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COST ASSESSMENT OF THE COMBINED RAINWATER HARVESTING WITH SOLAR IRRIGATION

Onur Taşkin*, Ali Vardar

Uludag University, Faculty of Agriculture, Department of Biosystems Engineering, Bursa, Turkey

Abstract: Water availability is becoming acute in all over the world. Increased water demands have generated interest in different systems. Rainwater harvesting is one of the promising way to meet water demand for agricultural irrigation. However, water transmission between water resources and the field requires energy. There are several ways for powering irrigation systems. One of the options is to use solar panels as an alternate energy source, and it is mainly use in where there is no electricity. This study represents the analysis of combined rainwater harvesting with monocrystalline or polycrystalline or amorphous silicon solar power based irrigation systems. The study found for all solar powered irrigation cost huge because of primary investment. Nevertheless, the need for fossil fuel can be decreased by using solar panels and proposed solution for the present energy crisis for the farmers.

Key words*: rainwater harvesting, solar panels, economic costs*

INTRODUCTION

Water resources are under threat due to a number of consecutive droughts, increasing ground water salinity and falling of ground water table by over exploitation [1]. Thus, different methods are analyses to water supply for agricultural irrigation. Rainwater harvesting is one of the way to meet irrigation water demand and becoming popular in different quantities.

The most basic need of all the people in the world is energy and it is needed more than ever [2]. Solar energy is the most abundant source of energy in the world. Solar power is not only an answer to today's energy crisis but also an environmental friendly form of energy. It is used widely for receiving electrical power with panels [3]. One of the applications of photovoltaic generation technology is used in irrigation systems for farming [4]. The use of energy for the supply of irrigation systems is of great importance for crop production [5]. Even though there are several sources of energy to turn on

* Corresponding author. E-mail: onurtaskins@gmail.com

motors, the usage of the sunlight as an alternate energy source. Among these solar panels is quite effective in rural areas as it produces direct current from sun radiations [2].

There are many separately studies that have been carried out of rainwater harvesting and solar irrigation worldwide, but integration of these systems are neglected. Researches have been made on the determination of rainwater harvesting potential; in central Italy [6], Sydney [7], Southwest Nigeria [8], Khartoum [9], Kleinmond [10], Namibia [11], Sylhet City [12], Uganda [13], Middle East [14], Metro Manila [15], Northern Taiwan [16] and Nagpur (17). On the other hand, solar irrigation systems in Turkey [18], Inner Mongolia [19], Brazil [5], India [4], Bangladesh [20], Jalgaon [2], Dangila [21] have been studied. Most of the studies carried out are not about economic analysis. The aim of this study was to determine the cost assessment of rainwater harvesting system for agricultural irrigation in the low rainfall and less radiation areas. Instead of conventional energy sources; monocrystalline, polycrystalline and amorphous silicon solar power based irrigation systems were compared.

MATERIAL AND METHODS

To accomplish the objective specified; rainfall amount, rainwater catchment areas, water storage tank and solar radiation data are described in the following sections.

1. Case study of combined rainwater harvesting with solar irrigation. Rainwater harvesting with solar irrigation system consists of a rainwater collection part, water storage tank, filter unit, pump and irrigation facilities. The solar irrigation used in the study can be divided into three types. Irrigation types consist from monocrystalline, polycrystalline or amorphous silicon solar power, shown in Fig 1.

Figure 1. Combining the rainwater harvesting with solar irrigation

2. Study area. High agricultural production has no direct relationship with high rainfall event. It is very important to have good distribution of the rainfall events along the growing season. Storage of rainfall that occurred at different times during the year can help to supply of water for irrigation in urban areas. Therefore, arid regions were taken in hand as a reference sample where evaporation is greater than rainfall. Annual rainfall in the arid areas is between 50 to 700 mm [22]. Thus, the estimated locations have 50, 200, 350, 500 and 700 mm mean annual rainfall. Stored water was calculated for 50 m^2 roof areas [23].

3. Calculation of rainwater harvesting. The emphasis of this study is on roof based rain water harvesting potential. The volume of harvested rainwater was calculated as follows.

The coefficient of runoff (*Cr*) for any catchment is defined as the ratio of the volume of water that runs off to the volume of rain that falls on to the surface [1].

$$Cr = \text{Volume of Run off} / \text{Volume of rain water that falls on the surface} \qquad (1)$$

The runoff coefficient has been taken as 0.8 which is taken as a standard for the designing of asbestos roof catchment system [1].

Potential of rainwater supply was calculated by using the formula given below [1].

$$S = R \cdot A \cdot Cr \qquad (2)$$

Where:
R [m] - mean annual rainfall,
A [m^2]- catchment area,
Cr [-] - coefficient of run off.

4. Solar energy production. The output of a solar array depends on the type of panels used, the amount of sunshine and atmospheric conditions. The maximum performance values and area requirements of the various solar panels are given in Tab. 1 [24].

Table 1. Performances and required area for solar panel types

Panel type	*Max. performance [%]*	*Area [m^0/kWp]*
Monocrystalline	*15*	*9*
Polycrystalline	*14*	*10*
Amorphous silicon	*7*	*20*

5. Estimating system costs and financial cost savings. The economic analysis is carried out through estimating financial cost. The three systems represent using monocrystalline or polycrystalline or amorphous silicon solar power based irrigation is compared (Fig. 2). The aim of the comparison is to find which option is financially more attractive and the criterion of economic feasibility is the ratio of benefits to costs. Market price is used to value the financial cost.

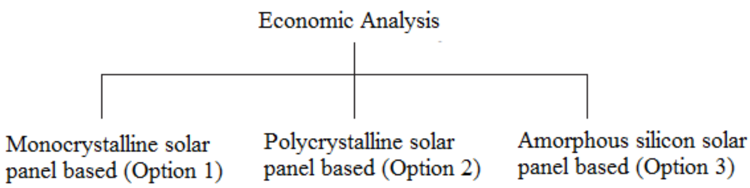

Figure 2. Economic analysis of solar power based irrigation systems

RESULTS AND DISCUSSION

Considering the evapotranspiration of grown products, stored water could use in the most appropriate time. Stored water from the samples was estimated between 2000 to 28000 liters (Tab. 2). Tank size is the most important factor affecting the total cost.

All countries have more or less solar energy potential as an alternative source. Therefore, less radiation areas were selected to be reference sample. The estimated locations have 500, 800, 1100, 1400 and 1700 KWh·m^{-2}-year radiation intensity. The solar panels convert this radiation to electrical energy. Within this study, power of the pump was met by the various solar panels. Solar panels that are used for powering water pump should be set to collect the maximum amount of energy, when water demands are greatest. Energy production due to solar panels and radiation intensity is given in the Tab. 3.

Table 2. Estimate of Potential Rainwater Harvesting

Mean annual rainfall [mm]	*Potential rainwater supply [m^2]*	*Stored water [l]*
50	*0.050 x 50 x 0.8*	*2000*
200	*0.200 x 50 x 0.8*	*8000*
350	*0.350 x 50 x 0.8*	*14000*
500	*0.500 x 50 x 0.8*	*20000*
700	*0.700 x 50 x 0.8*	*28000*

Table 3. Solar energy production

Radiation intensity [KWh·m^{-2}-Year]	*Energy production from solar panels*		
	Monocrystalline	*Polycrystalline*	*Amorphous silicon*
500	*75*	*70*	*35*
800	*120*	*112*	*56*
1100	*165*	*154*	*77*
1400	*210*	*196*	*98*
1700	*255*	*238*	*119*

Tab. 4 shows the results of economic analysis of the three types of rainwater harvesting systems, in which the present values of all effects (rainwater collection part, polythene water storage tank, 0.75 kW pump, filter unit, irrigation facilities and 1kW solar panel system and components) are calculated. Although the most efficient panels are monocrystalline, polycrystalline panels are rifer in the market and cheaper. Thus, usage of this panel is significantly lower costs.

Table 4. Economic Analyses

	Mean annual rainfall [mm]				
	50	*200*	*350*	*500*	*700*
Monocrystalline solar panels	*2054 $*	*2948 $*	*4299 $*	*5155 $*	*6612 $*
Polycrystalline solar panels	*1994 $*	*2888 $*	*4239 $*	*5095 $*	*6552 $*
Amorphous silicon solar panels	*2834 $*	*3728 $*	*5079 $*	*5935 $*	*7329 $*

CONCLUSIONS

The water availability problem and the potential for potable water savings by using rainwater harvesting have been assessed. Farmers are suffering from water shortages. Application of rainwater harvesting systems can minimize the water crises and provide water for irrigation. Also, energy need of the pump meet by solar panels which contribute to cleaner production.

This study presents an economic analysis of rainwater harvesting with solar irrigation. Three different solar power based irrigation systems were compared. All solar powered irrigation systems cost huge because of primary investment. However, the results of the economic analysis show that high efficiency and low price because of the widespread usage of monocrystalline and polycrystalline panels have advantageous position against to amorphous silicon. In addition, to obtain most economic return, it is necessary to choose suitable crops and growing patterns.

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PROCENA TROŠKOVA KOMBINOVANJA SAKUPLJANJA KIŠNICE SA SOLARNOM IRIGACIJOM

Onur Taşkin, Ali Vardar

Univerzitet Uludag, Poljoprivredni fakultet, Institut za inženjering biosistema, Bursa, Turska

Sažetak: Dostupnost vode postaje otežana širom sveta. Povećane potrebe za vodom povećale su interesovanje za različitim sistemima. Sakupljanje kišnice je jedan od načina koji obećavaju zadovoljenje potreba za vodom za navodnjavanje u poljoprivredi. Prenos vode od izvora do parcela zahteva energiju. Postoji nekoliko načina za pogon sistema za navodnjavanje. Jedna od opcija je upotreba solarnih panela kao alternativnog izvora energije koji se koristi tamo gde nema električne energije. Ovaj rad predstavlja analizu sakupljanja kišnice sa navodnjavanje sa monokristalnim, polikristalnim ili amorfno-silikonskim solarnim pogonom sistema za navodnjavanje. Rezultati su pokazali da su za svako navodnjavanje sa solarnim pogonom bili veliki troškovi zbog velikih primarnih ulaganja. Ipak, potrošnja fosilnih goriva može da bude smanjena upotrebom solarnih panela i ovo može da bude rešenje za sadašnju energetsku krizu.

Ključne reči*: sakupljanje kišnice, solarni paneli, ekonomski troškovi*

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