Science Letters ISSN 2345-5463

Research article
2020 | Volume 8 | Issue 1 | Pages 1-6

Open Access

Suitability Study of On-Farm Solar System as an Energy Source for Drip Irrigation

Malik Muhammad Akram, Muhammad Asif*

Directorate General Agriculture (On-Farm Water Management), Punjab Agriculture House, 21-Davis Road, Lahore, Punjab, Pakistan

ARTICLE INFO

Received
January 24, 2020
Revised
March 24, 2020
Accepted
March 25, 2020
Published
April 10, 2020

***Corresponding Author**
Muhammad Asif
E-mail
drasifpk@gmail.com

Keywords
Drip irrigation
Energy security
Greenhouse gas emission
Irrigation system
Water use efficiency

How to Cite
Akram MM, Asif M. Suitability study of on-form solar system as an energy source for drip irrigation. Sci Lett 2020; 8(1):1-6

Abstract

This study compared diesel, electricity provided by the national grid and on-farm solar system to find the most appropriate power source having the least cost and environmental impact, greater reliability and social acceptance for off-season production of drip-irrigated vegetables in plastic-covered tunnels. The cucumber was the test crop, and data were collected and averaged from 17 sites with an area ranging from 3 to 6 hectares at each site. The benefit-cost ratio and net return were calculated for economic viability and CO_2 emission was determined for all three power sources to assess the environmental impact. Results showed that the benefit-cost ratio for solar-power drip irrigation system was 1.65, whereas, for electric-power and diesel-power drip irrigation systems, it was 1.57 and 1.46, respectively. The water use efficiency of solar-power drip irrigation was 12.73 kg/ha/m^3, whereas, diesel and electric-power drip irrigations showed water use efficiency of 11.92 and 12.41 kg/ha/m^3, respectively. It was found that the on-farm solar system had the least CO_2 emission (0.02 ton/ha) compared to diesel and electric-powered drip irrigation systems (0.86 and 0.34 ton/ha, respectively). Drip irrigation system powered by diesel had the lowest net return ($3981) compared to drip irrigation systems powered by the on-farm solar system ($5641) and electricity from the national grid ($5028). These results showed that the on-farm solar system is most environmentally friendly and economically viable power source for drip irrigation. The study further concludes that special initiatives can help promote off-grid cheap electricity through the solar system to run a high-efficiency irrigation system that will not only reduce greenhouse gas emissions but also render opportunities for self-reliance, energy security and financial benefits.

SCAN ME

Introduction

Increasing energy costs are becoming a serious issue in agriculture. Due to the high cost of diesel and electricity and frequent shutdown of electricity, horizontal and vertical enhancement in crop productivity through a high-efficiency irrigation system is not possible. Irrigation water is the most critical factor in crop production and its efficient use enhances the productivity of other non-water inputs as well, scientists are pushing a more “crop by drop” approach implying more efficient irrigation and planting drought-tolerant plants that require less water. Drip irrigation is one of the technologies which helps achieve this objective [1]. This irrigation system delivers water to individual plants at times when the plant needs it so no water is wasted. Ideally, seeds are planted just below the perforations. Crops grown successfully using drip irrigation include orchards, watermelons, and cucumbers, hot peppers, melons, bell peppers, especially when grown under tunnels. A large-scale introduction of a drip irrigation system by on-farm water management has led to a large expansion of agriculture in Punjab, Pakistan and in many places drip irrigation is now the preferred irrigation technique. Studies have consistently shown a large water use reduction (80%) and a 100% increase in crop yields with drip irrigation [2]. This study also showed an improvement in the standard of living in the village by 80%. The only problem noted was a high expenditure of almost $576/hectare incurred to run a drip irrigation system. Thus, the problem of energy shortages that Pakistan is currently facing hindering the wide-scale adaptability of drip irrigation systems.

Solar power appears to be the cheapest choice as daylight is accessible for over 300 days in a year. Solar water pumping system is not only environmentally friendly, but also requires low maintenance and no fuel cost [3]. In addition, the use of solar power in agriculture would help preserve electricity, reduce the use of grid power and promote socio-economic development. [4, 5]. Solar power is also more financially possible compared to the diesel irrigation system, which ensures cheaper access to water that helps improve the socio-economic and living conditions of farmers in remote areas [6, 7]. Coupling drip irrigation systems with solar energy [8] promotes irrigated agriculture in remote areas, for facilitating the farmers to eliminate the use of high-priced diesel. The use of solar systems has played a key role in the promotion of Hi-Tech technologies for enhancing crop yields, increasing farm incomes, improving the livelihood of people, enabling farmers to adjust the agricultural practices with varying environments. The solar power high-efficiency irrigation systems have been found water and nutrient efficient and most appropriate options to address various crop production issues of the country. In fact, the arid climate of Punjab provides ideal conditions for the adoption of solar energy for operating high-efficiency irrigation systems; drip irrigation system was rapidly popularized in Punjab, particularly on vegetables and orchards.

The solar power drip irrigation is the most preferred choice in the present energy situation; however, the high initial cost of the solar system is the main obstacle in the adoption of this innovation. Therefore, this study was designed as a socioeconomic and crop productivity analysis study of solar, diesel and electric power drip irrigation systems that will reveal its social adoption and environmental impacts. Furthermore, the environmental impact of the use of diesel, electricity and solar power systems was also compared. The proposed study aims to promote Hi-Tech agriculture amongst the farming community through using the most economical and environmentally friendly energy source for efficient utilization of farm resources through the effective application of precious inputs, leading to the uplift of farmers.

Materials and Methods

A field study was carried out at farmer’s field through detailed survey and data collection of drip irrigation systems powered with solar, diesel and electric sources of energy during 2019. A total of 17 sites of 3-6 hectare across the district Jhang, Pakistan were selected. The cucumber was the test crop grown under the plastic tunnels. The cucumber was sown manually during the first week of November. Forty plastic tunnels were erected, having three beds in each tunnel covered in each hectare. The distance between laterals was 1.37 m, row to row distance was 30 cm on one bed and plant to plant distance was 35 cm. The height, width and length of the tunnel was 2, 3 and 60 m, respectively. The plants were irrigated with the help of drip systems as per requirement. Drip irrigation system at each location has a typical control unit consisted of a pump, fertilizer venture, gravel filter, disc filters, control valves, pressure gauges and a flow meter. The data of water applied through drip were recorded through water flow meters. Each treatment (zone) had one valve to control the water application. The lateral lines of 16 mm diameter LLDPE pipes were laid along the crop rows and each lateral served two rows of the crop with emitters of flow rate 2.3 LPH spaced at 0.3 m along the drip line. Fertigation of recommended doses of NPK (370 kg ha^{-1}), P (123 kg ha^{-1}) and K (123 kg ha^{-1}) were used as urea, triple superphosphate (TSP) and sulfate of potash (SOP), respectively, under drip irrigation.

An economic analysis was carried out to test the economic and social viability of various sources of energy to run the drip irrigation system. Economic and crop productivity analysis was based on current year data collected through questionnaire surveys directly from the farmer's field. The useful life of the system was considered 10 years, maintenance costs were calculated @2.5% of the total cost. Depreciation was calculated at the rate of 15%. The fixed variable cost for the production of cucumber and its economic analysis was conducted. The cost of cultivation includes expenses incurred in land preparation, purchase of seed, fertilizer and other plant protection measures. Water use efficiency (WUE) was calculated to compare the performance of each energy source used to run the drip irrigation system.

WUE (kg/ha/m^3) = total yield (kg/ha) / total water used (m^3)

The benefit-cost ratio (BCR) is the ratio of the benefits of a project expressed in economic terms. The higher BCR, the better the investment. The benefit-cost ratio was calculated as follows:

Benefit-cost ratio (BCR) = total revenue (TR) / total cost (TC)

The emission CO_2 (tons of carbon dioxide per megawatt-hour [9]) was calculated by multiplying the total energy consumed with emission factors for solar, electric and diesel-powered drip irrigation system for one hectare of cucumber [10, 11].

The treatment differences were evaluated by one-way analysis of variance (ANOVA) and Duncan's multiple-range test was used to find differences among treatments at P = 0.05 (SPSS 19.0 statistical software, Chicago, IL).

Results and Discussion

Data presented in Fig 1 revealed that the solar-powered drip irrigation system (SPDIS) gave the highest crop yield (62.9 tha^{-1}) against the lowest from diesel-powered drip irrigation system (DPDIS; 55.5 tha^{-1}). The higher crop yield obtained under SPDIS was mainly due to cheaper and more stable water supply during the crop growth period. These results are in close agreement with the findings of Rajurkar et al. [12] and Dehghanisanij and Akbari [13], who reported that in SPDIS, increased plant yield was due to sustained supply of moisture and NPK throughout the crop growth period. The most direct benefit is the increased revenue and income that comes with the greater yields of the cucumber crop [14, 15]. The water use efficiency helps to assess the productivity of crop per unit water used. It was computed by taking the economic yield of crops and the total water used (including the effective rainfall) into consideration. Fig. 2 clearly shows that the cucumber had comparatively more water use efficiency in SPDIS

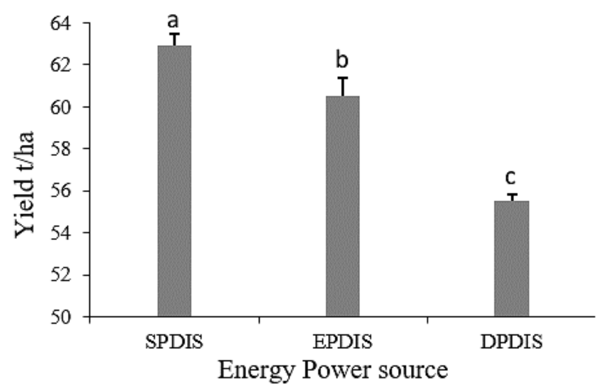

Fig. 1 Cucumber yield as affected by the drip irrigation system powered by different energy sources.
t/ha = tons per hectare; SPDIS = solar-powered drip irrigation system; EPDIS: electric-powered drip irrigation system; DPDIS = diesel-powered drip irrigation system.

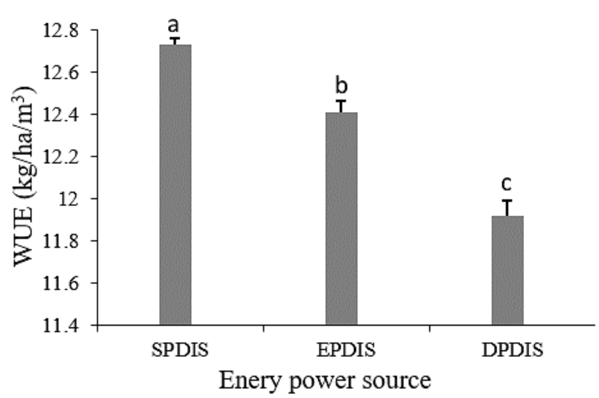

Fig. 1 Water use efficiency (WUE) as affected by the drip irrigation system powered by different energy sources.
SPDIS = solar-powered drip irrigation system; EPDIS: electric-powered drip irrigation system; DPDIS = diesel-powered drip irrigation system.

Table 1 Economical comparison of solar-powered drip irrigation system (SPDIS), electricity-powered drip irrigation system (EPDIS) and diesel-powered drip irrigation system (DPDIS).

Sr. No.	Type of costs	SPDIS	EPDIS	DPDIS
1	**Fixed cost ($/ha) Av. life 10 years**			
	a. System cost	432 a	212 b	202 b
	b. Tunnel cost	150	150	150
	Total fixed cost (a+b)*	582 a	362 b	352 c
2	**Seasonal system cost ($/ha)**			
	a. Depreciation	74 a	32 b	30 b
	b. Repair & maintenance (2.5%)	11 a	5 b	5 b
	c. Fuel cost	-	415 b	510 a
	Total seasonal system cost	85 c	452 b	545 a
3	**Seasonal cost of cultivations ($/ha)**			
	a. Land preparation	57	57	58
	b. Seed cost	624	624	624
	c. Fertilizer	520	507	470
	d. Pesticide	169	177	190
	e. Transportation	280	276	257
	f. Packing material	185	176	171
	g. Labor	1391	1371	1354
	Total seasonal cost ($/acre)	3226	3188	3125
	Total seasonal cost ($/ha)**	7968	7874	7719
4	Water used (m^3/ha)	4947	4873	4662
5	Yield (kg/ha)	62985 a	60515 b	55575 c
6	Income from producers ($/ha)	14277 a	13716 b	12597 c
7	Total cost $/ha (1+2+3)	8635	8688	8616
8	Net profit $/ha (6-7)	5641 a	5028 b	3981 c
9	Benefit cost ratio (6/7)	1.65 a	1.57 b	1.46 c
10	WUE kg/ha/m^3 (5/4)	12.73 a	12.41 a	11.92 b
11	CO_2 emission (t/ha) [10]	0.02 c	0.34 b	0.86 a
12	CO_2 emission/kg of cucumber	0.0003 c	0.0056 b	0.0154 a

* Fixed cost includes the cost of drip irrigation system with power source and tunnel structure cost.
** Total seasonal cost includes expenses incurred on land preparation, seed, fertilizer, pesticide, fuel, operation & maintenance cost of drip irrigation system

than other treatments. The water use efficiency in SPDIS was 12.73 kg $ha^{-1}m^{-3}$ while in electric-powered drip irrigation system (EPDIS), it was 12.41 kg $ha^{-1}m^{-3}$. The lowest water use efficiency was found for DPDIS (11.92 kg $ha^{-1}m^{-3}$). Thus, SPDIS can provide substantial benefits in water-saving to local prosperity in regions that adopt them. Similar results were obtained in the previous reports [14, 15].

The benefit-cost ratio and net profit were worked out to determine the economic feasibility of the cucumber using diesel, solar and electric powered drip irrigation systems. A maximum net profit of $5641/ha with benefit-cost ratio of 1.65 was recorded in SPDIS followed by EPDIS with the net profit of $5028/ha and benefit-cost ratio of 1.57. The lowest net profit of $3981/ha with benefit-cost ratio of 1.46 was obtained in DPDIS. The lower benefit-cost ratio obtained in DPDIS and EPDIS might be attributed to higher irrigation and maintenance costs compared to SPDIS. The solar power drip irrigation system was found a socially feasible option on account of an impressive benefit-cost ratio, which confirms that wide adoption of drip irrigation will generate enough social benefits to justify the subsidization of drip irrigation in the country. The better return per ha obtained under SPDIS than their corresponding energy sources diesel/electricity shows that solar and electric power systems are much better than diesel-powered drip irrigation systems. Similar results have been reported previously [16].

To evaluated the environmental impact of different power sources of the drip irrigation system, CO_2 emission was calculated. The results showed that SPDIS had minimum CO_2 emission of 0.02 ton/ha for cucumber crop, whereas DPDIS and EPDIS emitted 0.861 t/ha and 0.34 t/ha, respectively. These results further concluded that SPDIS is the best power source for lowering environmental impacts. The emission of CO_2 for diesel was much higher compared to other both power sources. Our findings are partially in agreement with the finding of NEPRA, Pakistan [17] and close conformity with the findings of Yousuf et al. [18]. Data analysis further revealed that diesel engine ran 75.3 hours to irrigate cucumber crop and consumed about 321.38-liter diesel and emitted 0.861 tons of CO_2 /ha, whereas EPDIS ran for 60.12 hours and consumed 482.16 KW of electricity and emitted 0.34 tons of CO_2 /ha in the atmosphere and the SPDIS consumed 820.14 KW of electricity produced by solar and emitted 0.02 tons of CO_2 during the growth period of cucumber crop per hectare area. Moreover, the CO_2 emission for 1 kg production of cucumber was also calculated, which was 0.0003 kg, 0.0056 kg and 0.0154 kg for SPDIS, EPDIS and DPDIS, respectively. These results conclude that SPDIS is the best power source for the environment [19]. The research concludes that SPDIS and EPDIS are the best sources economically but in the view of the energy scenario of Pakistan, farmers cannot depend on electricity due to heavy shortfall. Moreover, more than 96% of farmers, especially in the study area using DIS show their willingness for onward adoption of SPDIS. In view of greater social acceptance, it is recommended that special initiative should be taken to promote SPDIS, which will also result in the lowest CO_2 emission and a safeguard against the shortfall of electricity in Pakistan.

Conclusions

The SPDIS can provide substantial economic and environmental benefits as it has proved a clean, climate-smart and innovative energy technology for high-efficiency irrigation systems in remote areas, particularly in areas that are not connected to the electricity grid or where a regular supply of liquid fuels and maintenance services is not guaranteed. In countries with economic water scarcity, especially in desert areas, SPDIS can help to stabilize, increase and diversify production and buffer the effects of drought to overcome water stress during dry seasons. The SPDIS will encourage the farmers to grow high-value crops such as vegetables and orchards, which will help elevate poverty in such remote areas. The increased availability of food can improve food security and the nutritional intake of desert areas of the country. This article further emphasized that Pakistan has been blessed with an abundance of renewable energy resources, which have not been harnessed appropriately. The high cost and frequent interruptions in energy/electricity supply may constraint the use of drip irrigation. Exploiting renewable energy sources like the solar system will help in achieving energy security, self-reliance to meet energy needs, environmental protection and sustainable economic growth. Replacing or supplementing the conventional fuels for operating high-efficiency irrigation system sites with solar energy seems a workable option as sunlight is available for more than 300 days a year in the studied area of Pakistan with about 8 hours of effective daylight (5 KW/m^2/day). The arid/semi-arid climate provides ideal conditions for the adoption of solar energy for operating a drip irrigation system. Thus, solar panels of appropriate size for each specific farm may be a solution to ensure the off-grid provision of cheap electricity to drip irrigated farms. However, in order to promote the utilization of off-grid cheap electricity, special subsidies and support packages shall be announced by the government that would increase the buying capacity of the people. It is environment friendly and farmers also want to adopt it but fail just because of the high capital cost. If the government subsidizes solar as a power source for the drip irrigation system, then more than 80% of the farmers will convert their power source to solar, which will play a positive role in the electricity shortfall of the country. Such initiatives can not only help reduce greenhouse gas emissions but can also render opportunity for self-reliance, energy security and financial benefits.

Conflict of Interest

The author declares no conflict of interest for this study.

References

[1] Asif M, Akram M, Arfan A. Multi-locational trials to compare the relative water use and vegetable crops productivity by drip irrigation and conventional furrow irrigation systems in district Toba Tek Singh, Pakistan, Sci Lett 2016; 4:60-50.

[2] Asif M, Akram M, Rafique M.A. Impact of drip and furrow irrigation methods on yield, water productivity and fertilizer use efficiency of sweet pepper (*Capsicum annuum* L.) grown under plastic tunnel. Sci Lett 2016; 4:118-123.

[3] Foster R, Ghassemi M, Cota A. Solar Energy: Renewable Energy and the Environment. CRC Press, Taylor & Francis Group, 2009; pp. 32-40.

[4] Ahmad S, Ali I. Feasibility of solar powered pumping systems for deep tube wells in Pakistan, Managing Natural Resources for Sustaining Future Agriculture (Research Briefs). Natural Resources Division,

Pakistan Agricultural Research council, Islamabad, Pakistan. 2011; 3(18).

[5] Saad E, Shenawy E. T, Badr M. A. Economics analysis of diesel and solar water pumping with case study water pumping for irrigation in Egypt. Int J Appl Eng Res 2016; 11:950–954.

[6] Cuadros F, Lopez F, Marcos F, Coello J. A procedure to size solar-powered irrigation (photo irrigation) schemes. J Solar Energ 2004; 76:465-473.

[7] Mahmud E. Nather S. Renewable energy and sustainable developments in Egypt: photovoltaic water pumping in remote areas. J Appl Energ 2003; 74:141–147.

[8] Anonymous. Punjab Growth strategy. Govt. of Punjab Pakistan; 2018.

[9] Eggleston H.S, Buendia L, Miwa K, Ngara T. IPCC Guidelines for National Greenhouse Gas Inventories prepared by the National Greenhouse Gas Inventories Programm, 2006; Published: IGES, Japan. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl

[10] Nelson GC, Robertson R, Msangi S, Zhu T, Liao X, Jawajar P. Greenhouse Gas Mitigation: Issues for Indian Agriculture. International Food Policy Research Institute, Discussion Paper 00900; 2012. Available at http://www.ifpri.org/sites/default/files/publications/ifpridp00900.pdf

[11] Simsek M, Tonkaz T, Kacıra M, Comlekcioglu N, Dogan Z. The effects of different irrigation regimes on cucumber (*Cucumbis sativus* L.) yield and yield characteristics under open field conditions. Agric Water Manage 2005; 73:173–191.

[12] Rajurkar GB, Patel N, Rajput TBS, Varghese C. Effect of deficit irrigation on growth and yield of drip irrigated cabbage. Ind J Agri Sci 2015; 85:189–93.

[13] Dehghanisanij H, Akbari M. Micro irrigation in Iran-Current Statues and Future Needs. In Proceedings of the 8th International Micro Irrigation Congress, Tehran, Iran, 21 October; 2011.

[14] Musa M, Iqbal M, Tariq M, Sahi F, Cheema N, Jahan F. Comparative water use efficiency of drip and furrow irrigation systems for off-season vegetables under plastic tunnel. SAARC J Agric 2014; 12(1):62-71.

[15] Kuscu H, Turhan H, Demir AO. The response of processing tomato to deficit irrigation at various Phonological stages in a sub-humid environment. Agric Water Manage 2014; 133: 92–103.

[16] Emcon A. Feasibility assessment for the replacement of diesel water pumps with solar water pumps, Ministry of Mines and Energy, Barrier Removal to Namibian Renewable Energy, Programme (Namrep) 2006; pp. 3-6.

[17] National Electric Power Regulatory Authority, Government of Pakistan, State of Industry Report; 2012 (http://www.nepra.org.pk/industryreports.htm).

[18] Yousuf I, Ghumman AR, Hashmi HN, Kamal MA. Carbon emissions from power sector in Pakistan and opportunities to mitigate those. Renew Sust Energ Rev 2014; 34:71–73.

[19] Zhai Q, Cao H, Zhao X, Yuan C. Cost benefit analysis of using clean energy supplies to reduce greenhouse gas emissions of global automotive manufacturing. Energies 2011; 4:1478–94.