Study of the Impact of Solar Pumping Solutions on Agricultural Production in Senegal: The Case of Small Farms in the Niayes Area (Thiès Region)

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Abstract. The Niayes region represents Senegal's principal horticultural zone, contributing approximately 80% of the country's total horticultural production. A survey was conducted to investigate the impact of the distribution of solar pumps on farmers in this region. The transition enabled farmers to achieve an average savings of 713.24 USD in fuel costs. Moreover, the adoption of the solar water pump led to an 8% increase in agricultural production and a 5% increase in income per hectare. The initial six-month period of pump operation resulted in a total avoidance of 137.5 tonnes of CO2 emissions. The findings demonstrate the beneficial impact of solar pumping solutions on the environment, agricultural productivity, and economic viability in the Niayes region.

Keywords: Agriculture · Solar Water Pump · Senegal · Niayes region

1 Introduction

In many African countries, Sustainable Development Goal (SDG) 2, ending hunger, is an important catalyst for the achievement of many other SDGs. In Senegal, it is the most critical for development. According to the World Food Programme, around 1.3 million people in Senegal faced acute food insecurity during the lean season in 2023 [1]. The development of local agriculture is essential for reducing food insecurity. However, the lack of effective, sustainable, profitable, and environmentally-friendly practices and tools among the majority of farmers is hindering this process.

The Niayes agricultural zone in Senegal covers some 2,759 km^2 [2, 3], and is reputed to be the main market-gardening area responsible for the production of almost 80% of the country's vegetables [4]. In 2023, our study on 545 market garden plots in the Niayes revealed that 62.8% of these plots use diesel-powered pumps. In 2022, the solar energy company Nadji.Bi Senegal, in partnership with USAID-funded West Africa Trade & Investment Hub (Trade Hub) and La Banque Agricole, launched a new product, Woomal

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Mbay, designed to promote connected solar pumping and irrigation solutions in the Niayes area. This initiative is part of the drive to promote modern and green agriculture.

The following section presents the results of our study on the impact of the distribution of Woomal Mbay solar pumps in the Niayes region of Senegal. This study was conducted using data collected through interviews with farmers who were using the Woomal Mbay solution. The interviews were conducted at six-month intervals between 2023 and 2024. A total of 68 interviews on 53 farmers using a total of 57 pumps were the subjects of the data collection. The IoT data was used to evaluate the energy consumption of the pumps (Fig. 1).

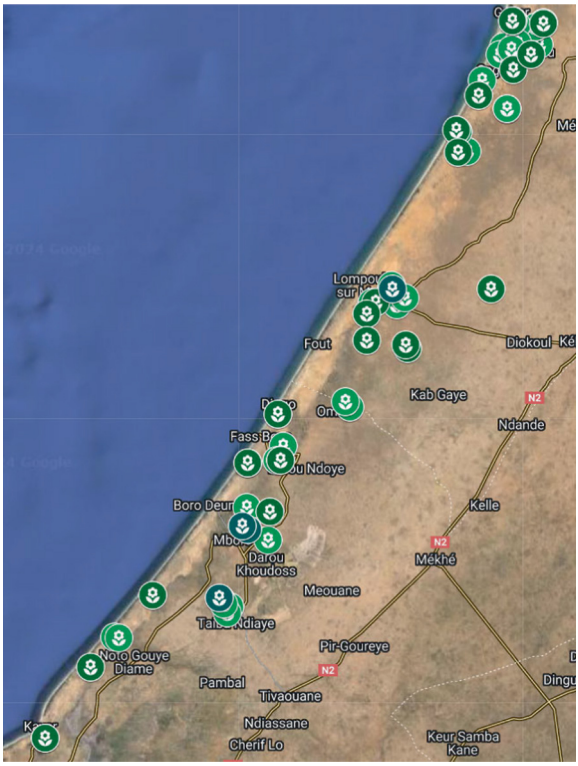

Fig. 1. Distribution of solar pumps installed in the different localities of the Niayes area, as studied in the framework of our research (source: Nadji.Bi Senegal Database).

2 Presentation of Solar Water Pumping System

Solar water pumping systems are composed of three principal components: the hydraulic pump, the inverter, and the solar panels. Nadji.Bi Senegal provides farmers with three system options, each designed for surfaces ranging from 1 to 3 hectares. The system is proposed to the farmer following a system selection study. This study involves the

assessment of the water requirement and the suitability of the pump for the farm. The following data is collected for this purpose: the type of crop, the dimensions and depth of the borehole, the presence of particles in the water (e.g., iron and salt), and the size of the cultivated area (including the highest point, geographical coordinates, and surface area). The selection process is typically conducted with the objective of attaining a performance of around 10 m3/h/ha for an average head of 20 m, with a daily operational period of five to six hours under clear skies (Table 1 and Figs 2, 3).

Table 1. Performance table for Solar Water Pumping Systems

System no1	**Power (kW)**	**Flow rate (m3/h)**	7	10	17	20	28	30
1	1.1	**Manometric head (m)**	29	20				
2	2.2		39.5	38	28	22		
3	3		33	32	30	28	24	22

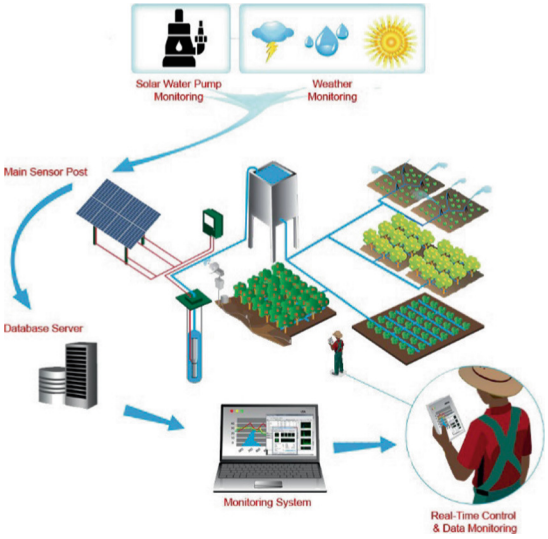

Fig. 2. Solar pumping system (source: Nadji.Bi Senegal Database).

3 Results

The age range of farmers surveyed was 23 to 71, with an average age of 47 and an average working experience of 18 years. With an average of four different crops per farmer, the most widespread of the 21 different crops identified are onions (51%), bitter eggplants (43%) and potatoes (40%). Of the 53 farmers surveyed, 17% were women.

Fig. 3. Woomal Mbay System No. 1 used by the farmer, replacing the previous diesel-powered motor pump system in the background (source: Nadji.Bi Senegal Database).

The survey of 53 farmers revealed that the crops generate 212 full-time jobs. The average age of these workers is 29.2 years, and there is an average of 1.80 full-time jobs per hectare. The number of part-time jobs created during harvest periods, which typically last for an average of four days, is 1,804. This is equivalent to 1,274 full-time jobs for a period of one month. The majority of these workers are women (62.20%), while a significant proportion are young people (42.96%).

45 sites were already under cultivation before the installation of the pump and their area was estimated to be 91.75 ha, with an average area per site of 2.03 ha. We observed that in 22 of these sites, the farmers used the solar water pump to increase their cultivated area by 30.75 ha, which represents an average increase in cultivated area of 33.52% for these 45 sites. The remaining 12 sites invested in the solar water pump to start cultivation on a new area, for a total of 19.5 hectares. In total, the solar water pump allowed the 57 surveyed sites to increase their cultivated area from 91.75 ha to 142 ha, an increase of 54.77%, with an average cultivated area of 2.49 ha.

A total of 1,375 tons of vegetables have been harvested since the installation of the solar water pump, resulting in a total turnover of 420,279,800 FCFA (approximately 691,671 USD). The respondents indicated that their agricultural production had increased overall by 8% per hectare as a result of the solar water pump. This translates into a 5% increase in farm income per hectare.

The majority of farmers surveyed indicated that they perceived solar pumping solutions as a more sustainable alternative to diesel pumps. This perception was supported by the survey results, which showed that out of 44 responding farmers, 63.6% had replaced their diesel pumps with solar water pumps. In addition, 36.4% of respondents indicated that they had replaced their pumping systems (solar or grid electricity) for performance reasons.

The substitution of diesel pumps with solar pumps by farmers led to a reduction in costs of 440,000 FCFA (approximately 713.24 USD) per hectare and per cropping

period. The survey of 53 farmers indicated that 60.4% of them cultivate crops twice a year, while 39.6% cultivate them three times. Eleven farmers have attested to an increase in the number of periods during which crops are cultivated throughout the year, as a consequence of the utilization of solar pumps.

A survey of 58 connected solar water pumps revealed that these pumps are used for an average of 4.07 h per day, with a daily output of 45.5 m^3 of water. Data collected (IoT data) from the 57 farmers surveyed showed an average consumption of 4,794 kWh per solar pump since installation. The average reduction in CO_2 emissions is 4.5 tons per pump, for a total reduction of 258.9 tons of CO_2 for the monitored pumps.

A total of 53 interviews were conducted and analyzed to assess the customer satisfaction rate (CSAT) of the Woomal Mbay solar water pump across all categories. The overall CSAT score is considered satisfactory, with an average customer satisfaction score of over 80%. The associated SamaPump Android application, which allows farmers to monitor their pump, the performance of the solar water pumps, and the after-sales service provided by the company were rated by respondents as satisfactory, with an average customer satisfaction score of over 80%, and the quality of the installation and study services provided for the solar water pump was rated as very satisfactory, with an average customer satisfaction score of over 90%.

4 Discussion

The results of this study on the use of solar pumps in the Niayes region of Senegal, via the Woomal Mbay project, demonstrate a notable shift from the use of diesel pumps to solar solutions. A substitution rate of 63.6% was observed among the farmers surveyed. This figure is consistent with trends observed in other parts of Africa, such as Morocco, where a significant majority (96%) of farmers expressed a desire to switch to solar pumps [5]. This convergence serves to illustrate a common recognition of the economic and environmental benefits of solar solutions, as evidenced by previous studies [5, 6]. Despite the initial challenge of high installation costs, the long-term benefits are clear [7].

From an economic standpoint, the utilization of solar water pumps has the potential to result in considerable annual cost savings for farmers. As evidenced in [5], the projected payback period for these pumps ranges from 2.7 to 3.6 years, with the adoption of solar pumps leading to an increase in profit margins, which have been estimated to range from 765.04 to 1137.50 USD per hectare.

Following the installation of solar pumps in the Niayes region, there has been an increase observed in the irrigated area and yields. These findings are also presented in [5, 8], where an extension of the irrigated area, the introduction of intercropping and an increase in the water supply for the same crops grown in areas of water scarcity have been noted. This increase in productivity is attributed to improved water availability and accessibility, which has enabled the expansion of cultivated areas.

A notable proportion of respondents expressed a high level of appreciation for solar water pumps. This sentiment was particularly evident in [9], where it was expressed by over 80% average customer satisfaction score. This indicates that solar pumping solutions are well-suited to the needs of farmers, as they can be easily adapted to suit a variety of circumstances.

In addition, Solar pumps also provide significant environmental benefits. During the initial deployment of solar pumps in the Niayes region, a total of 137.5 tons of CO2 emissions were avoided over a six-month period. This reduction in greenhouse gas emissions is consistent with the results of other studies showing that solar energy is instrumental in promoting sustainable and environmentally responsible agricultural practices, thereby increasing Senegal's food self-sufficiency. Moreover, the adoption of solar solutions serves to stem the rural exodus by contributing to the creation of green jobs, which in turn reduces the unemployment rate in rural areas, as our results have shown.

5 Conclusion

The results of our study show that the installation of solar pumps in the Niayes region has led to significant changes. The Woomal Mbaye project has facilitated an increase in farmers' incomes and the adoption of more effective agricultural practices. The Woomal Mbaye project is a valuable contribution to improving food security in Senegal. Further research would be beneficial to assess the challenges associated with the widespread adoption of solar pumps in the Niayes region and to determine the potential consequences of using this technology on water resources.

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