The application of solar water pump for drip irrigation to increase shallot yield on dry land

P Rejekiningrum, Y Apriyana and Harmanto

Indonesian Agroclimate and Hydrology Research Institute, Bogor, Indonesia

E-mail: popirejeki@gmail.com

Abstract. Solar Water Pump Irrigation System (SIPTS) is a renewable energy to solve water problem in agriculture. SIPTS could reduce greenhouse gas emissions and draw water to agricultural lands through supplementary irrigation. The objectives of research are to design a SIPTS for drip irrigation and to calculate the irrigation efficiency of SIPTS and GHG emission reduction. The results of the study indicate that the use of SIPTS could save fuel consumption from 70 to 14 L ha\(^{-1}\) season\(^{-1}\), resulting in a savings of 400%. Furthermore, the use of SIPTS could reduce GHG emissions originating from the use of hydrocarbon materials from 0.176 to 0.035 t of CO\(_2\) which is more environmentally friendly. In addition, the results of water content analysis show that the use of SIPTS with streamline drip irrigation has relatively higher water content than that of farmers' irrigation practices, this indicates that irrigation system is more effective in distributing water horizontally and vertically. Likewise, plant growth and shallot yield represented indicate higher growth and yield compare to farmers' practices.

1. Introduction

Shallot (Allium ascalonicum L.) which is mostly grown on dry land has good market prospects because most Indonesian people need, so it is in a strategic and superior commodity for national economy [1].

Shallots have shallow root systems and very susceptible to loss of moisture from the topsoil, so efficient irrigation or additional irrigation must be provided to maintain growth [1]. There was an increase in water use efficiency by shallot plants from 6 to 13% under the conditions of 75% water requirement from Plant Evapotranspiration (ETc) [2]. The use of drip irrigation on shallot plants is proven to meet water needs in the root zone, increase water use efficiency, and increase nitrogen use [3]. The advantages of drip irrigation technology can save water up to 55% compared to the method of flushing [4].

The exploitation of dry land is still very limited in Indonesia, whereas the potential for agricultural development is quite high. Agriculture on dry land requires irrigation, and determining the appropriate time and amount of irrigation water is intended to increase irrigation efficiency [5]. The use of irrigation water can be increased by reducing water application at a lower than normal amount until the plant is subjected to mild stress but has minimal impact on yield [6].

The main problem of agricultural development on dry land is the limited availability of water, especially in the dry season. One of the solutions to increase land productivity is by providing water for supplementary irrigation through optimizing the potential of existing water resources in the region. Farmers who are using water for supplementary irrigation often use pumps, both electric pumps and fuel pumps. Since not all lands have electrical energy infrastructure due to remote location constraints.
and/or limited electricity supply and/or high fuel prices, solar energy can become the solution to drive pumps. Solar power pumps take advantage of free solar radiation as an energy source for irrigation [7]. According to BMKG data, the potential for solar radiation in Indonesia is quite large, with an average radiation intensity of 4.8 kWh m\(^{-2}\) hour\(^{-1}\) throughout the year. However, the utilization has only reached 5 mWp, so that it can be optimized for the supply of electricity for irrigation which is expected to be able to meet the needs for irrigation, as solar power pumps have been developed [8].

Utilization of solar energy has various advantages, including: (1) this energy is available in large quantities in Indonesia, (2) it strongly supports national energy policies for energy savings, diversification, and distribution, (3) it to be installed in remote areas because it does not require energy transmission and transportation of energy sources [9].

Solar water pumps are more efficient and economical because they do not depend on electricity or other fuels, require less operation and maintenance costs, and do not even burden farmers and their groups in carrying out their farming activities. For this purpose, a solar water pump will be developed. Solar water pumps are easy to use, and they provide a high efficiency, stable performance and can be used for a long time [7].

The objectives of this research are: (1) to design a Solar Water Pump Irrigation System (SIPTS) for drip irrigation to save water and energy, and (2) to estimate the efficiency water use of SIPTS and GHG emission reduction.

2. Materials and methods

2.1. Study area

The location of research is in Tanjung Hamlet, Bleberan Village, Playen Sub-district, Gunung Kidul Regency, Daerah Istimewa Yogyakarta (DIY). The geographical location of the Bleberan Village is at an altitude of 188.20 m above sea level, average temperature of 23-33°C with relative humidity ranging from 80-85%, and average rainfall of 1,400 mm year\(^{-1}\). Soil type is dominated by the association of red and black grumosol mediterranean with limestone as the main parent material. Even though there is a long dry season, the water particles is still able to survive. There was a river above the ground, but in the dry season the water was dry.

2.2. Materials and tools

The materials used are (1) materials for the manufacturing of solar-powered pumps (solar panels, Solar Charge Controller (SCC), Master Circuit Board (MCB), dry batteries, inverters, power dividers, lighting lamps, installed electric power used for solar power pump assembly), (2) drip irrigation materials (PVC pipe, streamlined hose, TLTO, ball valve, vlosox, elbow, tee, water tank, water meter) which are directly connected to a solar-powered pump are used to build irrigation network, (3) field experiments for planting shallots used for field experiments on irrigation efficiency (seeds, fertilizers, pesticides, etc.). The tools used are a set of tools to assemble a solar-powered pump in the form of an electronic control device and a plant observation device (a ruler for measuring plant height, a caliper for measuring tuber thickness, and a scale for measuring tuber weight).

2.3. Methods

2.3.1. Design of solar water pump irradiation system. To determine a solar pump efficiency, it needs information on the availability and demand of water, the difference in height between the water source and the ground (head), and the potential to absorb solar radiation in solar panels. Debit and streamflow data was measured using a current meter, the solar radiation was measured from AWS, and the height difference was determined using a total station (TS). Meanwhile, irrigation water needs (amount and interval) were calculated using FAO water balance.

The length of operation of the pump is calculated based on the components of the solar pump installed, namely: (1) solar panel specifications, (2) dry battery specifications, (3) pump specifications,
and (4) current consumption of pumps and inverters. Furthermore, analyzing the determination of
the pump potential for effective irrigation areas related to the area of land developed for crop irrigation
applications.

2.3.2. Application of drip irrigation from solar water pump irrigation system for plant irrigation. The
irrigation required was calculated using the FAO method [10]. This method calculates the water
requirements of the plant by considering the physical characteristics of the soil and the depth of roots
at each phase of plant growth. The optimization of the irrigation interval was analyzed based on the
comparison between the net irrigation need (NID) for each plant growth phase and the cumulative
plant evapotranspiration. Plant evapotranspiration is calculated based on the following equation:

$$ET_c = K_c \times ET_o$$

where:
- $ET_c$ : crop evapotranspiration
- $ET_o$ : reference evapotranspiration
- $K_c$ : crop coefficient

To calculate plant evapotranspiration, we followed several steps:
- Identify the stage of plant growth, determine the length of each growth period and choose the $K_c$
  that corresponds to the growth period.
- Calculate $K_c$ in the middle of the growth period based on daily climatic conditions using the
  following equation:

$$K_c_{mid (Tab)} = K_{cmid} + \left[0.04(U_2 - 2) - 0.004(RH_{min} - 45)\right]^{0.3}$$

where:
- $K_c_{mid (Tab)}$ : the value of $K_c$ in the middle of the growth period is based on the table
- $U_2$ : daily average wind speed during
- $RH_{min}$ : daily average relative minimum humidity
- $h$ : plant height during the middle of the plant growth period (m)

2.3.3. Field experiment. The optimal irrigation interval is determined if the cumulative ETP of daily
plants is less or equal to the net irrigation need. Field testing, to test the ability of a solar water pump
that can function as a substitute for conventional energy for irrigation was carried out in Bleberan
Village, Playen Sub-district, Bantul Regency, Yogyakarta.

The experimental design used a Split Plot Design. The main plot was irrigation systems consisting
of conventional irrigation/farmers' practices ($A_0$), and recommended irrigation with 3 levels, namely
100% irrigation ($A_1$), 85% irrigation ($A_2$) and 70% irrigation ($A_3$) of water requirements for chili
plants according to FAO. The sub plot consists of the use of mulch, namely without mulch ($M_0$) and
with mulch ($M_1$).

Each treatment was repeated 4 times, with the following treatment combinations:
- Main plot: irrigation systems
  - $A_0$ = conventional irrigation
  - $A_1$ = recommended irrigation 100%
  - $A_2$ = recommended irrigation 85%
  - $A_3$ = recommended irrigation 70%
- Sub plot: mulch application (black plastic mulch)
  - $M_0$ = without mulch
  - $M_1$ = with mulch
Each treatment was repeated 4 times, with the following treatment:
1. $A_0M_0 =$ conventional irrigation + without mulch
2. $A_0M_1 =$ conventional irrigation + with mulch
3. $A_1M_0 =$ recommended irrigation 100% of FAO crop requirement (CR) + without mulch
4. $A_1M_1 =$ recommended irrigation 100% of FAO CR + with mulch
5. $A_2M_0 =$ recommended irrigation 85% of FAO CR + without mulch
6. $A_2M_1 =$ recommended irrigation 85% of FAO CR + with mulch
7. $A_3M_0 =$ recommended irrigation 70% of FAO CR + without mulch
8. $A_3M_1 =$ recommended irrigation 70% of FAO CR + with mulch

2.3.4. Calculation of the water efficiency of a solar pump compared to a centrifugal/jet pump pump. To optimize the use of water at the location where the equipment is installed, the SIPTS irrigation efficiency is calculated using a centrifugal pump that has been used by farmers. Efficiency is done by calculating the need for fuel costs in one planting season (PS), with several equations to calculate the followings: (1) total volume of irrigation needs during PS, (2) volume of pumped water for a particular time, (3) total duration of pump operation to meet irrigation needs, and (4) the total cost of fuel needs during PS. The equation used is as follows:

a. Calculation of the total volume of irrigation needs for PS:

$$K_V = \frac{K_I}{A}$$  \hspace{1cm} (3)

where:
$K_V =$ the total volume of irrigation needed for PS per unit area (m$^3$)
$K_I =$ total irrigation needs (mm)
$A =$ irrigated land area (m$^2$)

b. Calculation of the pump water volume for 1 hour

$$R_D = \frac{K_P}{O_t}$$  \hspace{1cm} (4)

where:
$R_D =$ pump water volume for 1 hour (m$^3$ hour$^{-1}$)
$K_P =$ pump capability according to specifications (l sec$^{-1}$)
$O_t =$ tested pump operating time (hour)

c. Calculation of the total operational duration of pump to meet irrigation needs

$$D_o = \frac{K_V}{R_D}$$  \hspace{1cm} (5)

where:
$D_o =$ the total duration of pump operation to meet irrigation needs (hour)
$K_V =$ the total volume of irrigation needed for planting season per unit area (m$^3$)
$R_D =$ pump water volume for 1 hour (m$^3$ hour$^{-1}$)
d. The total cost of fuel needs during the planting season

\[ B_o = D_o \times K_B \times H_B \]  

where:
- \( B_o \) = total cost of fuel needs during the growing season (IDR)
- \( D_o \) = total duration of pump operation to meet irrigation needs (hour)
- \( K_B \) = requirement of fuel oil per hour (L)
- \( H_B \) = price of fuel oil at that time ( IDR)

2.3.5. Calculation of greenhouse gas (GHG) emissions. The formula for calculating the value of CO\(_2\) emissions from gasoline as follows [11].

\[ E_{CO_2} = P_e \times CC_{Ce} \times RO \times \left( \frac{44}{12} \right) \]  

where:
- \( E_{CO_2} \) = CO\(_2\) Emissions (t)
- \( P_e \) = energy/fuel use (L)
- \( CC_{Ce} \) = energy/fuel carbon content (g L\(^{-1}\))
- \( RO \) = oxidation ratio

In figure 1 the stages of planting consist of cultivating soil, making experimental plots, watering, planting, and irrigation treatment.

**Figure 1.** Stages of shallot planting start from tillaging, plotting, planting, irrigating, and harvesting.
3. Results and discussion

3.1. Design of solar water pump irrigation system

In designing a solar powered pump, the following system equipment is needed: (1) Solar Panel Array, (2) Power Inverter, (3) Solar Charge Controller, (4) Battery Array from dry battery, (5) Timer, (6) Contactor, (7) Centrifugal Pump. The constituent components are presented in figure 2, the SIPTS configuration and design are shown in figures 3 and 4, respectively.

The working principle of the system is that solar panels convert sunlight into electrical energy which is channeled through the solar charge controller to charge the electric current to the dry battery. The electric energy in the dry battery is converted from direct current voltage to alternating current voltage by the inverter, then the inverter supplies AC power to the pump based on the timer control.

![Solar panel array](image1)
![Solar charge controller](image2)
![Power inverter](image3)
![Centrifugal pump](image4)

**Figure 2.** The components of a solar water pump.

**Figure 3.** Configuration of solar water powered pumps.
3.2. Solar water pump application for shallot plant irrigation

To calculate the irrigation needs (dose and interval) for shallot plants, it was carried out using the FAO equation with available water input data calculated based on the results of the analysis of soil physics samples at the research location [10]. The results of soil physics analysis and calculation of shallot water requirements are presented in tables 1 and 2.
### Table 1. Soil physics analysis to calculate water available.

| Growth stage   | Length of growing phase (Day) | Period         | ETo (mm day$^{-1}$) | Kc | ETc (mm day$^{-1}$) | Water content (%) |
|----------------|--------------------------------|----------------|---------------------|----|---------------------|-------------------|
| Initiation     | 10                             | 18-May-2017    | 27-May-2017         | 3.6| 0.7                 | 2.59              |
| Vegetative     | 20                             | 28-May-2017    | 16-Jun-2017         | 3.6| 0.9                 | 3.17              |
| Tuber formation| 15                             | 17-Jun-2017    | 1-Jul-2017          | 3.9| 1.2                 | 4.60              |
| Ripening       | 10                             | 2-Jul-2017     | 11-Jul-2017         | 3.9| 1.2                 | 4.49              |
| Harvesting     | 5                              | 12-Jul-2017    | 16-Jul-2017         | 3.7| 0.5                 | 1.85              |

### Table 2. The calculation of crop water requirement of shallot plants.

| Growth stage   | Length of growing stage (Day) | Period         | ETo (mm day$^{-1}$) | Water available (%) | Maximum depth of root (m) | Total water available (mm) | Groundwater decrease fraction (p) | Net irrigation requirement (mm) | Irrigation interval (Day) |
|----------------|--------------------------------|----------------|---------------------|---------------------|---------------------------|---------------------------|---------------------------------|-----------------------------|---------------------------|
| Initiation     | 10                             | 18-May-2017    | 27-May-2017         | 2.59                | 0.10                      | 16.6                      | 5                              | 5                           | 2                         |
| Vegetative     | 20                             | 28-May-2017    | 16-Jun-2017         | 3.17                | 0.10                      | 16.6                      | 5                              | 5                           | 2                         |
| Tuber formation| 15                             | 17-Jun-2017    | 1-Jul-2017          | 4.60                | 0.20                      | 33.3                      | 0.3                            | 10                          | 3                         |
| Ripening       | 10                             | 2-Jul-2017     | 11-Jul-2017         | 4.49                | 0.20                      | 33.3                      | 10                            | 10                          | 3                         |
| Harvesting     | 5                              | 12-Jul-2017    | 16-Jul-2017         | 1.85                | 0.20                      | 33.3                      | 10                            | 10                          | 6                         |
Calculation of the optimal dosage and irrigation interval for shallot plants is presented in table 3.

### Table 3. Irrigation volume, irrigation dosage, and irrigation scheduling of shallot plants.

| Growth period | Day after planting (DAP) | Day of Irrigation | Irrigation doses (mm) | Irrigation volume (m³) | Irrigation time at 100% doses | Irrigation time at 85% doses | Irrigation time at 70% doses |
|---------------|--------------------------|-------------------|-----------------------|------------------------|-------------------------------|-------------------------------|-------------------------------|
|               |                          |                   |                       |                        | Hour | Minute | Hour | Minute | Hour | Minute |
| Planting      | 0                        | 17-May-17         | 7.5                   | 0.9                    | 56   | 0      | 48   | 0      | 39   | 0      |
|               | 3                        | 20-May-17         | 7.5                   | 0.9                    | 56   | 0      | 48   | 0      | 39   | 0      |
|               | 6                        | 23-May-17         | 7.5                   | 0.9                    | 56   | 0      | 48   | 0      | 39   | 0      |
|               | 9                        | 26-May-17         | 7.5                   | 0.9                    | 56   | 0      | 48   | 0      | 39   | 0      |
| Second        | 12                       | 29-May-17         | 7.5                   | 0.9                    | 56   | 0      | 48   | 0      | 39   | 0      |
| vegetative    | 15                       | 1-Jun-17          | 7.5                   | 0.9                    | 56   | 0      | 48   | 0      | 39   | 0      |
|               | 18                       | 4-Jun-17          | 7.5                   | 0.9                    | 56   | 0      | 48   | 0      | 39   | 0      |
|               | 21                       | 7-Jun-17          | 7.5                   | 0.9                    | 56   | 0      | 48   | 0      | 39   | 0      |
|               | 24                       | 10-Jun-17         | 7.5                   | 0.9                    | 56   | 0      | 48   | 0      | 39   | 0      |
|               | 27                       | 13-Jun-17         | 7.5                   | 0.9                    | 56   | 0      | 48   | 0      | 39   | 0      |
|               | 30                       | 16-Jun-17         | 7.5                   | 0.9                    | 56   | 0      | 48   | 0      | 39   | 0      |
| Flowering     | 33                       | 19-Jun-17         | 9.9                   | 1.2                    | 74   | 0      | 63   | 0      | 52   | 0      |
|               | 36                       | 22-Jun-17         | 9.9                   | 1.2                    | 74   | 0      | 63   | 0      | 52   | 0      |
|               | 39                       | 25-Jun-17         | 9.9                   | 1.2                    | 74   | 0      | 63   | 0      | 52   | 0      |
|               | 42                       | 28-Jun-17         | 9.9                   | 1.2                    | 74   | 0      | 63   | 0      | 52   | 0      |
|               | 45                       | 1-Jul-17          | 9.9                   | 1.2                    | 74   | 0      | 63   | 0      | 52   | 0      |
| Tuber         | 48                       | 4-Jul-17          | 9.9                   | 1.2                    | 74   | 0      | 63   | 0      | 52   | 0      |
| formation     | 51                       | 7-Jul-17          | 9.9                   | 1.2                    | 74   | 0      | 63   | 0      | 52   | 0      |
|               | 54                       | 10-Jul-17         | 9.9                   | 1.2                    | 74   | 0      | 63   | 0      | 52   | 0      |
|               | 57                       | 13-Jul-17         | 9.9                   | 1.2                    | 74   | 0      | 63   | 0      | 52   | 0      |
|               | 60                       | 16-Jul-17         | 9.9                   | 1.2                    | 74   | 0      | 63   | 0      | 52   | 0      |

The results of dose analysis and irrigation intervals using the FAO method [10] show that the total irrigation needs of 464.3 mm are equivalent to 4,643 m³ ha⁻¹ season⁻¹, while the total water needs applied to irrigate shallot plants using real streamline drip irrigation techniques in the field based on the water meter designation figures during plant growth of 449.2 mm, equivalent to 4,492 m³ ha⁻¹ season⁻¹ with three-daily irrigation intervals with an average distribution of 7.5-9.9 mm ha⁻¹ season⁻¹. So this shows that between prediction and realization is relatively not different, a difference of about 15.1 mm between the forecast result and the realization of irrigation has occurs due to the influence of a little streamlined pipe seepage [4].

3.3. Effect of drip irrigation using SIPTS on plant growth and yield

The availability of water is an essential requirement for optimal tuber yield and quality. Providing proper water can not only make water use more efficient, but it can also prevent the possibility of developing fungal diseases, especially in conditions of high humidity. Research results by Bakhri et al. [12] the amount of water needed to irrigate the plants was highly dependent on the irrigation system used.

Furthermore, the irrigation system used by Palu shallot farmers is a furrow system [12,13]. With this system, for two months, it is irrigated seven times at an interval of 6 days, and the total water consumption is 140 m³ ha⁻¹. Thus, the farmer irrigation system requires more water than the A1 irrigation system (groundwater condition is 100% field capacity), which only requires 83.60 m³ ha⁻¹ of irrigation water or the equivalent of 0.16 m³ per channel provided through the system irrigation of the grooves.

The irrigation system for farmers in the research location generally uses a method of watering with a hose whose water source from the river around the area is taken to the surface using a centrifugal pump (jet pump) using gasoline as fuel. The fuel consumption used by farmers to irrigate their land during the dry season is 2-3 L ha⁻¹ day⁻¹.

Figure 6 shows the trend of shallot plant height at ten days after planting, 10, 30, and 60 DAP during the growing period, which seems to be different between the irrigation treatment recommended by SIPTS and farmer’s irrigation. The height of shallot plants on the recommended irrigation is 70, 85,
and 100% higher than that of the farmer’s pattern. At an irrigation dose of 85%, the average height of shallot plants is the highest compared to other treatments, while the shortest is found in shallots with farmer irrigation pattern.

![Figure 6. The trend of shallot plant height in irrigation and mulching treatment.](image)

The differences in irrigation levels of 70, 85, and 100% of the water used for shallot plants show different effects on plant height through Duncan Multiple Range Test (DMRT) (table 4). When the plants were 10, 30, and 60 DAP, the plant height in the irrigation treatment was 70, 85, and 100% higher than the height in the conventional irrigation treatment. The highest plant height was achieved at an irrigation rate of 85% with mulch and the lowest was treated with conventional irrigation without mulch. The height of shallot plants on land with mulch was higher than without mulch [4].

### Table 4. Effect of irrigation level and mulch on the shallot plant height.

| Treatment | 10 DAP | 30 DAP | 60 DAP |
|-----------|--------|--------|--------|
| A0M0      | 15.52  | 31.38  | 29.94  |
| A0M1      | 16.23  | 32.67  | 34.52  |
| A1M0      | 18.78  | 32.78  | 31.42  |
| A1M1      | 19.84  | 32.52  | 31.81  |
| A2M0      | 19.59  | 33.70  | 33.00  |
| A2M1      | 20.27  | 36.41  | 35.55  |
| A3M0      | 18.42  | 33.50  | 28.61  |
| A3M1      | 18.55  | 33.88  | 32.75  |

Notes: A0M0 = conventional irrigation without mulch, A0M1 = conventional irrigation without mulch, A1M0 = 100% irrigation without mulch, A1M1 = 100% irrigation with mulch, A2M0 = 85% irrigation without mulch, A2M1 = 85% irrigation with mulch, A3M0 = 70% irrigation without mulch, A3M1 = 70% irrigation with mulch.

Figure 7 shows the trend of shallots plant weight (gross and dry). Shallots can be harvested after the age of 60 to 70 days. The shallot plants are ready to be harvested when there are 60% tender stems, fallen plants, and yellowing leaves [4].
The weights of wet and dry shallot tubers in the recommended irrigation of 70, 85, and 100% were higher than those of the farmer’s pattern. At the irrigation dose, 85% has the most massive average tuber weight compared to that of other treatments, while the smallest value is found on shallots with farmers’ irrigation pattern.

Research results by Sumarna [14] indicated that the critical period of shallot plants due to lack of water occurred during tuber formation so that it could reduce production. To solve this problem, it is necessary to adjust the depth of groundwater and the frequency of water supply correctly, providing water with a height of 7.5 to 15 mm with a frequency of once a day gives highest the average weight of shallot bulbs.

The calculation of efficiency is carried out by calculating the fuel cost requirements in one shallot growing season by comparing the use of SIPTS and a centrifugal pump (jet pump) (table 5).

**Table 5.** Comparison of fuel costs in one growing season between SIPTS and jet pump.

| No | Parameter                                      | SIPTS       | Unit | jet pump       | Value | Unit |
|----|-----------------------------------------------|-------------|------|----------------|-------|------|
| 1  | Total irrigation needs                        | 104         | mm   |                |       |      |
| 2  | Land area                                     | 3,600       | m²   |                |       |      |
| 3  | Total volume of irrigation needs for MT        | 374         | m³   |                |       |      |
| 4  | Pump capability 5.5 HP                        | 2           | L dt⁻¹|                |       |      |
| 5  | Pump water volume for 1 hour                  | 7           | m³ hour⁻¹|            |       |      |
| 6  | The total duration of the pump operation to   | 7           | hour |                |       |      |
|    | meet irrigation needs                         |             |      |                |       |      |
| 7  | Fuel needs per hour                           | 2           | L hour⁻¹|            |       |      |
| 8  | Fuel needs for MT                             | 14          | L    | 70             | IDR L⁻¹|      |
| 9  | Fuel prices at the time of implementation     | 7,400       | IDR   | 7,400          | IDR L⁻¹|      |
| 10 | Total cost                                    | 103,600     | IDR  | 518,500        | IDR   |      |

Farmers do not count the component numbers 1 to 7 when irrigating; they just irrigate their land before it even floods. The data shows that the jet pump used by farmers requires approximately 2.5 L of fuel a day to start the pumping. So that during the planting season, the farmers need 70 L of fuel at
the cost of around IDR 518,500. Meanwhile, the SIPTS only requires 14 L of fuel at the cost of IDR 103,600 as an additional cost to buy fuel as a substitute when water production from the pump decreases on a cloudy day, so it must be supplied from a jet pump that uses fuel oil. The pump efficiency calculation shows that using a solar radiation pump can save fuel consumption from 70 L to 14 L, and the fuel purchase costs from IDR 518,500 to IDR 103,600 resulting in 400% savings [4].

3.4. The impact of using solar power on greenhouse gas (GHG) emissions

Reducing greenhouse gas emissions can be done by using alternative energy sources that do not produce greenhouse gas emissions such as solar, water, wind, and nuclear power. The results of the study [15] show that biomass can reduce greenhouse gas emissions. For example, hybrid electric vehicles can reduce greenhouse gas emissions as vehicle exhaust gases. It was using fossil fuels that will produce greenhouse gas emissions wisely and efficiently. It can be done by saving electricity and energy. For example, turn off electrical appliances when not in use, use energy-efficient lamps, and use solar panels as an alternative energy. The efficient lifestyle in using power from fossil fuels will be able to reduce the amount of greenhouse gas emissions resulted from the process of using energy from fossil fuels. Increasing energy efficiency is seen as one of the most promising steps in reducing global greenhouse gas emissions and reducing fossil fuel-dependence.

The calculation for one farmer/farmer group in one planting season (65 days of planting shallots) consumes an average of 2.5 L of energy per day so that in one planting season the equivalent of 70 L of gasoline to run the pump, it will emit as much carbon:

\[
GCE = 70 \text{ L} \times 693.63 \text{ g L}^{-1} \times 0.99 \times (44/12) = 176,251 \text{ kg} = 0.176 \text{ t CO}_2
\]

From the above calculation, it shows that direct CO$_2$ emissions from gasoline are 176,251 kg of CO$_2$ farmers per planting season or 0.176 t of CO$_2$ (t of CO$_2$ per planting season per farmer or farmer group).

As for the SIPTS which uses 14 L of fuel as a substitute when it is cloudy to turn on the pump, the total emission produced is as much:

\[
GCE = 14 \text{ L} \times 693.63 \text{ g L}^{-1} \times 0.99 \times (44/12) = 35,250 \text{ kg} = 0.035 \text{ t CO}_2
\]

It can be a consideration to use of SIPTS, which produces relatively little CO$_2$ emissions so that SIPTS is more environmentally friendly than the irrigation system using gasoline-fueled pumps [4].

4. Conclusions

The following conclusions and recommendations resulted from the study are as follows:

The total irrigation need for shallot plants on dry land is 464.3 mm or 4,643 m$^3$ ha$^{-1}$ season$^{-1}$. In comparison, the realization of the total water needs to be applied to irrigate shallot plants with the streamline drip irrigation technique in the field is 449.2 mm or 4,492 m$^3$ ha$^{-1}$ season$^{-1}$ in two-day irrigation intervals with an average of 2.5 to 3.3 mm. The difference of about 15.1 mm between the forecast result and the realization occurs due to the effect of slight streamline pipe seepage.

By using the solar water pump, fuel consumption can be saved from 70 to 14 L ha$^{-1}$ season$^{-1}$ and the cost of purchasing fuel decreases from IDR 518,500 to IDR 103,600 resulting in a savings of around 400%. The GHG emissions released to start the gasoline-fueled pump engine during the shallot growing season are 0.176 t of CO$_2$, while with SIPTS, farmers can reduce GHG emissions to 0.035 t of CO$_2$ ha$^{-1}$ season$^{-1}$.

The function of solar cell system decreases in cloudy weather, for this reason, it is recommended that in areas with a lot of rainfall, another approach should be used to produce electricity well without being affected by the weather. For further development to get great energy from solar cells, it is advisable to install an automatic solar tracking system that can follow the direction of sunlight.
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