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SCOPE OF SOLAR IRRIGATION SYSTEM IN SYLHET REGION OF BANGLADESH

M Rahman[1*], PK Sarkar[1] and Z Ferdous[2]

[1]Department of Irrigation and Water Management, Sylhet Agricultural University, [2]Department of Agricultural and Applied Statistics, Bangladesh Agricultural University

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Abstract

This research work was carried out in the Shalla and Dharmapasa Upazila areas of Sunamganj District under Sylhet Division, where two solar-powered irrigation pumps were installed. Daily radiation and temperature were favorable for solar energy harvest. The daily average solar radiation in that place was up to 650 kWh per meter square each month. The global radiation of the solar panel used in our research and the surface temperature of the element were related to each other. On relatively shady days, we find that the amount of electricity generated from solar panels is slightly less than on hot sunny days. The daylight hours were more than 12 hours. The pump was operated for irrigation work without any issues, and discharge was up to the expectations. The overall efficiency of the solar-powered pump was 86% (operational).

Key words: Solar irrigation, Sustainability, PV array, Discharge

Introduction

Adaptation of irrigation strategies in Bangladesh is known to play an important role in developing food grains. In this case, we need a large number of pumps in the rural areas of the country for irrigation in the coming days. Most of the current pumps are diesel engine driven where the power from the national grid is not sufficient for proper maintenance. On the other hand, there is a big problem for grid-connected irrigation pumps because the power supply in Bangladesh is not regular due to a shortage of electricity, and not every irrigation area in Bangladesh is supplied with electricity. Both diesel and grid-powered pumps are producing huge amounts of greenhouse gas (GHG) which is very harmful to our environment. Conventional irrigation systems are dependent on fossil fuels or hydrocarbons, which are limited in nature. This is the right time to think of an alternative, renewable, green energy like the abundant solar energy in nature. As an alternative to conventional methods, solar energy is a very suitable sustainable alternative.

Grameen Shakti is a non-profit company in Bangladesh established in 1996 under Grameen Bank. It aims to promote and supply renewable energy products in rural Bangladesh which is affordable for poor families. Benefiting from Grameen Bank's 40 years of microfinance experience and extensive network across the country, Grameen Shakti has become the largest partner (PO) of Infrastructure Development Company Limited (IDCOL). By the end of 2012, it had installed more than one million Solar Home Systems (SHS) in rural Bangladesh and now accounts for more than half of all IDCOL-supported installations. For working on renewable energy, Grameen Shakti won the European Solar Award in 2003 and the United Kingdom's Award for Sustainable Energy in 2006. It also works to promote biogas plants and improved cooking stoves. The work of SHS promoting rural energy extends beyond the installation. It is also dedicated to local capacity building and job creation, especially for women. By the end of 2013, it had set up 46 technology centers across Bangladesh where customers, mainly women, were trained as technicians to perform SHS services and repairs

****Corresponding author: M Rahman**, Department of Irrigation and Water Management, Sylhet Agricultural University, Email: toyon13@gmail.com*

in their local areas. To date, more than half a million clients have been trained to facilitate the creation of large-scale rural employment.

Solar pumping is an attractive alternative for irrigation and rural, urban drinking water pumping applications in developing countries especially India, China, other Asian and African countries, water for drinking and crop irrigation considering the huge solar potential and the fact that significant rural population lives in remote areas.

Solar irrigation pumps are based on solar photovoltaic technology that converts sunlight into electricity to operate the pump and transport water from the source to the irrigated fields. The system usually consists of a solar photovoltaic array, a control circuit (required electronics), a DC / AC motor pump-set, and a piping system. There may also be a water storage tank and battery, depending on the need. The motor converts the electrical energy supplied by PV into mechanical energy, which is then converted to hydraulic energy by the pump. The power of a solar irrigation pump (SIP) system is a function of three variables which include pressure, flow, and pump power (Chandel R and C, 2015).

Successful and widespread use of renewable energy in agriculture has the potential to meet simultaneously two of the UN's seventeen Sustainable Development Goals (SDGs) - SDG 2 (zero hunger) and SDG 7 (affordable and clean energy). While SDG 2 aims to eliminate hunger, improve food security and nutrition, and promote sustainable agriculture, SDG 7 aims to ensure access to affordable, reliable, sustainable, and modern energy for all (United Nations 2015). The establishment of SIPs in agriculture is seen as the most promising use of renewable energy, which simultaneously provides access to energy and contributes to food production. Recent advances in the design and operation of SIPs and the declining value of photovoltaic (PV) modules have contributed to recent global growth in their use, especially in off-grid areas in developing countries. The agricultural sector accounts for 14.8% of the Gross Domestic Product (GDP) (World Bank, 2016) and is responsible for the livelihood of millions of farmers in Bangladesh, making it essential for a reliable irrigation system.

Recent figures from the Sustainable and Renewable Energy Development Authority (SREDA) indicate that the number of diesel-powered irrigation pumps has increased further, reaching 1.34 million (SREDA, 2017). Difficulties in transporting diesel to the fields and inconsistencies in supply sometimes make farmers dependent on intermediaries, leading to higher diesel prices and the overall cost of irrigation and food production. 19% of the remaining irrigation units are powered by electricity from the national grid, which adds extra pressure to the electrical infrastructure. The country is still facing severe power shortages every day, and the excess demand for electricity from the national grid exacerbates the situation. Most of these electric irrigation pumps have to run at night. Regardless of the fuel used for irrigation; that is, diesel and electricity, the existing pumps are responsible for a significant contribution to the country's fossil fuel consumption and total greenhouse gas emissions. This scenario demonstrates the significant potential of Bangladesh's agricultural sector for the use of renewable energy technologies, especially solar photo voltaic-powered irrigation pumps. Following the global trend of increasing the use of solar energy in power irrigation pumps, the Government of Bangladesh has launched various projects to promote the use of SIPs across the country. Government agencies such as Bangladesh Agriculture Development Corporation (BADC), Rural Electrification Board (REB), Barind Multipurpose Development Authority (BMDA), and Infrastructure Development Company Limited (IDCOL) have acted as implementing agencies for the implementation of SIP projects. IDCOL aims to install 50,000 solar-powered irrigation pumps by 2025 (IDCOL, 2018). This is one of the challenges that need to be considered in the future when a large number of off-grid SIPs reach the national grid or when new grid-connected SIPs are considered for installation. Integration challenges will be particularly significant in off-seasons when pumps are not used, but solar panels will continue to generate and export electricity to the grid.

The Government of Bangladesh (GoB), through the Bangladesh Rural Electrification Board (BREB), is implementing a large-scale SWP project called "Photovoltaic Pumping for Agricultural Irrigation (SPPAI)", an Asian Development Bank Power System Efficiency Improvement Project (ADB). Bangladesh Agriculture Development Corporation (BADC) estimates that 1.24 million diesel-powered pumps are used for agricultural irrigation in Bangladesh (BADC, 2019). SWP is a mature, reliable, and economically attractive solution for water supply, including large-scale crop flood irrigation (IRENA, 2016). Solar water pumps can increase resilience by helping farmers and market systems prepare and improve economic, political, climate and natural disaster shocks to diversify risk (Sheladia, 2019). The maximum irrigation demand of 2,000 MW during the irrigation season is required to run only electric pumps (Al-Amin, 2017). Islam, Sarker, and Ghosh (2017) suggest that solar irrigation may be an alternative way to increase crop yields and help keep the environment clean without putting additional stress on the grid power or diesel fuel.

The subtropical monsoon climate of Bangladesh is characterized by extensive seasonal variations in temperature, rainfall, and humidity. There is a long rainy season from June to October, followed by incessant rainfall from March to June with a hot and humid summer. Throughout this long month, heavy rains often flooded large areas of arable land across the country. It is reasonable to assume that most SIP systems will not be launched during this long offseason. But once connected to the grid, solar photovoltaic units will generate electricity and feed into the grid. This situation could pose significant challenges to the stable and reliable operation of the national grid. This study mainly focused on the feasibility of sustainable renewable energy for irrigation in the study area (Sylhet region) as natural resources (fuel) become vulnerable day by day.

Materials and Methods

The study area was at the Sunamganj district of Bangladesh. Several landswere selected for field experimental purposes. These landswere irrigated by using a solar pump. Dharmapasha), is an Upazila of Sunamganj District in the Division of Sylhet, Bangladesh. Dharamapasha is located at 24.9000°N 91.0167°E. Sulla Upazila area 260.74 sq km, located between 24°34' and 24°49' north latitudes and in between 91°08' and 91°23' east longitudes.

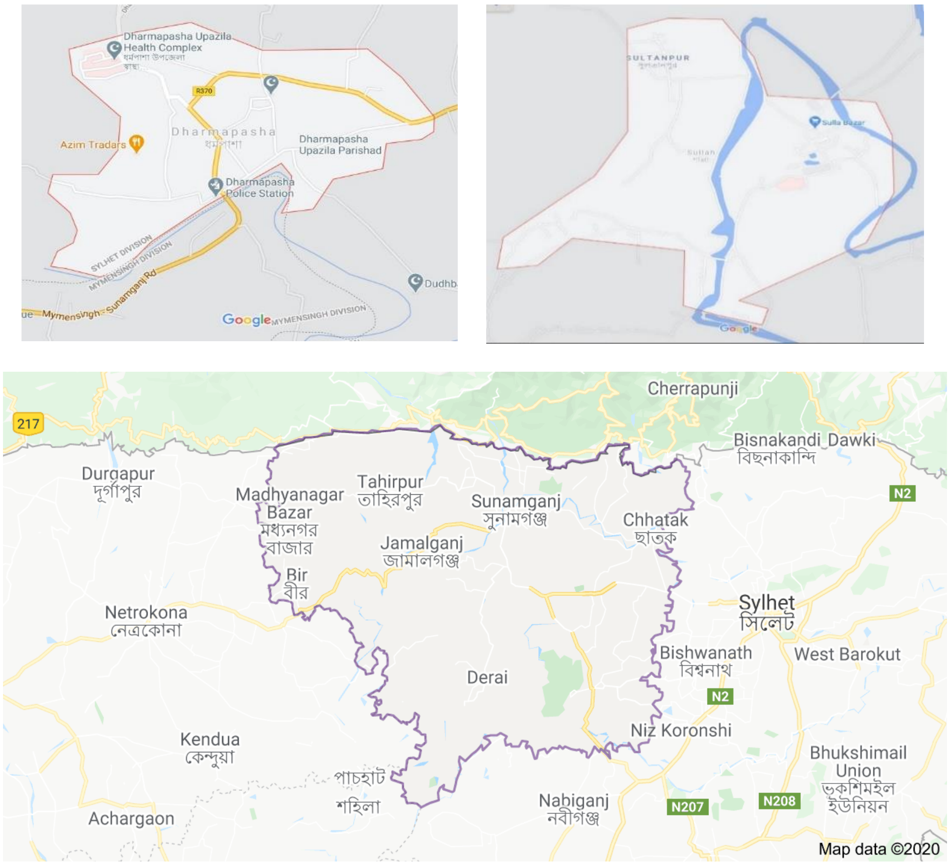

Figure 1. Study area; Dharamapasha and Sulla Upazila

Solar irrigation system in Sylhet region

A photovoltaic system or solar power system is a power system designed to supply usable solar power utilizing photovoltaic action. It consists of an arrangement of several components, including solar panels to absorb and convert sunlight into electricity. Among the others, two types of PV panels- Monocrystalline and Polycrystalline Panels are widely used.

Baseline survey

Field data were collected from solar pump suppliers, service providers, and users. Solar pumps were in operation in different locations of the country. Therefore, field-level data were collected from the relevant traders, service providers, and users associated with the selected pumps. Most of the solar pumps were in operation at field level, supplied and installed by BARI and Grameen Sakti, a non-government organization. Therefore, trader's data were collected from Rahimafrooz Renewable Energy Limited and Electro Solar Power Limited (a leading company that seals PV panels all around the country). Information on service providers was collected from the solar pump locations. Twelve solar pump users from each solar pump were randomly selected and directly interviewed. All primary data were collected from the experimental site (Sunamganj) and Secondary data were from each of the respondents using pre-tested interview schedules, books, journal articles, research reports, the internet, etc. Three sets of interview schedules (solar pump suppliers, service providers, and users) were prepared for primary data collection.

Mechanical analysis

Experiments were conducted in the experimental field. Multimeter, tachometer, and pyranometer were used to measure generator output (Voltage and AC), AC motor speed (rpm), and solar intensity (W/m^2), respectively. An AC motor was coupled to a centrifugal pump. The motor was modified to respond smoothly to the low current supply PV generator throughout the daytime through the months. The motor starts smoothly when the solar intensity reaches 495 W/m^2 (threshold level).

Bangladesh's climatological database for solar energy applications was used to get solar radiation values for the site under investigation. These values, which provide solar radiation averages for 10 years (2010-2020), were used to determine the pumping system output as a relation between solar intensity and solar generator output power.A preliminary experiment was conducted to acquire a relationship between PV pumping system outputs and solar-radiation intensity values; which could rapidly differ from minute to minute during the day and through different seasons. Solar radiation, power consumption (as Voltage and Current), motor RPM and pump flow varied.

Flow chart of the research plan

1. Data collection for system building

For this study, first of all, all related agricultural primary data will be collected from the study area of Sunamganj for a specific dry season. The data of basic agriculture will be obtained by direct observation of crop fields and data records from the local department of agricultural extension. The most cultivated crop was rice and a widely used irrigation practice in this area was basin irrigation.

2. System Design and Installation (Designing a Small-Scale Solar Water Pumping System)

Summary of the system's main components are shown here as below for 16 acres field of rice:

Components

Centrifugal pump

Solar irrigation system in Sylhet region

Peak power requirement	3200 W
Required voltage	50 V
Max input voltage	50 V
Max input current	18 A
Name of the model:	ACI.Ggm.6AR
Horsepower:	3 hp
Kilowatt:	2.25 KW
Discharge capacity:	1000 lt/min
RPM:	2850 rpm

Solar panel

Peak power	320 W

Solar panels configuration

Number of panels	**10**
Peak power	3200 W

Pipe

Type	PVC
Length	60 m
Diameter	38 mm

Irrigation system

Type	Basin

3. System operation and Data collection

After system setup**,** when all elements were fully functional, data was collected for the system for evaluating the system in several ways. The radiation data was measured using a PCE-SPM 1 device for the study period. The data for temperature, relative humidity, and length of daylight for the study area were collected from the field and Bangladesh meteorological department. The discharge of the pump was calculated from the collected raw data from the field. The volumetric method was used for discharge calculation. The formula used was;

Discharge, $Q = V/t$… … … (1)

Where Q is the discharge lt/min

V is the volume of water in litter

t is the time in minute

The rotation of the pump was measured by using a tachometer. The efficiency of the pump was measure by using the followed formula;

Efficiency, $e = (1- (Q/Q_{max}))* 100\%$... … … (2)

Where e is efficiency in %

Q is actual discharge in lt/min

Qmax is the manufacturer's standard maximum discharge in lt/min

A digital multimeter is used to measure the voltage and amperes being generated by a panel under different light conditions. This study used UNI-T UT136B+ Digital Multimeter. Micro Soft corporation tools were used for data calculation and visual representation.

Results and Discussions

Power input vs radiation

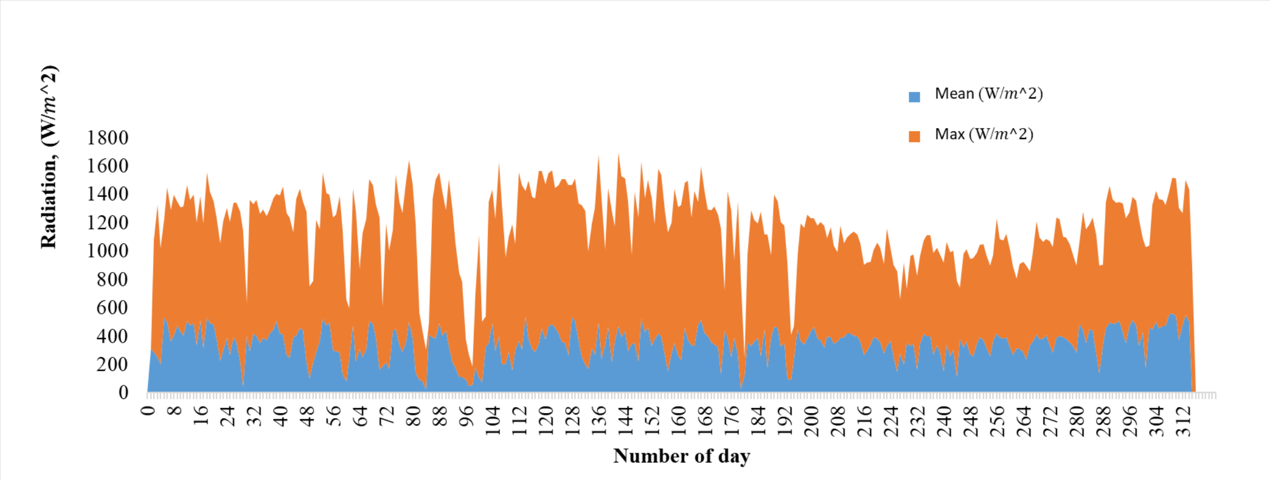

Figure 2. Daily radiation at the field station.

The available radiation on site is shown in Figure 2 above; this figure shows that the radiation is very much favorable for conversion to electric energy. The height value was 1700 w/m^2 recorded, and the average was around 600 w/ m^2. The deflection of radiation was not too high as suspected. Overall condition was satisfactory for set up a solar panel array for harvesting solar energy. Overall condition was satisfactory for setting up a solar panel array for harvesting solar energy, which was subsequently supported by the findings of Putra *et. al.* (2021) from Indonesia.

The available field condition was shown in Figure 3 below, and this figure shows that the recorded temperature was 30 degrees Celsius on an average with respective solar radiation. The relative wind humidity (RH) was near 87 %.

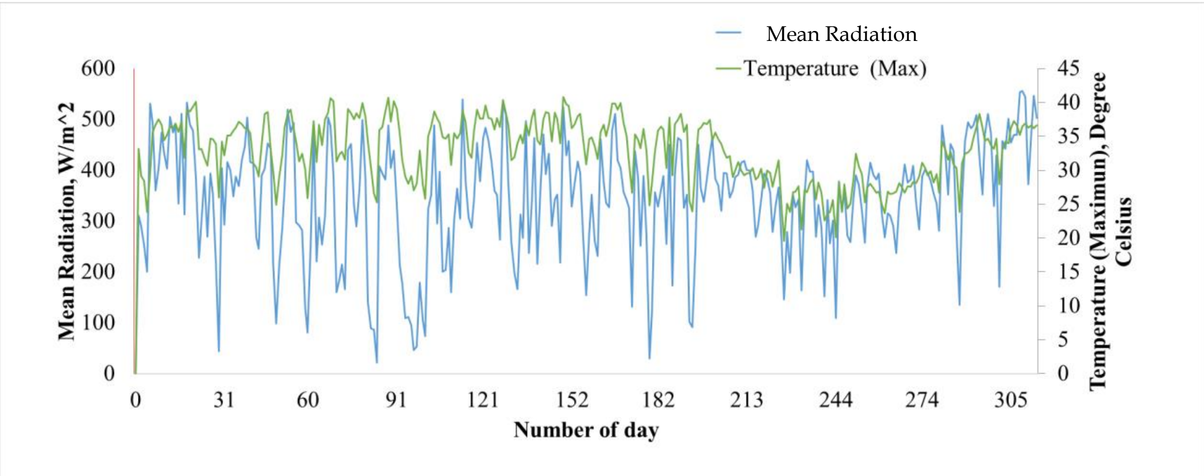

Figure 3. Field condition status.

Monthly average solar radiation

The monthly averaged solar radiation data is shown for the locations. It seems that April is the most favorable time for the high level of direct sun radiation, and the lowest value was found in September. Most likely, January to June is the best 6 months for adopting solar energy.

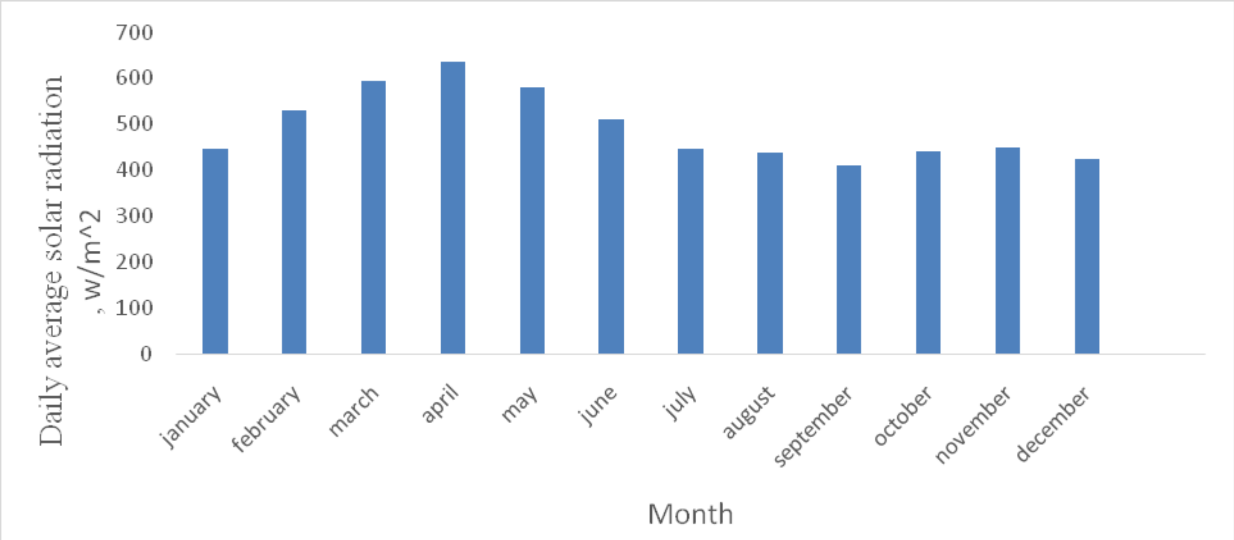

Figure 4. Monthly average solar radiation data for the location.

The solar water pumping station on a sunny day

Figure 5 shows that the temperature has become high as radiation does. The recorded height temperature was 37 degrees Celsius when the respective radiation was 770 W/ m^2. The panel became too hot as direct sunshine was incorporated. The panel became too hot as direct sunshine was incorporated, which was supported by the findings of Putra et al. (2021).

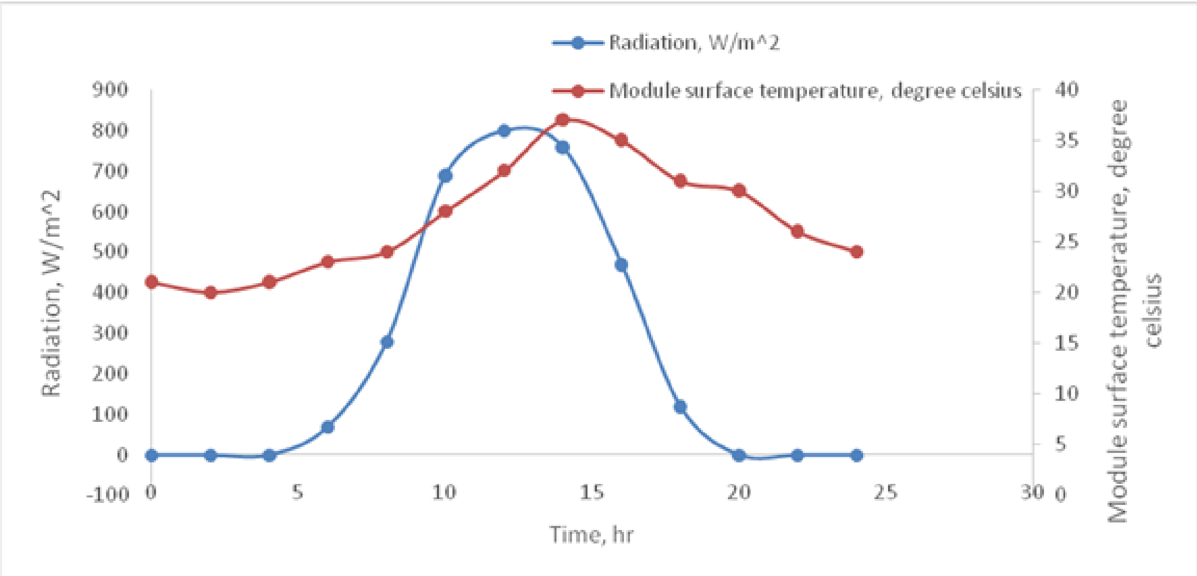

Figure 5. The solar water pumping station on a sunny day

The solar water pumping station on a cloudy day

On a cloudy day, the temperature does not go so high as sunshine are fallen in a fragmented manner on the panel array. The height temperature recorded was 29°C with respective radiation of 640 w/ m^2. The availability of radiation was not smooth as on a sunny day. This type of condition is not desirable for solar energy harvesting.

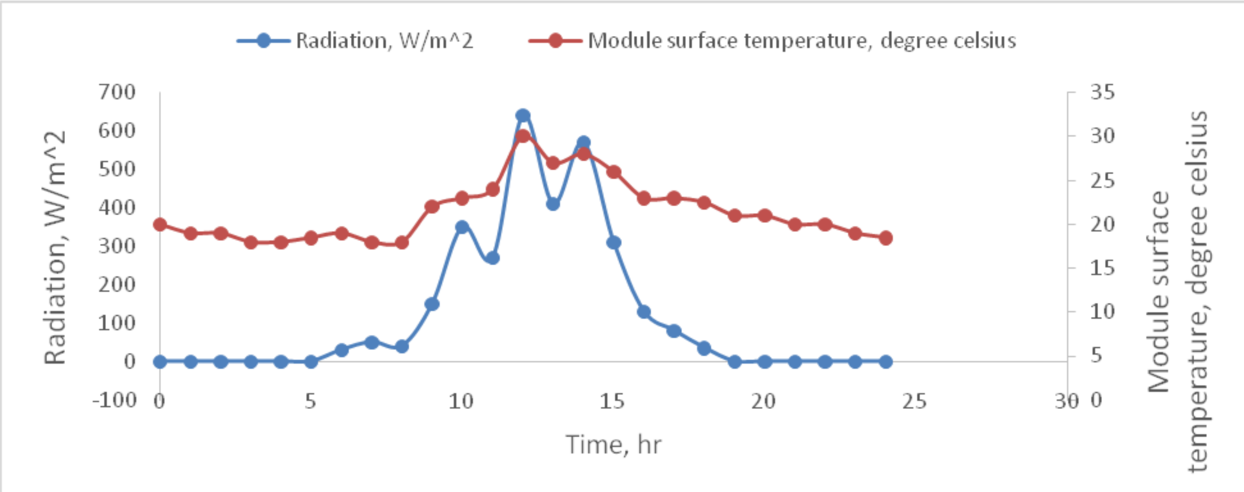

Figure 6.The solar water pumping station on a cloudy day.

Available daylight hours at field level

In Figure 7 we can observe that the length of the day remains almost the same, but it might be reduced to around 1 hour per month. The longest day of July 2020 was 13.15 hours, which is a very decent amount of light hours for harvesting solar power for irrigation purposes.

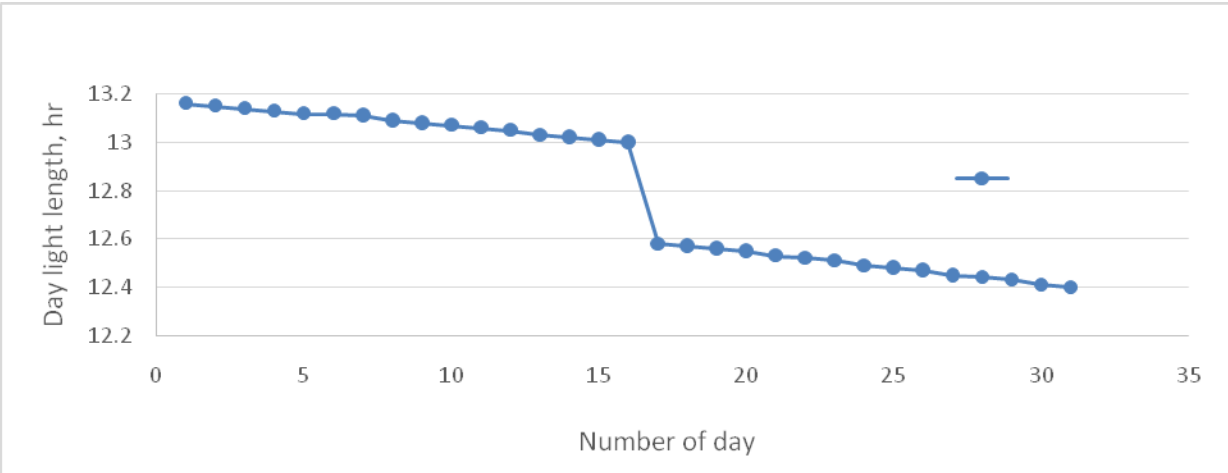

Figure 7. Available daylight hours at field level (July 2019).

Time vs flow rate curve, on an average sunny day

In Figure 8 we can see that the flow rate is very promising here by using solar power. Pumping started at 7 am. The peak flow is available when it's noon. From 10 am to 3 pm the flow rate is very high and constant. The amount of discharge continuously increased with the increasing time from 9 am. The discharge rate was between 150 lt/min to 900 lt/min. Most of the time discharge was about 700 lt/min. This supports the findings of Matheswaran et. al. (2021). They found 50 m^3 for responding to 5.4 KWh/m^2 effective global irradiance.

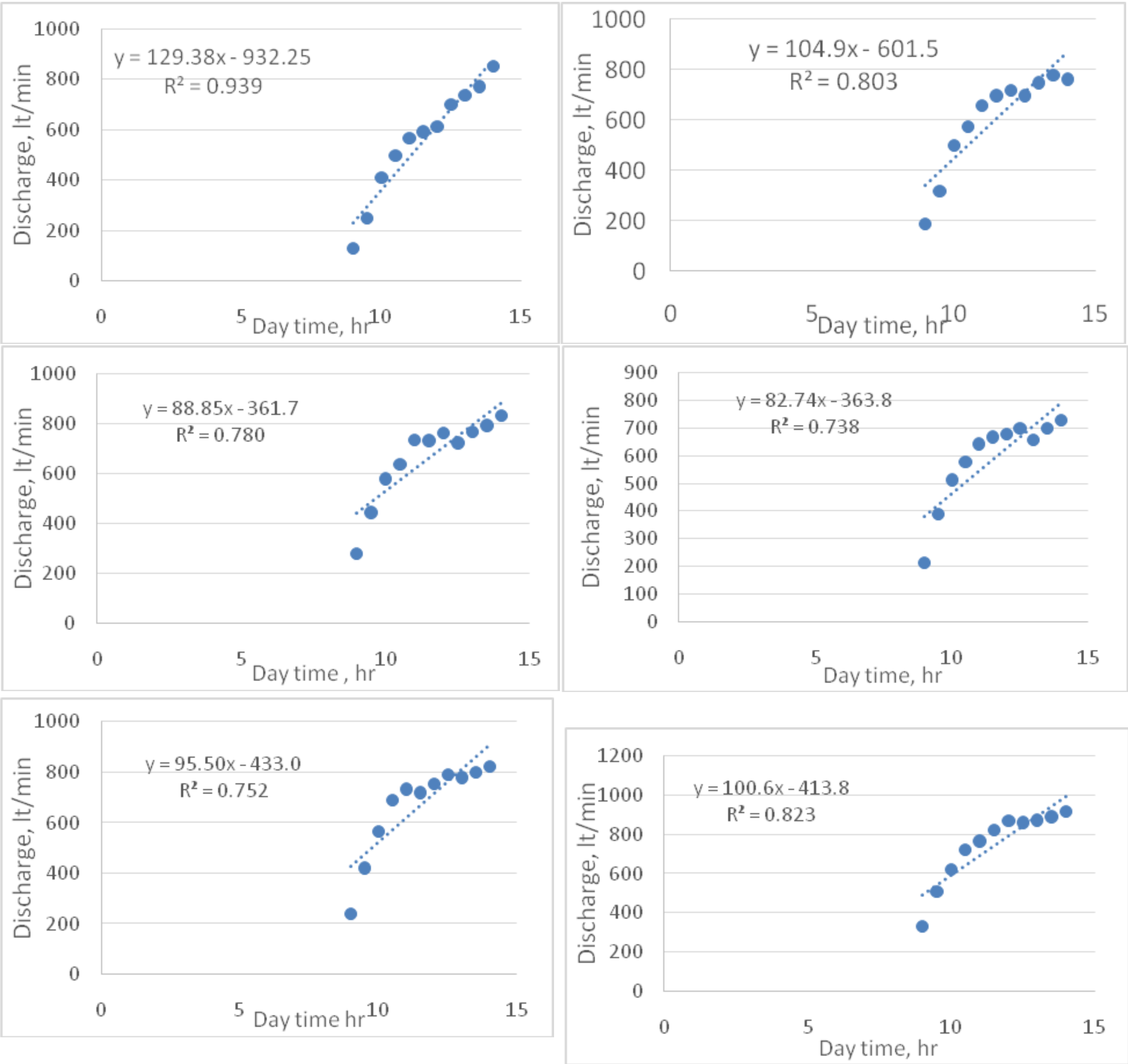

Figure 8. Discharge curve on sunny days

Time vs flow rate curve, on an average cloudy day

In Figure 9 we can see that the flow rate is very limited for a certain period of time here by using solar power. Pumping might be starting from 10 am. The peak flow is available when it's noon. From 10 am to 3 pm the flow rate is moderate and constant.

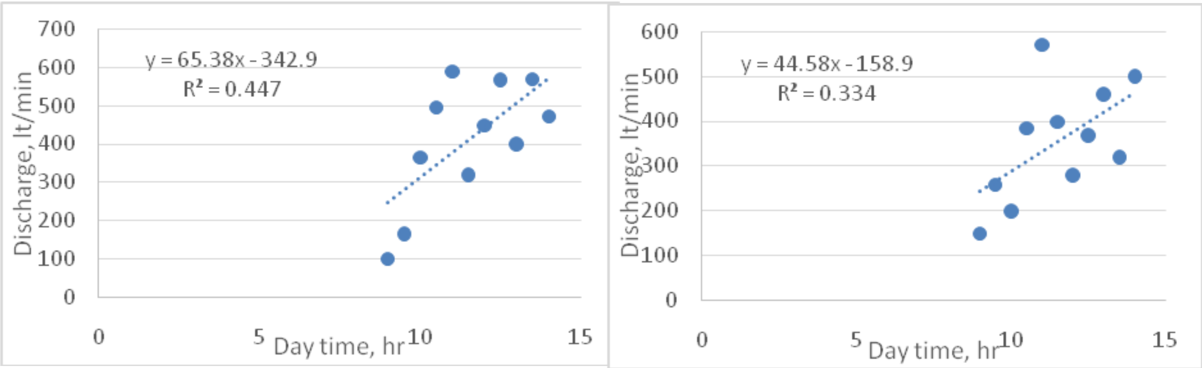

Figure 9. Discharge curve on sunny days on cloudy days

System power generation, rotation, and efficiency

Figure 10 shows that the RPM is very with ups and downs for a certain period of time here because of power variation. Efficiency was found height 86% (operation) and the corresponding RPM was around 2300 rpm where the manufacturing value was 2850 rpm. This deflection of 550 rpm was observed due to power shortage. Full capacity rotation may be found if a total of 2.25 kW power could be supplied. Efficiency was increasing with respecting RPM. The range of efficiency was 43% to 86%. This supports the findings of Matheewaran et. al. (2021). They found 82% efficiency for responding to 959 W/m^2 effective global irradiances, but the highest efficiency was 96 % which is a bit higher compering our findings. Al-Amin et. al. (2017) found 63% efficiency overall from the system, which is 23% less than our calculated value.

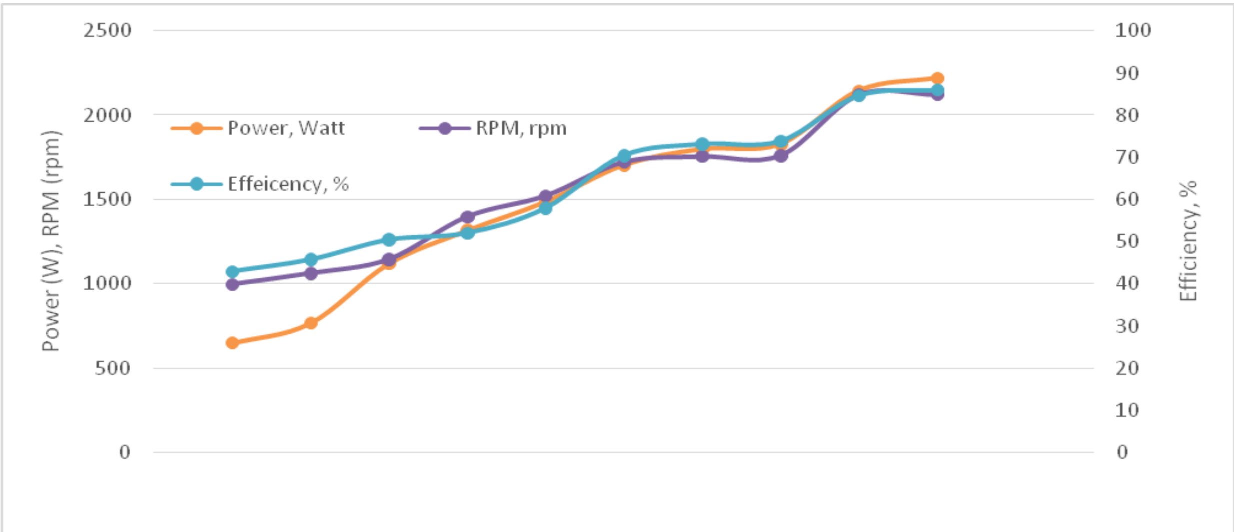

Figure 10. System power generation, pump rotation, and efficiency curve

Correlation between pump delivery and solar radiation

Linear relationships concerning solar radiation values (W/m2) with pump discharge (lt /min) were obtained using the curve fitting equation (500≤R≤900) as illustrated in Figure 11. The range of discharge was 150 lt/min to 900 lt/min. The relation between Radiation and discharge is highly correlated. The correlation coefficient was between 0.6 to 0.95 in most of the cases. The result is well fitted with Al-Amin et. al. (2017). Al-Amin et. al. (2017) found that similar discharge for radiation ranges from 740 to 860 W/m^2.

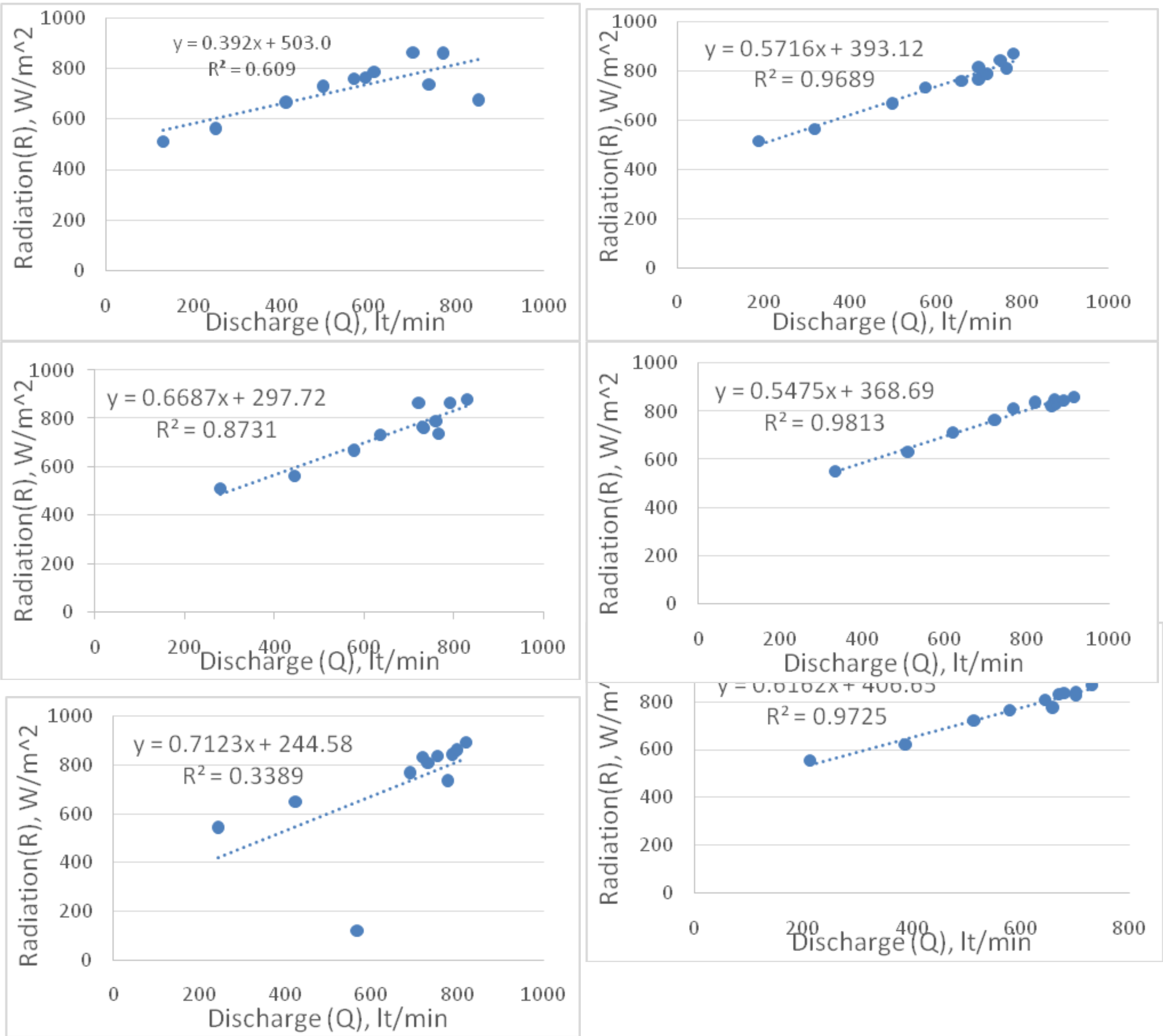

Figure 11. Pump discharge at different solar radiation levels.

Power consumption and solar radiation

The power consumption of the pump with respect to radiation is shown in Figure 12. The power consumption increases with the radiation. The correlation coefficient was 0.95, which indicate pump get handsome amount of power as radiation increase.

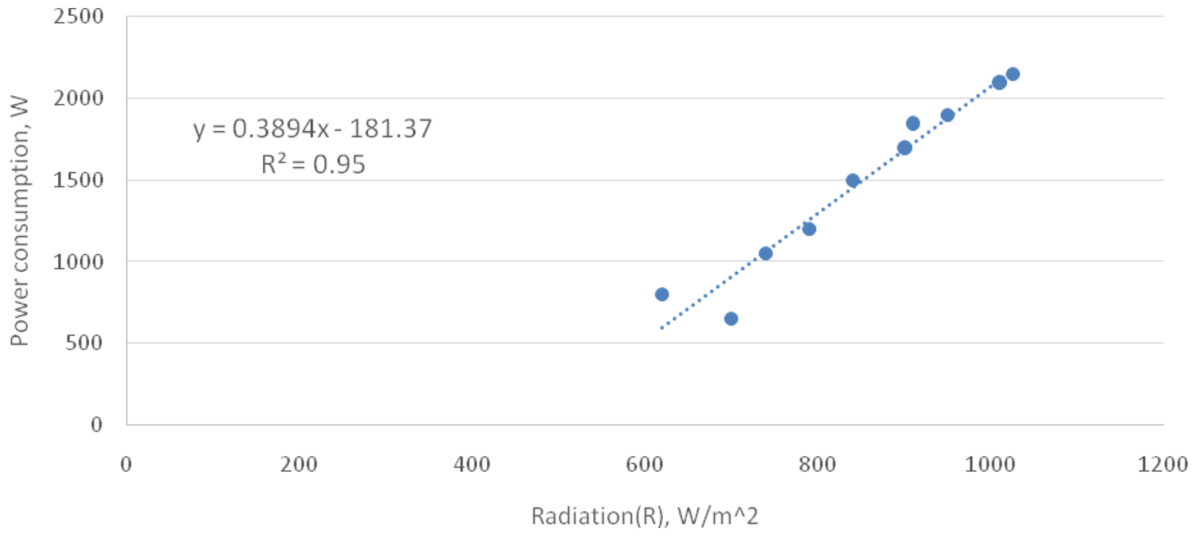

Figure 12. Power consumption with different solar radiation available in field level

Conclusion

Solar irrigation has high scope to expand its wings in the western part of Bangladesh especially in haor areas of Sunamganj district, due to its environmental condition and lack of on-grid connection. Solar irrigation system shows very promising performance in this area and also open an opportunity to increase irrigated crop area to meet the crop demand of time. A solar-powered irrigation system is highly recommended for its high mechanical feasibility, according to the research findings. If any electrical power comes from oil or coal production, then any use of solar, including a solar pump, reduces the use of these fossil fuels, which are highly reliable and durable. In this climate-changing era, solar irrigation may play a key role in reducing the promotion of coal-based thermal power plants and overhead grid lines in this diversified inhabits of endangered species of birds and other avis. It will not promote bio inhabit disturbance but also increase the life standard of local farmers without or minimum manipulation of environmental elements. It will be possible to eliminate local water conflicts among farmers as the timeliness of water will be no more an important issue due to using a solar irrigation system.

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