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Solar Energy Use in Agriculture for Enhancing Farmers' Income: A Case of Solar Tubewell in North-Western Rajasthan

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Abstract

This study conducted in north-western Rajasthan, has examined the capital cost and subsidy in the installation of solar tubewell, its feasibility and benefits realization and has identified constraints in the adoption of solar tubewells. Following random sampling technique, primary data were collected from 124 sample farmers. The study has shown that although, adoption of solar tubewell has a direct relation with farm-size, a considerable proportion of small and marginal farmers also adopted solar tubewells. In recent years, the subsidy component has been reduced in total investment on solar tubewells. Solar tubewells provide impressive economic and water-saving benefits to the farmers and investment with current rate of subsidy in solar tubewell has been found to be feasible. However, without subsidies, investment in solar tubewell is not economically feasible. Due to financial considerations, all categories of farmers were reluctant in adoption of solar tubewells to the expected extent. To realize the benefits of solar energy use in agriculture, efforts should be directed towards more financial incentives to ensure faster adoption and group-adoption and provision for buy back of surplus power to discourage over-exploitation of groundwater and realization of extra income by the farmers.

Key words: Solar tubewell, capital investment, subsidy, diggi, drip & sprinkler irrigation, farmers' income, Rajasthan

JEL Classification: O13, P18, Q15, Q25, Q28

Introduction

The Government of India has set a target of doubling farmers' incomes by 2022. It has also set an ambitious target of 100 GW of solar power generation by 2022. Sharing the same time period, the twin goals are very much in tandem with each other. In the growth of agriculture in India, the role of irrigation, especially groundwater irrigation, is well documented and hence to enhancing farmers' income, groundwater irrigation has to play a major role. The groundwater extraction for irrigation now totally depends on electric and diesel sources of energy. Therefore, the agricultural sector in India is one of the major consumers of both diesel and electricity. The sector shared 17.30 per cent of the total electricity consumption in India during 2015-16 (MOSPI, 2017) and accounted for about 13 per cent of total diesel consumption in India (PPAC, 2013). It has been estimated that the replacement of existing diesel and electricity based pump sets with solar pump sets can lead to a reduction of 62 billion kilogram equivalent of carbon dioxide (kgCO2e) emissions and savings of USD 11.5 billion per annum (Infraline Energy, 2014). Solar pump sets have been found more cost viable than diesel pump sets and electric pump sets in Bihar

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(Tiwary, 2012). Solar energy use can also help in reducing the electricity and diesel subsidy bill of the government and farmers' dependency on erratic electricity supply and costly diesel. Therefore, the use of solar energy in agriculture is a potential area in the country and has vast scope to make substantial contributions towards the increasing farmers' income by reducing cost of irrigation and enhancing access to irrigation, especially in the remote areas.

Rajasthan provides one of the most attractive destinations for harnessing solar energy for various purposes, especially for irrigation on account of largest number of sunny days (325) in a year and one of the best solar insolation (6-7 kWh / m^2 / day). To harness the huge amount of solar energy, the Government of Rajasthan had installed 14 solar pumps on experimental basis in 2008-2009. The state had formulated an integrated solar water pump scheme in 2011-12 by combining various schemes of central and state governments. The subsidies available under various programmes were clubbed and the government subsidized 86 per cent of the capital cost of solar tubewell in 2011-12 with a target of 500 pumps in 14 districts. Form 2013-14, the plan was available for all the 33 districts in the state (GoR, 2015). To avail the subsidy on solar pump, the farmer has to meet three requirements – a storage source, a drip or sprinkler system and cultivation of cash crops. Presently, a maximum of 75 per cent (30% for farmers with electricity connection, 60% for farmers without electricity connection and 75% for farmers who have withdrawn their priority application for electricity connection) of the total capital cost of solar tubewell is subsided. So far, 29667 solar pumps have been installed in the state (2014-2017), which is the highest number in India (GoR, 2017). The state government plans to install 10,000 solar pumps in 2017-18 and now pumps of 7.5-10 horse power (hp) will also be included in the scheme (HT, 2017). Several studies have shown that solar energy use in agriculture generates impressive returns to the farmers (see Gulati *et al.*, 2016; Shah and Kishore, 2012; Tewari, 2012; Goyal, 2013). However, the feasibility of investment in solar tubewell and constraints to its adoption were not studied. Therefore, the present study was undertaken to examine the capital cost and subsidy in the installation of solar tubewell, its feasibility and benefits realization, and assess the constraints in adoption and operation of solar tubewells by the farmers in the state.

Data and Methodology

To study the solar energy use in agriculture, Hanumangarh and Shri Ganganagar districts from the north-western region of Rajasthan were selected on account of higher installation of solar tubewells in the region. A list of solar tubewell owners was obtained from both the districts and 64 farmers were selected randomly. An equal number of farmers without solar tubewells were also randomly selected from the same villages. The primary data were collected from these 124 sample farmers for the year 2016-17 on various aspects of solar tubewell, diggi, drip and sprinkler irrigation and other aspects of farming. The selected farmers were classified as small (landholding up to 2 ha), semi-medium (2-4 ha), medium (4-10 ha) and large (more than 10 ha) farmers and tabular analysis was conducted to calculate investment, costs and subsidy in installation of solar tubewell for water extraction from *Diggi* (canal) and groundwater aquifer. The tabular analysis was used to calculate the benefits of solar tubewells in terms of saving in cost on diesel and electricity used for water extraction to irrigate the actual area of different crops and the number of irrigations applied on the selected farms. Net present worth, benefit-cost ratio and internal rate of return were calculated to assess the feasibility of investment in solar tubewell for water extraction under different alternatives. The farmers' perceptions on the constraints in the adoption and operation of solar tubewells and source of information for the promotion of solar energy use in tubewells were also recorded and analyzed.

Results and Discussion

The total 124 selected farmers comprised 23 small, 20 medium, 49 semi-medium and 32 large farmers. The more than half (51.6%) of the total holdings had solar tubewells in the selected farms (Table 1). The farm-size-wise analysis showed that 39 per cent, 40 per cent, 51 per cent, 69 per cent of the small, medium, semi-medium and large categories of farmers had installed solar tubewells, respectively. The same pattern was followed in case of solar tubewells installed for water extraction from the canal-fed diggi. Adoption of water saving technologies is a pre-requisite for availing subsidy on solar tubewell in Rajasthan. Hence, a good proportion of farmers have adopted water-saving technologies like diggi, drip and sprinkler sets in the study area. Of the total farmers, 63.7 per cent have

Table 1. Details of solar tubewell, diggi, drip and sprinkler in north-western Rajasthan

Farm size	Farms	Solar tubewell (diggi)		Solar tubewell (groundwater)		Total solar tubewell		Irrigation technology					
								Diggi		Drip		Sprinkler	
	No.	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Small	23	7	30.4	2	8.7	9	39.1	15	65.2	7	30.4	2	8.7
Semi-medium	20	6	30.0	2	10.0	8	40.0	14	70.0	7	35.0	1	5.0
Medium	49	21	42.9	4	8.1	25	51.0	32	65.3	20	40.8	2	4.1
Large	32	13	40.6	9	28.2	22	68.8	18	56.3	9	28.1	5	15.6
All	124	47	37.9	17	13.7	64	51.6	79	63.7	43	34.7	10	8.1

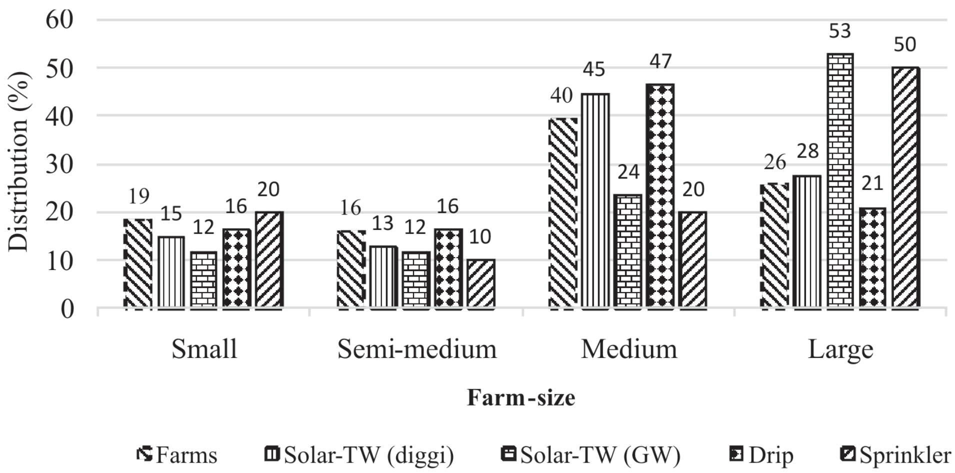

Figure 1. Farm-size-wise distribution of solar tubewells in north-western Rajasthan

adopted water saving diggi and 34.7 per cent have adopted drip irrigation technologies on their farms. Further, in the groundwater irrigated areas, the farmers have also started installation of sprinkler irrigation along with solar tubewell on account of pre-condition for solar subsidy (Figure 1). It is concluded that adoption of solar tubewell has a direct relation with farm-size.

Investment and Subsidy

The investment and subsidy in the installation of solar tubewells were studied and are presented in Table 2 for diggi and in Table 3 for groundwater. The average investment in solar tubewell installation for water extraction from the canal-fed diggi was found to be ₹ 4.92 lakh per 3.3 hp tubewell (Table 2). The subsidy on these solar tubewells was 82 per cent of the total investment. The farmers' own investment was only 18 per cent (₹ 0.89 lakh per 3.3 hp tubewell) and ranged upto 28 per cent in recent years. The farmers opined that 4.4 ha of cultivated area per tubewell is irrigated and the expected life of solar system is 19 years.

The investment in solar tubewell for groundwater extraction is a comparatively new phenomenon in the region and only 17 per cent of the total solar tubewells were installed for groundwater extraction. Although, there was higher hp (4.2) per tubewell installation in solar tubewell for groundwater extraction, the investment was found to be nearly same (₹ 4.81 lakh) (Table 3). The average subsidy on these tubewells was only 73 per cent of the total investment and it ranged from 60 per cent to 86 per cent over the years. As a result, the farmers' own investment was found to be higher (₹ 1.28 lakh per tubewell) in solar tubewells (groundwater) in comparison to solar-operated tubewells (diggi). This is on account of installation of most of these tubewells in recent years where the subsidy component has been reduced by the government. The average irrigated area per tubewell is 3.6 ha and the expected life of solar system is 22 years.

Table 2. Year-wise investment and other details of solar tubewell (diggi) in north-western Rajasthan: 2009-2016

Year	Solar tubewells (No.)	Average hp per tubewell	Average investment (₹)	Average subsidy (%)	Average own investment (₹)	Average area irrigated (ha)	Average expected life (years)
2009	3.0	3.2	436111	84	70000	8.33	20
2010	3.0	3.7	483333	82	85000	4.42	15
2011	6.0	3.0	513413	86	70833	3.90	25
2012	14.0	3.0	436327	83	73643	3.80	20
2013	11.0	3.2	518939	86	73091	5.53	19
2014	3.0	4.2	576667	74	151333	3.00	23
2015	2.0	3.0	486667	74	126000	2.19	20
2016	5.0	4.6	550000	72	154200	3.85	18
All	47.0	3.3	491682	82	89404	4.43	19

Table 3. Year-wise investment and other details of solar tubewell (groundwater) in north-western Rajasthan: 2010-2016

Year	Solar tubewells (No.)	Average HP of tubewells (No.)	Average investment on tubewells (₹)	Average subsidy (%)	Average own investment (₹)	Average area benefited (ha)	Average expected life (years)
2010	1.0	3.0	500000	86	70000	2.50	20
2011	2.0	3.0	375000	83	62500	3.13	25
2013	1.0	3.0	500000	86	70000	2.50	20
2014	3.0	3.7	450000	70	133333	4.83	23
2015	2.0	5.0	520000	84	85000	2.50	20
2016	8.0	4.8	512857	68	165857	3.57	22
All	17.0	4.2	481176	73	128000	3.65	22

Benefits of Solar Tubewells over Diesel and Electric operated Tubewells

The economic benefit in the adoption of solar-powered tubewells over diesel and electricity powered tubewells is the income realization from solar-powered tubewells. For the calculations of benefits, the actual crop-wise area irrigated and number of irrigations applied per unit of crop area by the solar tubewell owner farmers were considered and the cost of irrigating the same cropped area by diesel and electricity powered tubewell owners was considered as income to solar tubewell owners. The average savings from the solar-powered diggi tubewells was found to be ₹ 36,624 and ₹ 47,321 per tubewell considering the cost of diesel-operated diggi and groundwater tubewells, respectively. On the other hand, the average savings from the solar powered tubewell (groundwater) was found to be lower (₹ 31200/ tubewell) considering the cost of the electricity. The saving per ha of irrigated area through solar tubewell was highest (₹ 10433) over diesel operated tubewells (groundwater), followed by ₹ 10433 over diesel tubewell (diggi) and was lowest (₹ 2496) over electricity-operated tubewells (groundwater). As a result of decrease in or zero operational cost of irrigation and saving in the water, there was an impressive increase in irrigation area on farms. The increase in the area was highest (three-times) by switching from diesel to solar operated tubewell (groundwater), followed by 43 per cent increase from electricity to solar-operated tubewell (groundwater) and 38 per cent increase from diesel to solar-operated diggi tubewell.

Table 4. Benefits of solar tubewells in north-western Rajasthan

Benefit	Solar tubewell over diesel tubewell (diggi)	Solar tubewell (groundwater)	
		over diesel tubewell	over electric tubewell
Saving (₹/solar tubewell)	36624	47321	31200
Saving (₹/ha irrigated area)	5564	10433	2496
Increase in irrigated area (ha/farm)	1.8	3.4	3.8
Increase in irrigated area (%)	38.1	303.2	42.9

Source: computed by authors

Table 5. Farmers' perceptions about the benefits of solar-operated tubewell in north western Rajasthan

Particulars	Farmers' perception (%)				
	Higher	Moderate	Lower	No change	Negative
Saving in electricity /diesel cost	87.3	7.9	4.8	-	-
Saving of canal water	86.4	13.6	0.0	-	-
Better utilization of canal water	64.4	30.5	1.7	3.4	-
Saving of groundwater	-	2.9	5.9	35.3	55.9
Better utilization of groundwater	-	6.3	10.0	23.3	60.3
Equity in water allocation among farmers	-	38.5	15.4	46.2	-
Enhanced yield	81.3	17.2	1.6	-	-
Improved quality of kinnow fruits	60.3	33.3	4.8	1.6	-
Labour saving	-	-	3.8	11.5	84.6

Farmers' perceptions regarding benefits of solar-powered tubewells over diesel- and electricity-powered tubewells were recorded in terms of higher, moderate, lower, no change and negative benefits and the results are presented in Table 5. Most of the farmers reported higher savings in electricity and diesel cost and higher saving and better utilization of canal water. However, most of the farmers perceived the negative effect on groundwater extraction (56%) and poor application of groundwater (60%). The same concern on subsidised solar pumps in Karnataka was also highlighted by Shah *et al.* (2014). They reported that the subsidised solar pumps, which provide quality energy at near-zero marginal cost, can pose a bigger threat of groundwater over-exploitation than free power has done so far. By giving the opportunity to sell excess electricity generated by their solar pumps, the farmers will be encouraged for optimal exploitation of groundwater (IWMI, 2015). Buy back of excess electricity will also enhance the farm income. Higher labour requirement was also observed by most of the farmers after shift to solar system. Enhanced yield and improved quality of kinnow fruits on account of timeliness in the application of irrigation and efficient utilization of available irrigation water were favoured by 81 per cent and 60 per cent of the respondents. Equity in water allocation among farmers was also observed by some farmers, especially in groundwater irrigated area on account of working of water markets. It may therefore, be concluded that there are many economic and water saving benefits of solar energy use in agriculture in north-western Rajasthan.

Feasibility of Solar-operated Tubewell

The economic feasibility analysis of solar tubewells revealed that with 75 per cent and 68 per cent (actual realised by the farmers in the year 2016) subsidies on investment, solar tubewells generated impressive net present worth of ₹ 1.1 lakh to ₹ 2.6 lakh, benefit cost ratio of 1.62 to 2.90, and internal rate of return of 10.95 per cent to 40.33 per cent (Table 6). However, without subsidies investment in solar tubewell was not found economically feasible.

Table 6. Economic feasibility of solar-operated tubewells in north-western Rajasthan

Particulars	Subsidy (%)	Net present worth (₹)	Benefit-cost ratio	Internal rate of return (%)
Solar-operated tubewell (diggi)	0	-251758	0.55	-
(considering diesel cost as saving)	60	78242	1.34	5.90
	75	160742	2.1	20.62
	68 (Actual)	144042	1.89	16.07
Solar tubewell (Groundwater)	0	-124857	0.7602	-
(considering diesel cost as saving)	60	182695	1.86	15.24
	75	259583	2.9	40.33
	68 (Actual)	221873	2.28	24.03
Solar tubewell (Groundwater)	0	-238807	0.5414	-
(considering electricity charges as saving)	60	68745	1.32	5.57
	75	145633	2.07	19.99
	68 (Actual)	107923	1.62	10.95

Table 7. Farmers' perceptions about sources of information on solar-operated tubewells

Source of information	Respondents' perception (%)				
	Small	Semi-medium	Medium	Large	All
Other farmers	56.3	58.3	51.4	47.6	52.4
Government department	37.5	41.7	57.1	47.6	48.8
Newspaper & TV	31.3	33.7	37.1	39.3	35.7
Dealers/agents	12.5	33.3	31.4	47.6	32.1
Village Agri-fair	6.3	25.0	20.0	28.6	20.2
Cooperative societies	6.3	8.3	5.7	14.3	8.3
NGOs	-	-	2.9	4.8	2.4

Sources of Information on Solar-operated tubewell

The farmers' perceptions were recorded on the source of information regarding government schemes and subsidy on solar tubewells and benefits of solar tubewells and are presented in Table 7. More than half of the respondents revealed other farmers and government department as the major sources of information. Nearly one-third of the farmers also perceived mass media as 'newspapers & television' and 'dealers and agents' of the solar pump supplier companies as sources of information. Village-agri fair was reported to be a source of information by one-fifth of the total farmers. However, role played by primary cooperative societies, NGOs and scheduled commercial banks in promotion of solar tubewells was perceived to be poor by the farmers.

Constraints to Adoption of Solar-operated Tubewells

A perusal of Table 8 shows that the financial constraints namely, inadequate subsidy and high initial investment were the major constraints in adoption of solar system by all the categories of farmers. High interest rate on loan and delay in sanction of loan were also perceived by one-third and one-fourth of the respondents as major constraints. The farm level, solar technology-related and extension services related constraints were not found the major limiting factors in adoption of solar tubewells. Thus, on account of financial factors all categories of farmers are reluctant to adopt solar tubewells to the expected level. Therefore, there should be more financial incentives to ensure a faster adoption of solar tubewells and also to address equity concerns.

Table 8. Farmers' perceptions about constraints in adoption of solar system in north western Rajasthan

Particulars	Respondents' perception (%)				
	Small	Semi-medium	Medium	Large	total
Financial constraints					
Inadequate subsidy	56.3	47.4	56.8	78.3	59.8
High initial investment	56.3	42.1	61.4	52.2	54.9
High interest rate on loan	12.5	21.1	40.9	43.5	33.3
Delay in sanction of loan	12.5	21.1	27.3	39.1	26.5
Inadequate loan	12.5	5.3	20.5	30.4	18.6
Higher price charged under scheme	31.3	5.3	20.5	17.4	18.6
Farm level constraints					
Large fragmentation of holdings	6.3	26.3	13.6	17.4	15.7
Saline groundwater	25.0	15.8	11.4	26.1	17.6
Low off-farm income	12.5	15.8	13.6	8.7	12.7
Small landholding (less than 0.6 ha)	25.0	-	-	-	4.6
Solar technology related constraints					
Lack of knowledge about solar system	12.5	31.6	31.8	26.1	27.5
Non-availability of quality solar system	6.3	10.5	13.6	13.0	11.8
Delay in installation of solar system	6.3	5.3	15.9	4.3	9.8
Extension services related constraints					
Lack of exposure visit	12.5	7.6	6.0	8.7	9.8
Lack of demonstration by KVK/ agriculture/ horticulture department	4.0	5.3	5.1	4.3	5.7

Table 9. Farmers' perceptions about constraints in operation and maintenance of solar tubewells in north-western Rajasthan

Constraint	Respondents' perception (%)				
	Small	Semi-medium	Medium	Large	total
Little/ No problem	33.3	62.5	56.0	40.9	53.1
More labour requirement	55.6	50.0	53.3	22.7	34.4
Fog during winter	22.2	25.0	33.4	13.6	18.8
Lack of technical know-how	11.1	12.5	13.3	4.5	7.8
No follow up services by supplier (solar)	22.2	-	-	4.5	4.7
Non–availability of quality spare parts	-	-	13.3	4.5	4.7
Breakdown of solar energy use system	11.1	-	-	4.5	3.1

Constraints in Operation and Maintenance of Solar Tubewells

More than a half of the all solar tubewell owners were found to be fully satisfied and faced little or no problem in the operation and maintenance of solar tubewell (Table 9). However, one-third of the total farmers opined that solar-operated tubewells required more labour hours in comparison to diesel and electric operated tubewells. Fog during winter seasons was observed as a major constraint in the operation of solar tubewells by nearly one-fifth of the total farmers. The lack of technical know-how, no follow up services by solar pump-set supplier, non–availability of quality spare parts and breakdown of the solar pump system were not perceived to be the serious problems in the operation and maintenance of solar tubewells. It was important to note that subsidy on diggi is not available in groundwater irrigated areas. Even then, nearly two-fifths of the solar tubewell farmers in the groundwater-irrigated area constructed earthen diggis using polythene sheet on the basement for efficient utilization of groundwater when it was needed. However, most of the earthen diggis were reported to be damaged by wild animals. Hence, lack of subsidy on the investment in lined diggi in groundwater irrigation areas was also considered a major constraint in the operation of solar tubewells.

Conclusions and Policy Implications

The study has found that to achieve the twin objectives of doubling farmers' income and generating 100 GW of solar power by 2022, use of solar energy in agriculture is important. The Government of Rajasthan has taken important steps in promoting solar energy use in agriculture. The study has shown that although, adoption of solar tubewells has a direct relation with farm-size, a good proportion of small and marginal farmers also adopted solar tubewells in the study area. The average investment in solar tubewells was around ₹ 5 lakh and the average subsidy provided by central and state governments was more than three-fourths of the total investment. However, in recent years, the subsidy component has been reduced in total investment on solar tubewells.

The reported benefits of solar tubewells include substantial saving in the cost of diesel and electricity and increase in irrigated area due to saving of water. However, the negative impact of solar tubewell on groundwater extraction and inefficiency in groundwater application were also recorded by the majority of groundwater user farmers. Inclusiveness among farmers was also observed in groundwater-irrigated area on account of working of water markets. The investment at current rate of subsidy in solar tubewell has been found feasible as it generates impressive net present worth, benefit-cost ratio and internal rate of return. However, without subsidy, investment in solar tubewell was not economically feasible. The other farmers, government departments and extension system, newspapers & television and dealers & agents of the solar tubewell system supplier companies were reported to be major source of information regarding subsidy on solar tubewells and benefits of solar tubewells. The role of primary cooperative societies, NGOs and scheduled commercial banks was not significant in promotion of solar tubewells. Among financial constraints, inadequate subsidy amount and high initial investment were the major factors in the adoption of solar power tubewell by all the categories of farmers.

The study has suggested the need of enhancing financial incentives to ensure faster adoption of solar energy use in water extraction. The institutions like primary cooperative societies, NGOs and scheduled commercial banks could also be involved in the promotion of solar tubewells. For efficient use of groundwater, adoption of diggi should be promoted by providing appropriate subsidy. Appropriate steps should be taken to connect solar tubewells to the grid with a provision for buy back of surplus power to discourage over-exploitation of groundwater and realization of extra income by the farmers.

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