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Economic and environmental benefits of replacing 7 HP diesel irrigation pumps with solar irrigation pumps in Rajasthan, India

Yash Gautam[1], OP Singh[2]
[1] Research Scholar, Department of Agricultural Economics, Institute of Agricultural Sciences, BHU, Varanasi, Uttar Pradesh, India
[2] Associate Professor, Department of Agricultural Economics, Institute of Agricultural Sciences, BHU, Varanasi, Uttar Pradesh, India

Abstract
Agriculture plays a vital role in shaping Indian economy. After independence, agriculture in India saw significant development regarding production and technology. Green revolution made India not only self-sufficient in food at aggregate level, but also a net food exporting country. when the focus was on increasing food production, environmental impacts were highly neglected which resulted in the disturbance of weather phenomena and the best example of this is the disturbed cycle of monsoon. Due to frequent monsoon failure, uneven distribution of rainfall and excessive rainfall in several regions of the country not only farm production was adversely affected but condition of farmers also deteriorated. India relies heavily on fossil fuels to meet its energy requirements. Currently India is the third largest Greenhouse gas emitter in the world after China and USA. With the inception of KUSUM scheme and various subsidy provisions, the penetration of solar pumps in the farming community has increase, especially in Rajasthan. Following study analyses the economic and environmental benefits of switching from diesel pumps to solar irrigation pumps. It was found that when 7 HP diesel irrigation pump was used to irrigate one hectare each of groundnut, bajra, wheat and barley then it would have consumed 660 litres of diesel which would release 1716 Kg of CO_2 in the atmosphere. Also, if the total carbon dioxide emissions were converted into carbon credits and sold in international markets then it would help in giving financial boost to solar industry.

Keywords: Economic, environmental, 7 HP diesel irrigation pumps, solar irrigation pumps

Introduction

Agriculture plays a vital role in shaping Indian economy. Apart from food, it is also the major source of employment in India. Till today, agriculture is the backbone of the nation's economy. It has significant contribution in country's GDP and employment generation. Some 70 per cent of its rural households still depend primarily on agriculture for their livelihood (FAO, 2018). After independence, agriculture in India saw significant development regarding production and technology. Strategies in the past, for development of the agriculture sector in India focused primarily on raising agricultural production and improving food security. During the last half century (1965 to 2015), food production of India multiplied by 3.7 times whereas the population multiplied by 2.55 times. This resulted in 45 per cent increase in food production per person. It made India not only self-sufficient in food at aggregate level, but also a net food exporting country (NITI AYOG, 2017). However, the strategies did not explicitly recognize the need to raise farmers' income and did not mention any direct measure to promote farmers' welfare or income. There are various areas in agriculture that can be exploited to increase farmers' income like improvement in resource use efficiency, increasing cropping intensity, diversification towards high value crops, etc. These methods should not only be beneficial for the farmers but should also go hand in hand with the environment. This is because, when the focus was on increasing food production, environmental impacts were highly neglected which resulted in the disturbance of weather phenomena and the best example of this is the disturbed cycle of monsoon. Due to frequent monsoon failure, uneven distribution of rainfall and excessive rainfall in several regions of the country not only farm production was adversely affected but condition of farmers also deteriorated. According to FAO, agriculture in India still remains largely rain fed and vulnerable to the vagaries of the monsoon and so are the fates of millions of Indian farmers. To overcome this problem, farmers started using diesel water pumps and electric water pumps to irrigate their fields. This although reduced the dependence of farmers on monsoon to some extent but increased their cost of production. India uses more than 4 billion litres of diesel and around 85 million tons of coal per annum to support water pumping for irrigation. If one million diesel pumps were replaced with solar pumps then it would result in diesel use mitigation of approximately nine billion litres over the life cycle of solar pumps. It would save ₹ 8,400 Crores on diesel subsidy and reduce CO2 emission up to 25.3 million tonnes. Foreign exchange savings of USD 300 million per annum on diesel imports for replacement of one million diesel pumps translating into forex savings of USD 4.5 billions over pump life (KPMG, 2014) [3]. Today, India relies heavily on fossil fuels to meet its energy requirements. Around 69.5 per cent of the total power is generated by thermal power plants (MoP, 2020). In India electricity generated by burning fossil fuels contributes 37.8% of the total greenhouse gasses released in the atmosphere (GOI 2016). Burning of fossil fuels increases carbon-dioxide emission which is a major contributor to the climate change crisis today (Schock *et al.*, 2007) [6]. In 2016, World Health Organization (WHO) released a report in which, 11 Indian cities have occupied positions in the list of top 25 polluted cities of the world (WHO,

2017) [7]. Currently India is the third largest Greenhouse gas emitter in the world after China and USA. Unquestionably, neither the energy demand of India is going to decrease nor the development process can be stopped. So, for continued development at the current pace along with reducing the GHG, India needs to switch its source of energy from fossil fuels to renewable sources like Solar, Wind, etc. Renewable energy sources are capable to solve the problem of sustainable development associated with fossil fuel based power plants as these energy sources are unlimited, eco-friendly and provides energy with negligible emissions of air pollutant and greenhouse gases (Singal, 2007) [8]. It is clearly feasible to replace the current fossil fuel infrastructure with solar power and other renewable, and reduce CO2 emissions to a level commensurate with the most aggressive climate change goal (Fthenakis *et al.*, 2009) [9]. In subsequent efforts, Jawaharlal Nehru National Solar Mission (JNNSM) also known as National Solar Mission was launched on the 11th January, 2010 by former Prime Minister Dr. Manmohan Singh. It was one of the eight key National Mission's which comprise India's National Action Plan on Climate Change (NAPCC). The objective of the National Solar Mission was to establish India as a global leader in solar energy. During the presentation of Union Budget 2018-19, Central Government had announced Kisan Urja Suraksha Evam Utthaan Mahabhiyan (KUSUM) Scheme for farmers. Subsequently, government will provide subsidy on setting up of solar power plants on their barren land. Through KUSUM Scheme, government will solarize agricultural pump sets in the effort to double the income of farmers by 2022. Considering the importance of solar pumps, following study was undertaken.

Methodology

Study was based on primary data which was collected with the help of survey schedule. Rajasthan was purposively selected because it receives the highest annual global radiation (≥2400 kWh/m^2) and the installation of solar irrigation pumps are maximum. District Jaipur was selected purposively because number of solar irrigation pumps installed was maximum in the district. Respondents were selected using snowball method of sampling. Respondents included farmers who were using 7 HP diesel pump for irrigation, but later replaced it with solar irrigation pump. To examine the economic benefits of solar irrigation pumps, the amount spent on diesel fuel used for running diesel pump was calculated. After the adoption of solar irrigation pump, farmer didn't purchase diesel so the expenditure on diesel was saved which was the economic benefit.

Environmental benefit realized by adoption of solar irrigation pump was reduction in carbon emissions. To find out the reduction in carbon emissions, first of all diesel saving on irrigation were quantified with the help of following relation:

1 litre diesel = 2.6 kg CO_2 emission (Jat *et al.*, 2006) [10]

1 kg CO_2 = 0.27 kg carbon (Paustian *et al.*, 2006) [11]

Results and Discussion

Economic benefits of solar irrigation pumps

In the study area, average area under groundnut, bajra, wheat and barley was 0.7 Ha, 0.99 Ha, 1 Ha and 0.41 Ha respectively. Diesel consumption for irrigating total area of wheat, barley, bajra and groundnut crops by using 7 HP pump is presented in Table 1. A 7 HP diesel pump took 11 hours on an average to irrigate one hectare area in the study area. Average rate of diesel consumption of the 7 HP diesel pump was 2.5 litres per hour. Cost of diesel during the study period was estimated to be ₹ 81.99 per litre (Table 1). In case of groundnut, total area allocated by sample farmers was estimated to be 0.70 hectares per farm. Total number of irrigations provided by the sample farmers to groundnut crop were 12 during the crop period. Fuel consumption by the 7 HP diesel pump to irrigate 0.70 hectares of groundnut crop of the sample farmers was estimated to be 231.00 litres. So, total amount spent on diesel would be equal to ₹ 18.939.69 per growing season of the crop (Table 1). Bajra crop was irrigated three times on an average in one growing season by the farmer in the study area. So, 81.68 litres of diesel was used to irrigate 0.99 hectares area of the bajra crop by a 7 HP diesel irrigation pump. Therefore, total cost of pump fuel consumption at the rate of ₹ 81.99 per litre of diesel was ₹ 6,696.53 for one season of barley crop (Table 1). Sample farmers in the study area were providing on average six irrigation to wheat crop during entire period of the crop. Total diesel required to irrigate 1 hectare area of wheat crop was estimated to be 165.00 litres. Therefore, total cost of diesel fuel used for irrigating wheat at the rate of ₹ 81.99 per litre was ₹ 13,528.35 (Table 1). Sample farmers were irrigating barley three times during the entire growing season in the study area. The diesel consumed by 7 HP pump to irrigate 0.41 hectares area of barley crop was estimated to be 33.83 litres. So, the amount that would have been spent on diesel at the rate of ₹ 81.99 per litre was ₹ 2,773.31 (Table 1).

Table 1: Diesel consumption by a 7 HP diesel irrigation pump per farm

S. No.	Crop	Area per farm (Ha)	Number of irrigation	Time required per irrigation(Hrs/Ha)	Diesel consumption per hectare (L/Ha)	Diesel consumption per farm (Litres)	Total Cost of diesel @ ₹ 81.99 per litre
1	Groundnut	0.70	12	11	330.00	231.00	18,939.69
2	Bajra	0.99	3	11	82.50	81.68	6,696.53
3	Wheat	1.00	6	11	165.00	165.00	13,528.35
4	Barley	0.41	3	11	82.50	33.83	2,773.31
5	Total				660.00	511.50	41,937.89

It was found from the result that if 7 HP diesel irrigation pump was used to irrigate 0.70 hectares of groundnut, 0.99 hectares of bajra, 1.00 hectare of wheat and 0.41 hectares of barley then the total consumption of diesel would be 41,937.89 litres per year. This indicates that one farmer had to spend a total of ₹ 41,937.89 to irrigate their crops in a year. Since, solar irrigation pumps were used in the study area, so, there was no diesel consumption for the purpose of irrigation. Thus, the savings on diesel consumption was equal to the expenditure on fuel, amounting to ₹ 41,937.89 per farm. Also, it was found that 511.50 litres of diesel were saved during a year by the adoption of solar irrigation pumps (Table 1).

Environmental benefits of solar irrigation pumps

Environmental benefits realized by adoption of solar irrigation pump was reduction in carbon emissions due to running of diesel pump for irrigation purpose. To estimate the reduction in carbon emissions, first of all diesel savings on irrigation were converted into the amount of CO_2 (in Kilograms) and then the amount of carbon dioxide was converted into the amount of Carbon.

Table 2 shows the diesel consumption, carbon dioxide and carbon emission by irrigating one hectare each of wheat, barley, bajra and groundnut by 7 HP diesel irrigation pump.

In case of groundnut crop, irrigating one hectare for one season consumed 330 litres of diesel. Upon burning this much of diesel, 858 Kg of carbon dioxide would get released in the atmosphere thereby contributing 231.66 Kg of carbon in atmosphere (Table 2). Three irrigations of bajra in one-hectare area in one season used 82.5 litres of diesel as fuel. It would produce 214.5 Kg of carbon dioxide converting into 57.91 Kg of carbon in the atmosphere (Table 2). Irrigating one hectare of wheat by 7 HP diesel irrigation pump consumed 165 litres of diesel. This would produce of 429 kg of carbon dioxide thereby emitting 115.83 Kg of carbon in the atmosphere (Table 2). Irrigation by 7 HP diesel pump in barley consumed 82.5 litres of diesel per hectare per season. Burning 82.5 litres of diesel fuel would produce 214.5 Kg of carbon dioxide and hence contribute 57.91 Kg of carbon in atmospheric air (Table 2).

Table 2: Diesel consumption, carbon dioxide and carbon emission from one hectare of each crop irrigated by 7 HP diesel pump

S. No.	Crop	Diesel consumption (Litres/Ha)	Amount of CO_2 (Kg/ha)	Carbon emission (Kg/Ha)
1	Groundnut	330	858	231.66
2	Bajra	82.5	214.5	57.91
3	Wheat	165	429	115.83
4	Barley	82.5	214.5	57.91
5	Total	660.00	1716.00	463.32

Computation of carbon emissions from total area irrigated by diesel pumps of selected crops in Rajasthan

Table 3 shows diesel consumption, carbon dioxide and carbon emissions, when the total area of groundnut, bajra, wheat and barley which was irrigated by diesel pumps of different HP in Rajasthan, was assumed to be irrigated by 7 HP diesel irrigation pumps. In case of groundnut, irrigating 1,65,545.3 hectares area by 7 HP diesel irrigation pumps would require 54.63 million litres of diesel as fuel. This would produce 1,42,037.90 tonnes of carbon dioxide leading to the emission of 38,350.23 tonnes of carbon in atmosphere per year (Table 3). Total area of bajra irrigated by diesel pumps was 54,620.05 hectares in the state. If this area was irrigated by 7 HP diesel irrigation pumps then it would consume 4.51 million litres of diesel. It would produce 11,716.00 tonnes of carbon dioxide leading to the emission of 3,163.32 tonnes of carbon in atmosphere per year (Table 3).

Table 3: Diesel consumption, carbon dioxide and carbon emission from total area irrigated by 7 HP diesel pump of selected crops

S. No.	Crop	Area irrigated by diesel pumps (Ha)	Total diesel consumption (Million Litres)	Total carbon dioxide (Tonnes)	Total carbon emission (Tonnes)
1	Groundnut	1,65,545.34	54.63	1,42,037.90	38,350.23
2	Bajra	54,620.05	4.51	11,716.00	3,163.32
3	Wheat	8,80,779.3	145.33	3,77,854.32	1,02,020.67
4	Barley	78,976.86	6.52	16,940.54	4,573.94
5	Total	11,79,921.55	210.99	5,48,548.76	1,48,108.16

Irrigating 8,80,779.3 hectares area of wheat would consume 145.33 million litres of diesel which would produce 3,77,854.32 tonnes of carbon dioxide. This huge amount of carbon dioxide would contribute to 1,02,020.67 tonnes of carbon in atmosphere (Table 3). Total area irrigated by barley in the state was 78,976.86 hectares. By using 7 HP diesel irrigation pumps to irrigate this area, diesel consumption would be 6.52 million litres. Using 6.52 million litres of diesel as fuel would produce 16,940.54 tonnes of carbon dioxide thereby emitting 4,573.94 tonnes of carbon in air per year (Table 3).

Table 4: Carbon credit generated by replacing 7 HP diesel pump with solar irrigation pump

S. No.	Crop	Area irrigated by diesel pump (Ha)	Carbon di oxide emission (tonnes)	Carbon credit*	Carbon price @ USD 40	Carbon price @ USD 80
1	Groundnut	1,65,545.3	1,42,037.90	1,42,037.90	5,681,516.00	11,363,032.00
2	Bajra	54,620.1	11,716.00	11,716.00	4,68,640.00	9,37,280.00
3	Wheat	8,80,779.3	3,77,854.32	3,77,854.32	15,114,172.80	30,228,345.60
4	Barley	78,976.8	16,940.54	16,940.54	6,77,621.60	1,355,243.20
	Total	11,79,921.55	5,48,548.76	5,48,548.76	21,941,950.40	43,883,900.80

* 1 carbon credit = 1 ton carbon dioxide emissions

Table 4 shows the carbon credits that could be generated by replacing 7 HP diesel pumps with solar irrigation pumps in the selected cropping system in Rajasthan. It was found that if 11,79,921.55 hectares area which was originally irrigated by 7 HP diesel pumps, were irrigated using solar irrigation system then it would generate carbon credit equal to 5,48,548.76. If these credits were sold in the international carbon market at the prices suggested by High Level Commission on Carbon Prices to

effectively reduce carbon emissions to meet the Paris Agreement goals then it would generate revenue equal to USD 21,941,950.40 when sold at USD 40 and USD 382,98,676.80 when sold at USD 80.

Conclusion

From the findings of the study that it was observed that when 7 HP diesel irrigation pump was used to irrigate one hectare each of groundnut, bajra, wheat and barley then it would have consumed 660 litres of diesel which would release 1716 Kg of CO_2 in the atmosphere. Hence, total carbon emission would have been 463.32 Kg. If the total area of 11,79,921.55 hectares of groundnut, bajra, wheat and barley was irrigated using 7 HP diesel irrigation pumps then it would consume 210.99 million litres of diesel to run the pump. This would produce 5,48,548.76 tonnes of carbon dioxide thereby emitting 1,48,108.16 tonnes of carbon in the atmosphere per year. India can benefit significantly in terms of carbon credit in international market if it replaced as many diesel irrigation pumps with solar irrigation pumps.

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