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RAINWATER HARVESTING IN A 600 kW SOLAR PV POWER PLANT

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ABSTRACT

Water, which is the source of all life, is a product that should be consumed carefully. While the demand for water increases due to the increasing population in the world, global warming, and drought, freshwater resources are decreasing day by day. In this context, sustainable water and agriculture management gain importance in the fight against drought and climate change. This study aims to analyze a PV power plant type rainwater harvesting system (PVPPRWHS) in a 600 kW grid-connected solar photovoltaic (PV) power plant. An experimental rainwater harvesting was carried out in only 128 m^2 of Altınoluk Solar Power Plant, which has a surface area of 4320 m^2. Using rainwater for PV cleaning provides an innovative approach. This study showed that the potential for collecting rainwater from a small part of the PV plant is approximately 118 m^3 per year and that the harvesting system will reach 1646 m^3/year when applied to the whole plant. A study was also conducted to reveal the rainwater collection potential of the power plants in Çorum, which have been licensed since 2016. The highest rainwater harvesting potential belongs to the two power plants located in the Sungurlu district, Derekisla and Alembeyli, which are 10129 m^3/year and 11591 m^3/year, respectively. The total rainwater harvesting potential of the power plants that have been licensed since 2016 in Çorum has been calculated as 56388 m3/year. This study presents an innovative approach with rainwater harvesting from solar power plants with a large surface area for the use in panel cleaning and agriculture of the obtained water, combating climate change and drought.

Keywords: Solar power plant, PV panel, rainwater harvesting, agricultural irrigation

INTRODUCTION

Water, which is the source of all life, is a product that should be consumed carefully. While the demand for water increases due to the increasing population in the world, global warming, and drought, freshwater resources are decreasing day by day. In this context, sustainable water and agriculture management gain importance in the fight against drought and climate change.

Kılıç and Abuş (2018) examined the potential of rainwater collected from the roof of a residence with a surface area of 200 m^2 to meet the non-residential water needs. The collected rainwater was used for 172 days in garden irrigation, ornamental pool, car wash and to meet the water needs of poultry. 47% of the total water consumption of the house is obtained from rainwater. The depreciation period of the system was found to be 10.3 years. Recently, studies on dual-use have been carried out [Dupraz et al., 2011, Pringle et al., 2017]. The concepts of combining solar PV and agriculture, dubbed "agrivoltaics" (Dupraz et al., 2011) or dual-use of water for both solar PV and aquaculture, called "aquavoltaics" (Pringle et al., 2017) or a PV power system floating on a water source, defined "floatovolatics (FV)", are appropriate works for sustainability. Santra (2018) performed rainwater harvesting in an agri-voltaic system. Interspace area (49% of the total installation area) and below panel area (24% of the total installation area) were used for crop cultivation. Ghisi et al. (2009) reported that there is a potable water saving potential of up to 33% using the rainwater in petrol stations and when the tank capacity is increased, this rate can reach 57%. Kaya, (2020) investigated the solar energy and rainwater potential of the roofs of the buildings in the İzmit district and found the rainwater usage rate of about 33% for 2017.

The idea and practices of collecting rainwater from roofs are widely used. Agrivoltaics and aquavoltaics concepts have been frequently mentioned recently. Although there are many PV power plants around the world, as far as we know, there is no study on rainwater collection in these plants. PV power plant capacity is increasing rapidly in the world, although there are some agrivoltaic applications, as far as we know, there is no power plant-based study on rainwater collection in these power plants. This study aims to help to allow for the most efficient and effective production approaches for all PV power plants

MATERIAL and METHOD

For rainwater harvesting, a group of 144 PV panels with 32° inclination angle located in Çorum was examined. Fig. 1 shows the rainwater harvesting system. The rainwater harvesting system has a gutter assembly that collected and funneled water from the PV arrays to branch pipes. The branch pipes are directed water to tank or tanks. The storage capacity of a rainwater harvesting system varies depending on rain amount and water consumption. In the first attempt pilot study, the rainwater harvesting system has a 1 m^3 tank. In the second attempt pilot study, a system with a tank capacity of 25 m^3 was installed. In addition, a 5.5 kW booster was added to the system. A hydrophore and a 400 m long waterline were installed to irrigate the walnut saplings in an area 40 m higher than the existing power plant.

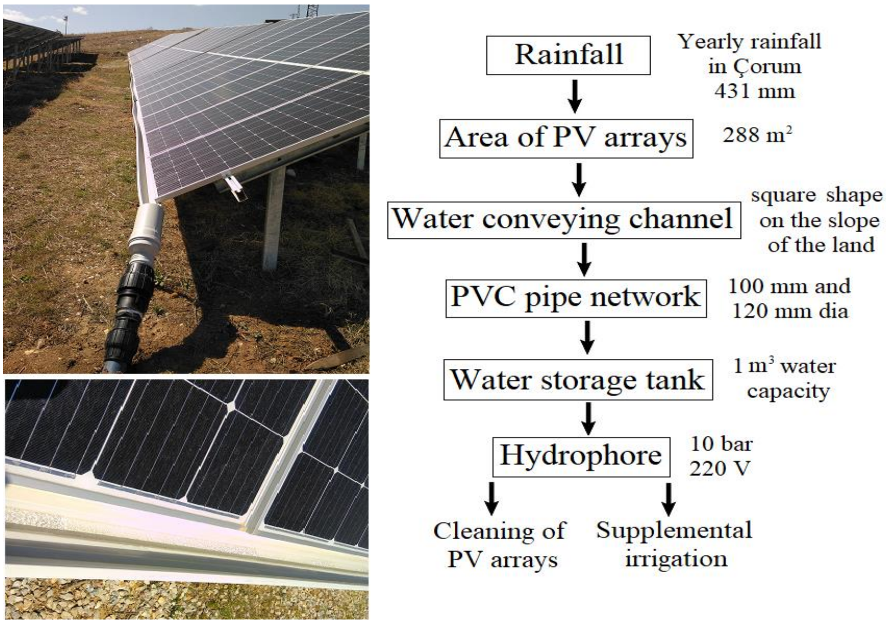
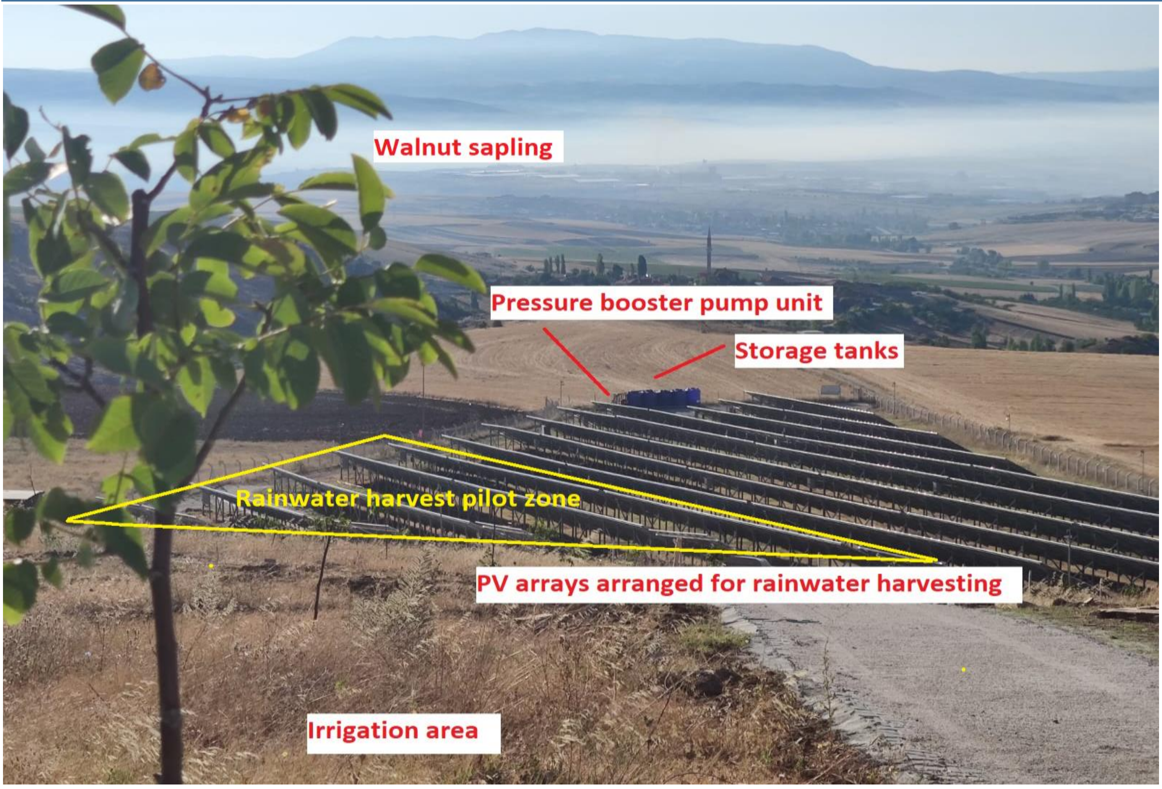


Fig. 1. Rainwater harvesting system

Fig. 2 shows the power plant and rainwater harvesting system. The rainwater harvesting system was installed in May 2020. Rainwater harvesting was done between June and November 2020. Rainwater collected from PV arrays in the upper part of the power plant is collected in storage tanks in the lower part of the power plant for use for PV cleaning and irrigation when necessary. Then, the accumulated water is transported to the nursery area above the power plant with the help of a hydrophore, with the help of pipes, and the saplings are irrigated with the drip irrigation system. Water stored in tanks is also used for PV cleaning and other processes.



a) Rainwater harvesting system

b) PV array and water collection channel

Fig. 2. Power plant and rainwater harvesting system.

Rainwater yield can be calculated as follows [Kılıç and Abuş, 2018].

*Rainwater yield=Rainfall area*precipitation amount*roof coefficient*filter efficiency coefficient* (1) where the rain catchment area is the total PV area. The precipitation amount is the total annual rainfall determined by the General Directorate of Meteorology. Roof coefficient: It is the coefficient specified by German standards as 0.8 in DIN (1989). In other words, it is the coefficient expressing that 80% of the rainwater falling on the roof can be collected. Filter efficiency coefficient: It is the coefficient specified as 0.9 in DIN (1989) by German standards. In other words, it is the efficiency coefficient that assumes that the obtained rainwater will suffer 10% filter loss. In this study, the *roof coefficient*filter efficiency coefficient* was taken as 0.95.

The yearly amount of harvestable rainwater (RWH) from PV arrays can be calculated as follow;

$$RWH = RW_{tot} A_{PV\ array} C_r \quad (2)$$

Thus, monthly and annual precipitation amounts are to be calculated. C_r is runoff (loss) coefficient, $A_{PV\ array}$ is rainwater collection area (total roof area of PV arrays, m^2), RWH is the yearly amount of harvestable rainwater from the PV arrays (m^3) and RW_{tot} is total annual rainfall (m).

RESULT and DISCUSSION

Fig. 3 shows the rainfall amount for Çorum in the measurement from 1929 to 2020 (TSMS, 2021). The annual rainfall for Çorum is approximately 431 mm. The monthly highest and lowest precipitation occur in May and August, respectively. Similarly, the monthly highest and lowest average rainy days are seen in May and August with 15.5 and 3.8 days, respectively. Fig. 4 shows the rainfall amount in September and November 2020.

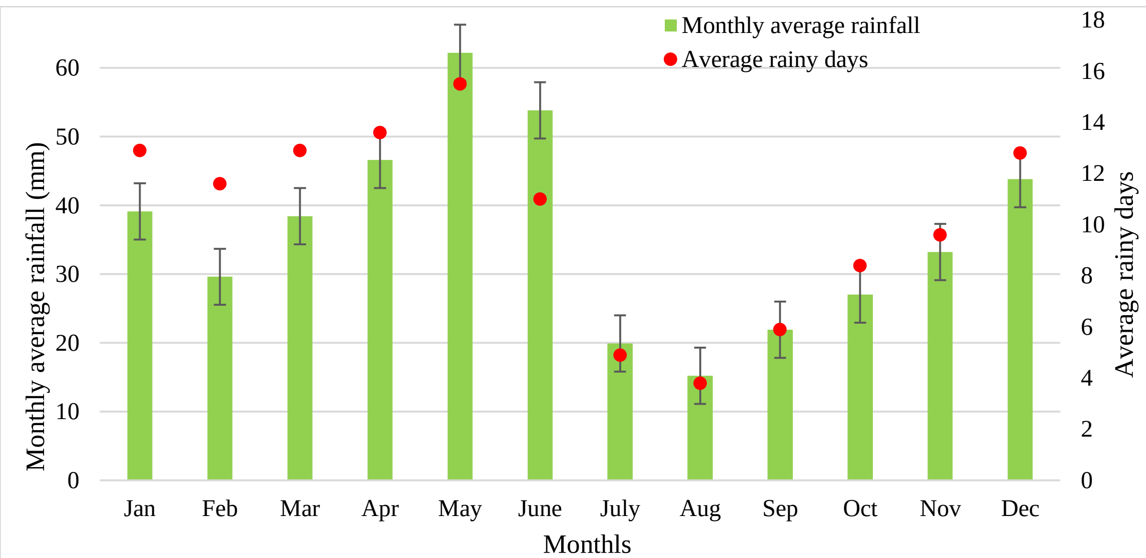


Fig. 3. Rainfall amount for Çorum, from 1929 to 2020 [TSMS, 2021].

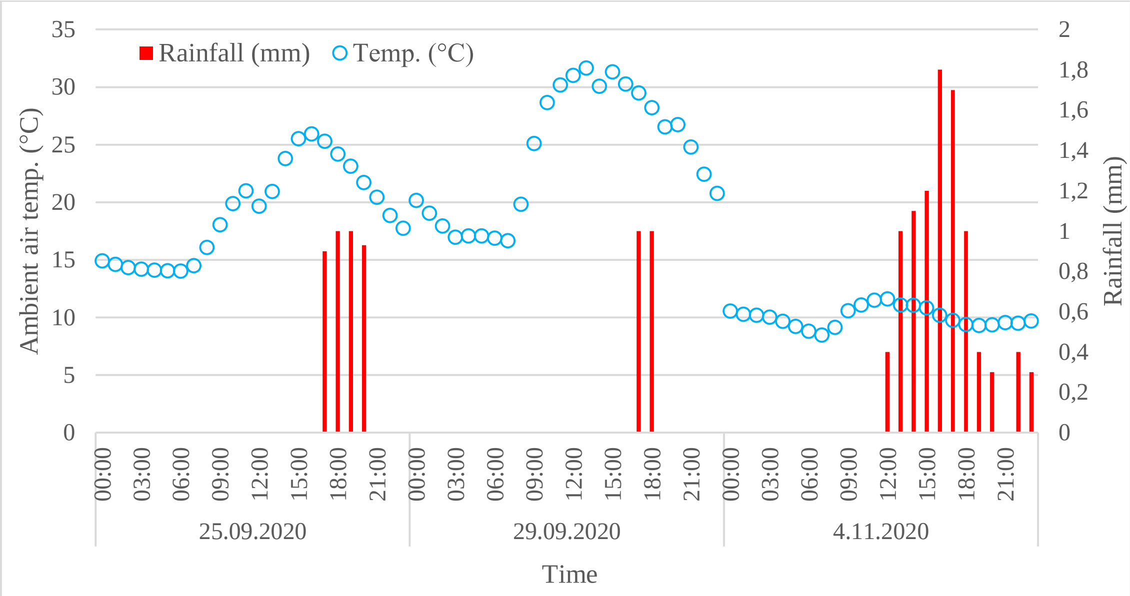


Fig. 4. Rainfall amount in September and November 2020

Fig 5 shows the average monthly rainwater harvesting potential at the PV plant. In this study, the PV panel surface area used for rainwater harvesting is 288 m^2. It was calculated that around 118 m^3/year of harvest can be made annually from the current rain harvesting system. Rainwater harvesting potential for all of the current power plant was calculated as 1646 m^3/year. Abdulla (2020) stated that for a roof area of 100 m^2, the water collection tank capacity ranges from 3.5 m^3 to 29 m^3 for annual precipitation ranging from 50 mm to 800 mm.

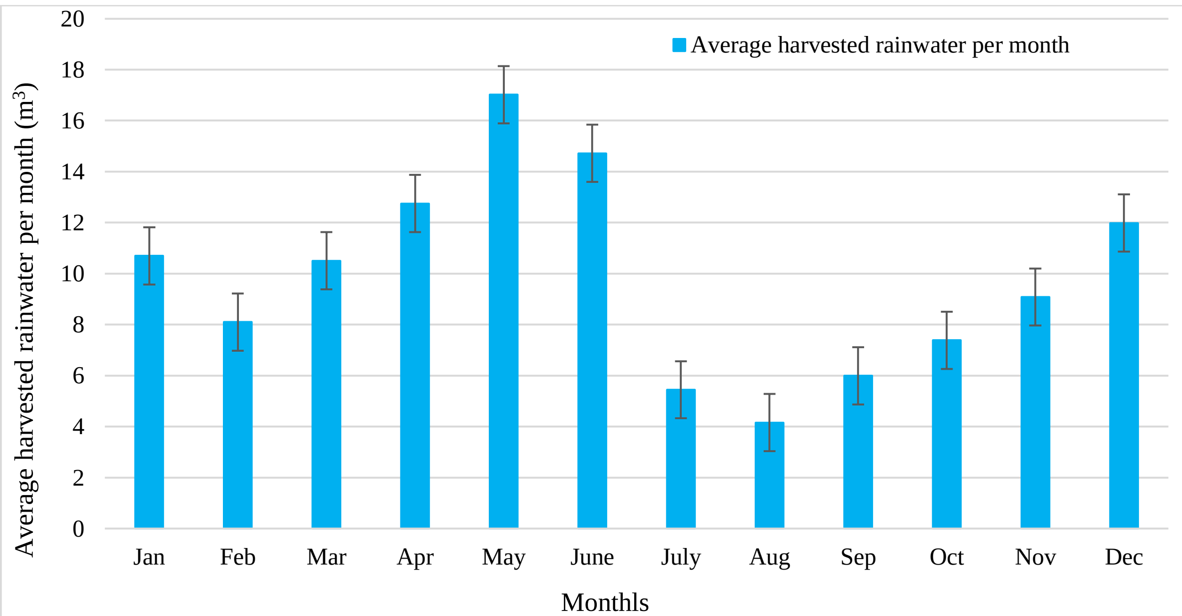


Fig. 5. Average monthly rainwater harvesting potential at the PV plant.

Fig. 6 shows the first attempt for rainwater harvesting with a 1 m^3 tank. Fig. 7 shows the second attempt for rainwater harvesting with a 25 m^3 tank. The system was first tested with a 1 m^3 tank in order to detect system errors and detect water loss and leaks. In addition, slope and flow compatibility was observed. After the system was fully arranged, 5 tanks of 5 m^3 each were placed. Finally, the hydrophore unit and drip irrigation system were installed.

Fig. 6. First attempt for rainwater harvesting with 1 m^3 tank.

Fig. 7. Second attempt for rainwater harvesting with 25 m^3 tank

The study was found to be extremely successful in collecting rainwater while generating electricity. For this reason, a study was conducted to reveal the rainwater collection potential of the power plants in Çorum, which have been licensed since 2016 (Fig. 8). While the rainwater harvesting potential of the power plant where the rainwater harvest is made is calculated as 1646 m^3/year, the highest potential belongs to the 2 power plants located in the Sungurlu district, Derekisla and Alembeyli, which are 10129 m^3/year and 11591 m^3/year, respectively. The total rainwater harvesting potential of the power plants that have been licensed since 2016 in Çorum has been calculated as 56388 m^3/year.

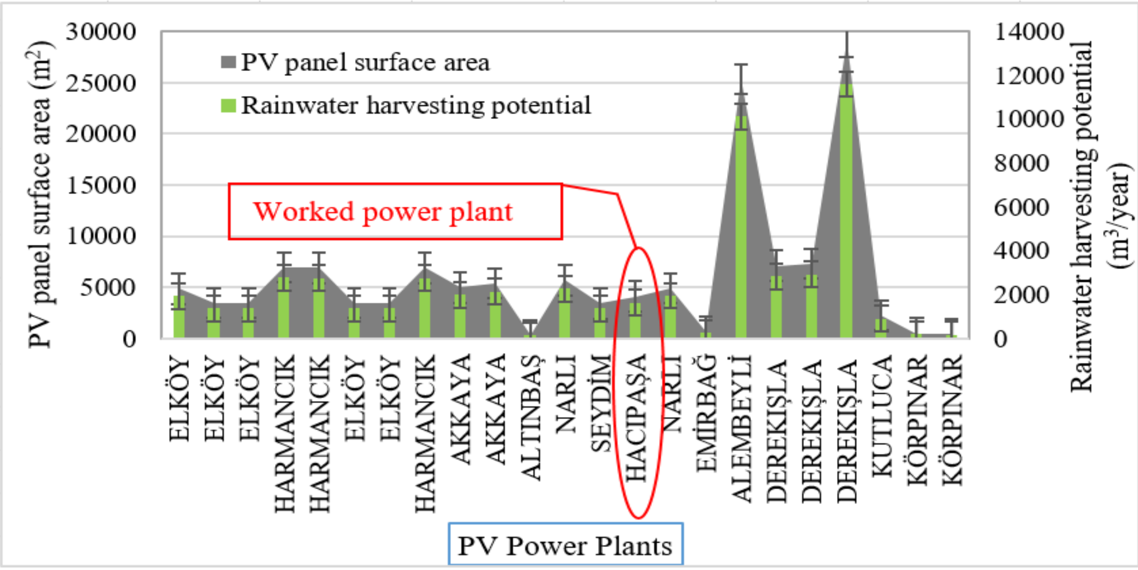


Fig. 8. Rainwater harvesting potential in licensed power plants established in Çorum from 2016 to 2021.

CONCLUSION

This study has been tried to find a solution to the water scarcity caused by climate change by conducting regional studies with innovative adaptation technologies and systems. A new concept study was carried out by using a solar power plant with large surface areas in rainwater harvesting with a different approach. Thus, while ensuring the adaptation of the people of the region to a new situation such as water scarcity, a regional solution has been produced for the harvest, storage, and efficient use of wasted freshwater resources. By making use of this study data, annual reports of water usage statistics of the people of the region and annual rainwater harvest amount can be created, so that the availability of solar power plants in rain harvesting will be revealed and total reserve calculations in Turkey and the world can be made. Rainwater harvesting systems, which can be created with small investments in PV power plants, are seen as much more effective methods compared to the methods of producing water from the air.

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