

Pl: Rainfall (mm/h); q = 0.6 to 1 l/h: Flow rate of a line of drippers; q = 0.6 to 1 l/h: Flow rate of a line of drippers; a = 1.2 to 1.5 m: Spacing between two ramp lines; Eto = 60 m^3/d.ha: Potential evapotranspiration; Kc = 0.95: Crop coefficient; M = 5 to 20 l/s Main water; t_{en} = 7h: Sunshine time per day; Δh = 10%: Hg, Pressure losses; ha = 4.5 m; Hr = 5m: Tank location height; η_P: Pump efficiency, which varies from 45 to 55%; η_{mot}: Engine efficiency, which varies from 80 to 85%; $\eta_g = \eta_P \times \eta_{mot}$: Overall yield which varies from 31.5 to 44%; η_{cont}=95%: Controller efficiency; $\eta_{pv} = (1 - losses)$ =80%: Efficiency of the photovoltaic system; η_{Cont}=0.95: Controller performance; E_d = 5.36 kWh/m².d: Average irradiation of the worst month; E_{dref}=7.52kWh/m^2.d: Reference irradiation.

RESULT AND DISCUSSIONS

The various results obtained during this study relate to: water requirements, pumping capacities, geometric characteristics of the drip irrigation system, the pumping system, characteristics of the photovoltaic field and the installation diagram of the system.

Drip irrigation system

The sizing characteristics of the drip irrigation system are shown in (Table 2).

Table 2. Characteristics of the irrigation system

Designation	Value	Unit
Water requirement per month	100	mm/month
Reduction coefficient	75	%
Daily water requirement	2.5	mm/d
Percentage of soil moistened	1.5	%
Watering frequency	0.90	j
Practical net dose	3	mm
Actual dose	2	mm
Raw dose	2,6	mm
Watering duration per month	0.25	h/ month
Daily watering duration	3	h
Number of trees per ramp	125	-
Ramp length	50	m
Spacing between ramps	0,4	m
Number of drippers per boom	125	-
Boom flow	1080	l/h
Ramp diameter	16	mm
Ramp door length	50	m
Number of ramps per station	125	-
Number of ramp doors	4	-
Ramp door flow	2520	l/h
Ramp door diameter	25	mm

The type of dripper chosen is self-regulating, anti-siphone and delivering a flow rate of 2 l/h under a pressure of 1 bar. According to the manufacturers, the spacing of the drippers is recommended by the manufacturer and is 0.4 m. The drippers are spaced 40 cm apart, there are 125 of them on a 50m long ramp. There are 500 ramps spread over an area of one hectare. The total cultivated area is subdivided into four (4) positions of 2500 m^2 with 125 ramps per position.

Photovoltaic pumping system

The choice of pumps required for the pumping station is based on important criteria including flow rate, total head (HMT) and power. The sizing parameters of the photovoltaic pumping system are shown in table 3.

Table 3. Sizing parameters of the photovoltaic pumping system

Designation	Value	Unit
Daily needs	30	m^3
Speed	5	m^3/h
HMT	26	m
Hydraulic power	400	W
Daily energy	3000	Wh/d
Power to install	1200	Wc
Number of panels	8	-
Number of batteries	10	-
Regulator	60	A
Inverter	1400	W

The daily water requirements for drip irrigation of four types of vegetable crops (onion, cabbage, tomato and eggplant) estimated at 30 m3 on an area of one hectare. The required water flow is 5 m^3/h. The total gauge height (HMT) evaluated is 26 m, this value is relatively lower than the HMT of several boreholes in Guinea, i.e. on average from 30 m to 120 m [15].

The daily energy demand of the system is 3000 Wh/d, for a hydraulic power of 400 W. The peak power to be installed is 1200Wp, thus, the number of panels is 8 of 150Wp, the number of batteries is 10; the inverter has a power of 1400W and the maximum regulating current of the regulator is 60A. The cost of carrying out the project is estimated at: two hundred and twenty million Guinean francs (220000000 FG). The installation diagram of the The entire pumping system is illustrated in (Figure 3).

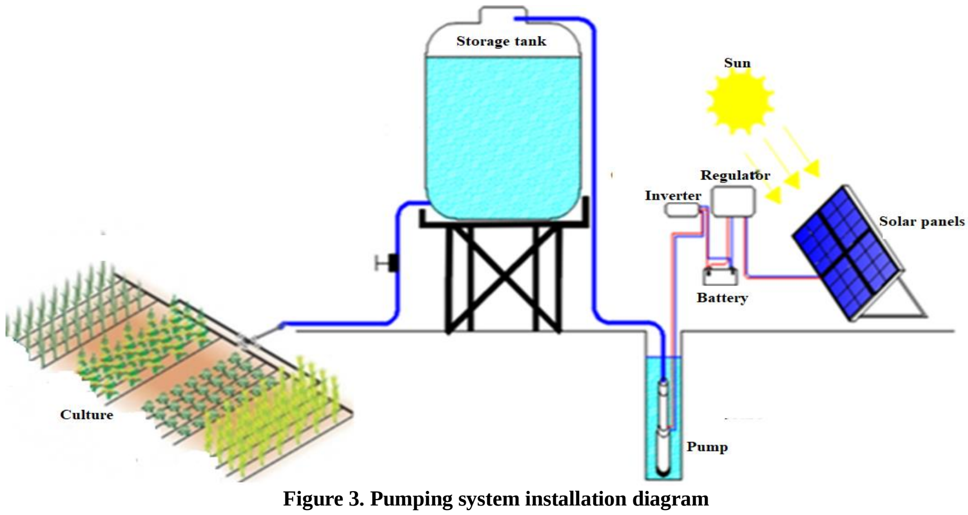

Figure 3. Pumping system installation diagram

CONCLUSION

This work focused on the study of the sizing of the parameters of a drip irrigation system using a photovoltaic solar pumping system for the irrigation of market gardening crops in the agricultural plain of the National School of Agriculture and Breeding of Tolo, Mamou, Guinea. It made it possible to know the average water needs of the types of market gardening chosen, taking into account hydrological characteristics and hydraulic equipment. The parameters of the irrigation system: water requirement, flow rates, drip network, soil humidity level, watering frequency, daily watering duration, pressure losses were determined. Likewise the characteristics of the solar pumping system: daily photovoltaic pumping capacity, HMT, solar irradiation, hydraulic power, daily energy, peak power of the panels, type of panel, number of panels, battery capacity, accessory elements of the PV field (regulator, inverter, cable etc.) are determined.

Declaration by Authors

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