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Application Example of a Small Solar Pumping System in the Djiboutian *Wadi* Agriculture

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Abstract: The Republic of Djibouti is located in northeastern Africa and in a low altitude, therefore the temperature is one of the highest region in the world. The average annual rainfall is approximately 130 mm, and the rain is heavy with a wide range of yearly variation. Therefore the productivity of agriculture is extremely low. The scarcity of rainfall means that agricultural productivity is extremely low, and is typically restricted to areas along *wadis*, and the most common water sources are wells. In addition, most surface soils contain very little organic matter and are volcanic in origin. We have examined the potential application of greening technology, such as "Waterharvesting", "Stone mulch" and "Double suck" in Djibouti from 1990. The purpose of these methods is to increase the infiltration of surface water and to maximize the efficiency with water can be used. In 2007, we installed a small solar pumping system in a farm of*wadi*-type agriculture to investigate the possibility of the new integrated farming. The study site was a 1.5 ha vegetable farm in the city of Dikhil. We attempted to integrate traditional farming methods with the use of a small solar pumping system, other water-saving technologies such as "Stone mulch", and "Bokashi" composting technology in the field in March 2011. The 480 W solar pumping system that was initially installed at the site was subsequently upgraded by an additional 200 W. The maximum flow was approximately 95 L/min, and the amount of water pumped was 39 m^3/day (at 27 MJ/m^2) and the quantity of water used each day was 60 m^3/day.

Key Words: Bokashi, Djibouti, Solar pumping system, Stone mulch, Waterhavesting

1. Introduction

The Republic of Djibouti is located in northeastern Africa and in a low altitude, therefore the temperature is one of the highest region in the world. The average annual rainfall is approximately 130 mm, and the rain is heavy with a wide range of yearly variation. The scarcity of rainfall means that agricultural productivity is extremely low, and is typically restricted to areas along *wadis*, and the most common water sources are wells. Techniques such as "Solar energy use distillation devices", "Water harvesting", "Double suck" and "Stone mulching" have been used in Djibouti since 1990. These modern techniques promote the infiltration of water into the ground, and utilize small amounts of water effectively in Djibouti (Ismael*et al.*, 2003, Takahashi*et al.*, 2010; Tajima*et al.*, 2006). In 2007, we combined the traditional *wadi*-type agriculture methods with more modern methods that used domestic animal waste for Bokashi composting. We also examined the potential for integrating farms to increase productivity among the vegetable growers in the suburbs of Dikhil. Among the modern technologies that were introduced was a small solar-powered pumping system for pumping groundwater. This study presents the findings of field work that we conducted until March 2011.

2. Objectives

In this study, we integrated the use of a small solar pumping system into the traditional *wadi*-type agriculture system employed in the Republic of Djibouti. We also investigated the operating conditions of the system.

3. Description of Study Site

The farm where the solar pumping system was installed was one of the farms owned by Mr. Djama Guedi who was a resident in Dikhil. The farm was Arouo farm of area 1.5 ha located on 42°33'E, 11°8'N, 673m above sea level, in Arouo *wadi*. The main crops were melon, onion, eggplant, tomato, forage crops (sugarcane, crotalaria, alfalfa). And a domestic animal was goat. **Figure 1** shows the whole view of the Arouo farm, and **Figure 2** shows a ground plan. The characteristic of the farm of Mr. Djama Guedi installed in the *wadi* was demarcated by a 2 m-height stone wall except some portion around the farm, and there was a hollow (flood control

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Fig. 1. Whole view of the Arouo farm.

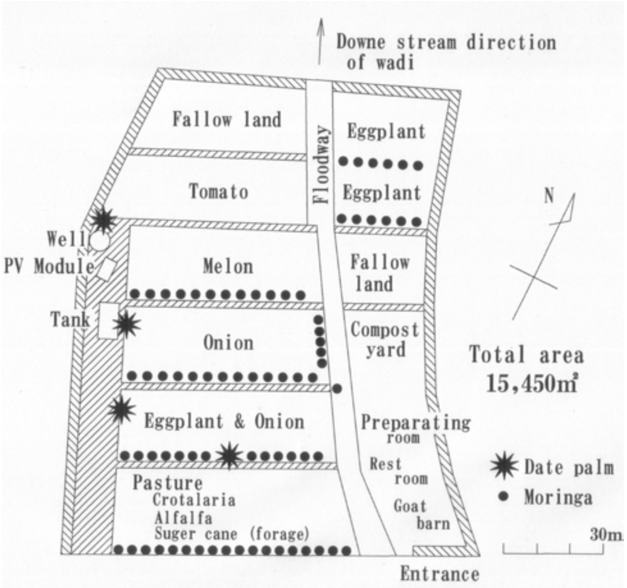

Fig. 2. Ground plan of the Arouo farm.

channel) which water flows to at the time of a flood in the center of the farm.

The farm where the solar pumping system was installed was subdivided into sections, each of which measured approximately 1,200-1,300 m^2 and was demarcated by a 1 m-high stone wall. Each division is supplied with irrigation water though a steel pipe with an outer diameter of 76.3 mm ($2^1/_2$"). Each division is accomplished by furrow or basin irrigation.

There were approximately 20 breeding goats on the farm. Sugar cane leaves used to feed the goats and litter of the shed, and was collected with feces and urine to produce the compost. To promote fermentation of the compost, some water was added. The surface of the compost was then covered with sugarcane leaves to limit the loss of water. In addition, the goats were used for milk and meat.

4. Summary of the Solar Pumping System

The solar pumping system installed in the field in March, 2008 was consisted with 480 W solar module (BP solar BP380J × 6) and a CU200 controller and SQF5A-6 submarine type pump (Grundfos SQflex series). After installation of the system, additional 200 W solar module (Photowatt PWX500 ×

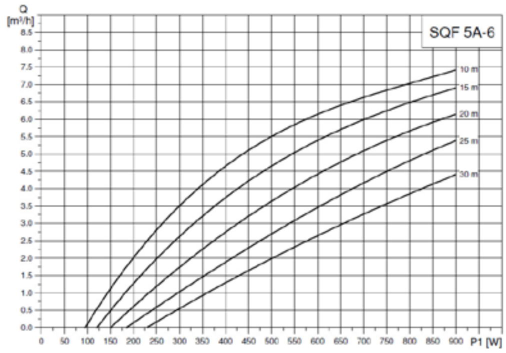

Fig. 3. The relationship between hydraulic head and quantity of water under the power input condition (P1Watts).

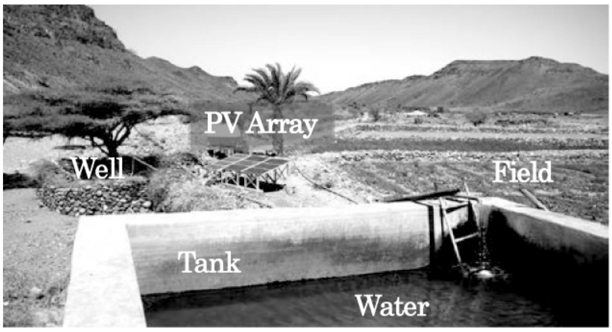

Fig. 4. Whole view of solar pumping system.

4) was installed by the farmer. A concrete water tank (10×5 ×1.5 m) with a capacity of 75 m^3 was installed at the highest point on the farm. The hydraulic head (pump lift) was approximately 15 m. **Figure 3** shows the relationship between hydraulic head and quantity of water under power input condition (P1 Watts). Based on this Figure 3, the flow with the 480 W PV module would be approximately 4.5 m^3/h if it were pumping water from a hydraulic head of 15 m. After the addition of the 200 W module, potential flows could be increased to approximately 6.8 m^3/h. **Figure 4** shows the solar pumping system that was installed.

5. Measurements and Considerations

5.1. Result of measurement

We visited the site in March, 2011 which was approximately three years after the system had been installed. A data logger was installed to measure temperature, relative humidity (RH), quantity of sunlight, PV module temperature, PV module voltage and water tank water level of the water tank every five minutes from March 2 to 4 2011. According to the farmer, daily water use was approximately 50 m^3/day. Details of the crops that were cultivated are shown in Figure 2. **Figure 5** shows schematic of the PV module. About the modules of additional 50W, it was guessed using a middle terminal by the measurement result of the output voltage of this terminal that it was connected in parallel.

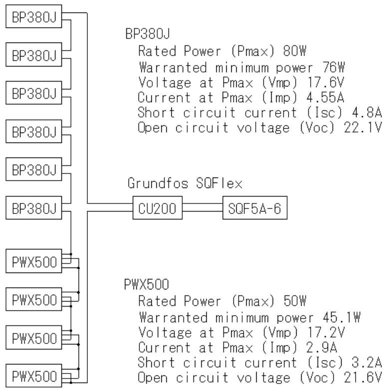

Fig. 5. Wiring of PV array.

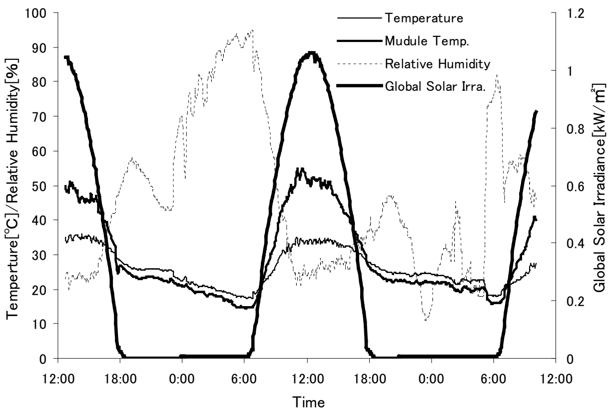

Fig. 6. Measurement results of temperature relative humidity and global solar irradiance.

RH was low during the daytime (about 20%), which is typical of the dry season, but it was relatively high by night time. It is a characteristic of Djibouti located in the shore. The maximum temperature of the PV module was 54.8°C, and the minimum was 14.4°C. The maximum temperature of PV module was approximately atmospheric temperature +15°C. The global solar irradiance was 1.06kW/m^2 and the global solar radiation was 27 MJ/m^2・day. In addition, the PV module array was set up 0° to the south and the tilt angle was 10° to horizontal level.

5.2. System operation

One of the 80 W PV modules that were initially installed was damaged by a stone that had been thrown at the equipment. Innumerable crack on all of the hard glass of PV module surface was observed. And as for the damage, we were apprehensive about infection in the cell of the damage point. **Table 1** shows measurements of the output voltage of each PV module under operating conditions. The output voltage of the damaged PV module was approximately half for 16.6 V of a sound module and repeating 7 V and 3 V in a period for approximately per a second. The output power of array was 450 W (voltage 123 V, current 3.66 A), under condition of

Table 1. Output Voltage of Modules.

Module	Output[V]	Notes
BP80	16.6	
PWX500	8.4	1/2 parallel output
PWX500(broken)	3～7	1/2 parallel output
Arrey	123	

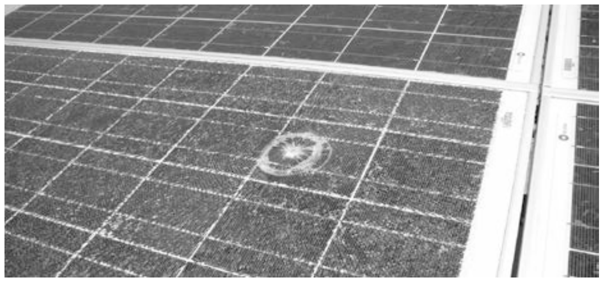

Fig. 7. The damaged PV module by Stone.

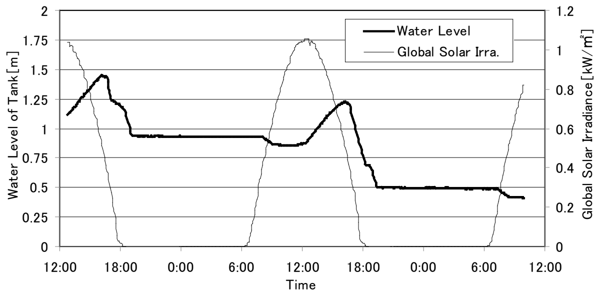

Fig. 8. Measurement result of the water level of tank.

global solar irradiance 856 W/m^2. The ratio of output against the specifications of the module was 72.9% (=350/480) at 350 W against the PV module specification of 480 W by a measurement at the original setting of May, 2008. We tried to apply this ratio to the 2011 result.

For the specifications of the module of 680 W(=480+200), we can expect an electricity output of 496 W(=680×72.9%). Consequently, the loss in power output due to damage by the stone can be calculated as 9.24 %(=(496-450)/496). **Figure 7** shows the state of a module damaged. **Figure 8** shows changes in the water level of the tank over time. The weather during the sampling period was clear, and the pump was operated under sunny conditions of approximately 530 W/m^2 (global solar irradiance) or more. Generally, the system was considered to be operated it under favorable conditions during the daytime.

5.3. Evaluation of the system

We calculated the relationship between the quantity of sunlight and quantity of water pumped and the quantity of water actually used. **Figure 9** shows the result of estimation that was converted to the water level of the tank. The quantity of water pumped was 39 m^3/day (0.78 m), and the quantity of used water were 60.5 m^3/day (1.21 m). And from result of Figure 9, we can calculate output and input of the tank. The

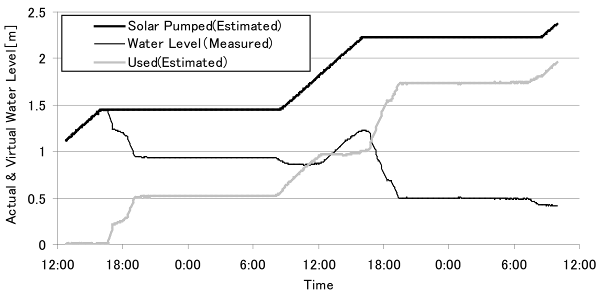

Fig. 9. Water balance of tank by virtual water level.

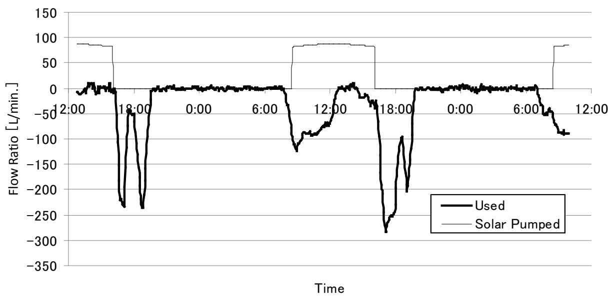

Fig. 10. Input and Output of water tank.

maximum pumping flow rate was 88.0 L/min., the maximum water using flow rate was 280 L/min. If the damage to the module was 9.24%, then assuming no electricity energy was lost, the quantity of water pumped would be 43.0 m^3/day (=39.0 × 100/(100-9.24)). And 957 W (=680 × 60.5/43.0) is necessary to serve 60.5 m^3/day of the actually use quantity of water. This result corroborated those in Figure 3 which showed that 900 W would be required to pump lift the water at a rate of 7.0 m^3/h at hydraulic head 15 m. Since, if 27 MJ/m^2・day is provided, we can expect the daylight hours of 7.5 hours (=27000/3600) at 1 kW/m^2, therefore quantity of pumping of 52.5 m^3/day (=7.0×7.5) is provided.

6. Conclusion

In arid areas, optimal utilization of water for agriculture is essential. This requires the adoption of integrated farming method that use domestic animals, forage crops and compost, as these are all have a marked influence on water use and supply. Integrated farming methods employed near *wadis* are well suited for arid land farming particular at the scale (1.5 ha) examined in this study. In addition it was found that a small solar pumping system such as that examined in this study (900-1,000 W) was effective for farms of this size in arid environments.

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