



Solar energy an income accelerating option for irrigation of Kinnow orchard: An example in Rajasthan state of India

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ABSTRACT

The PV solar device for pumping water from underground and from other source of water for irrigation has been recognized as very new initiative. Three year socio-economic study sponsored by Ministry of Human Resource under higher education scheme has been conducted in two districts of Rajasthan applying standard methodology to assess comparative advantages of PV solar device for irrigation of kinnow orchard. Hence, study found that solar irrigation system has enhanced the returns of farm and played a partial catalyst role to enhance the income of the farm. Therefore, the economic as well as environment benefits need to realize for popularization of the solar device for betterment of farming society which would reduce the dependency on electricity of farmers for irrigation specially and other works depend on electricity generally. Hence, provision of incentives on solar devices should be made to the farmers.

Key words: Feasibility, Income, Kinnow, PV, Solar, Rajasthan

Energy is a partial tool for economic growth and social progress of any of country and the region (Anonymous 2012). Photo voltaic (hereafter PV) has become an energy generating tool becoming very popular which increased with its exponential growth. PV has evolved for small scale applications in many fields and it has become a main source of energy. Initially, for providing economic incentives solar PV systems were implemented by many of countries. Consequently, 'economies of scales' cost of PV declined significantly (Woodford 2018). The net irrigated area of India from 56936 thousand ha in 2001 increased to 68385 thousand ha (20.10%) in 2019-20. Out of net irrigated under canal (23.90%), tanks (2.70%), tube-wells (45.70%), other (shallow) wells (16.61%) and other sources (11.07%) of irrigation in India (GoI 2019). The first Solar pumping system in India started during 1992 (MNRE 2016). Among the states of India the state of Punjab was the first state in which solar irrigation pumps were initiated, where surface irrigation was extensively available (Tewari 2012).

Consequently, India has first rank in operation of solar water pumps with 62000 units (Chandrasekaran 2016). The government of India's recent ambitious initiative brought installation as a mission at larger scale throughout the country (MNRE 2016). Under this mission pumps were established for irrigation and drinking water purposes (Chandrasekaran 2016). The various state nodal agencies and National Bank for Agriculture and Rural Development (NABARD) are coming forward to achieve the set targets (MNRE 2016).

In Rajasthan establishing the solar unit programme was started in 2008-09 with a target of 14 solar pumps. Further, in 2010-11 the target of 50 units to 500 in 2011-12, 2200 solar units in 2012-13 and to 10 thousand units in 2013-14 to cover all the 33 districts of the state (Singh *et al.* 2017). Since the state of Rajasthan is rich in renewable energy resources, especially wind and solar for irrigation. In respect to solar the state of Rajasthan is blessed highest numbers of sunny days (325) which produces of 6-7 kWh/m² per day solar radiation on earth (Lal *et al.* 2013). Presently, out of without electric connection for irrigation about 75 per cent of farmers have withdrawn their application for electricity connection. It became possible because of novelty (high benefit cost ratio) of the PV solar pump (Panwar *et al.* 2011 and IRENA 2015). Consequently, 29667 units of PV solar pumps have been installed in the state of Rajasthan in the year of 2014-2017, which was the highest number (Singh *et al.* 2017). In future the state is planning to enhance the PV units with its 7.5-10.0 hp (Singh *et al.* 2017). Mostly the PV solar units have been established in farmers' farm to pump out the irrigation water particularly in orchard

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crops. Among the orchard crops *kinnow* crop has been recognized as major crop in the state. The PV solar system improved yields of crops and enlarged profits (IRENA 2015). The state of Rajasthan, *kinnow* fruit crop covered 8.8 thousand ha, 189.48 thousand MT and 21.48 MT per ha area, production and yield, respectively in the year 2016-17 (GoR 2016). Therefore, in backdrop of above facts of PV solar units this paper is an effort to assess the benefits of irrigation through PV solar units in Kinnow orchard in Rajasthan state of India.

MATERIALS AND METHODS

The site for present investigation was in Sri-Ganganagar block of Sri-Ganganagar and Khajuvalla block of Bikaner districts of Rajasthan as highest number of solar units were installed to irrigate the kinnow orchard in these blocks under districts. The temperature of these districts ranges from 35⁰ to 40⁰ C with 325 numbers of sunny days (Goyal 2013) which is highest in our country. For investigating the apparent impact of solar energy for acceleration of income of the farmers a total of 200 kinnow growers were selected and categorized into three groups, viz. irrigation system of solar (160 adopters) and diesel (40 non-solar-adopters) from both the districts under investigation (Table 1). Primary data comprising fixed costs like cost of solar pump, cost of diesel pump, cost of well or tube well construction, cost of pond (diggi) construction, cost of drip system, depreciation of tools and implements, interest accrued on fixed cost, salvage and rental value of assets and land, respectively, life span of solar, electric and diesel pump, establishment cost of

kinnow orchard, cost of seedlings, plant protection, manures and fertilizers, training or pruning, intercultural operation, gap filling, irrigation, harvesting of kinnow and cost of ward and watch and others like repair and maintenance cost of the systems like, diesel, solar system, drip system, tube-well and pond (diggi) were collected for the crop year of 2015-18 (Consecutive three years) from selected solar adopters and non-adopters.

Analytical framework

The data were analyzed to draw an apparent inferences of impact of solar irrigation system over traditional system (diesel) by applying standard techniques like cost concepts (GoI 1979), the comparative life cycle cost analysis (Narale *et al.* 2013), Net present value (NPV), benefit – cost ratio (BCR) and Break – Even point (BEP) analysis (Reddy and Raghu 1996).

The comparative life cycle cost worked out by using formula of

$$LCC = CC + MC + EC + RC - SC$$

where, CC = Capital cost, MC = Maintenance cost, EC = Energy cost, RC = Replacement cost, SV = Salvage value.

The Net present value (NPV) worked out by using

$$NPV = \sum_{i=1}^n \frac{Y_n}{(1+r)^n} - C$$

where, Y_n = Net cash inflows in the nth year, r = Discount rate, C = Initial cost of investment, n = Economic life of the kinnow orchard.

NPV of the project should be accepted if its value is positive, and reject if its value is negative. If the NPV is zero, it is a matter of indifference.

Benefit cost ratio (BCR)

Benefit-cost ratio (BCR) is the ratio discounted net benefits to the initial investments. The BCR has been worked out as

$$BCR = \frac{\text{Gross present value of income}}{\text{Gross present value of costs}}$$

Break-even point (BEP)

Break –Even point is the point at where total cost curve and total revenue are equal other which indicates the quantity of production at which the producer neither loss nor make a profit. It was calculated as:

$$BEP = \frac{FC}{(P - VC)}$$

where, FC = Fixed cost in per ha of kinnow, P = Price per q of kinnow in rupees, VC = Variable cost per q of kinnow in rupees.

RESULTS AND DISCUSSION

Life cycle cost of different irrigation system

The economic viability of any assets and technology

Table 1 Selection of solar adopter and non-adopter under irrigation system (Number)

Block	Village	Respondents under irrigation system				Total	
		Solar (Adopter)		Diesel (Solar non-adopter)		TR	SR
Sri-Ganganagar		TR	SR	TR	SR	TR	SR
	11Q	30	23	15	5	45	28
	13Q	35	27	12	4	47	31
	15-Z	21	16	16	6	37	22
	9-Q	18	14	12	5	30	19
Sub total		104	80	55	20	159	100
Khajuvalla	17 KYD	36	28	9	4	45	37
	6 PHM	23	18	16	7	39	25
	7 PHM	23	18	10	4	33	22
	3 KYD	20	16	12	5	32	21
Sub total		102	80	47	20	149	100
Total		206	160	102	40	308	200

TR- Total Respondents, SR- Selected Respondents. Q, Z, KYD and PHM are minor/distributors of Gang Canal and 11, 13, 15, 9,17,6,7 and 3 are number of mori (hole) and Village situated at 11, 13, 15, 9,17,6,7 and 3 number mori of Q, Z, KYD and PHM Minor known as 11Q, 13Q,15Z,9Z, 17KYD, 6PHM, 7PHM and 3KYD Village.

depends on its life cycle (useful life). The farmers always interested in long lasting technology due to one reason or other. Therefore, for estimating the life cycle cost of different irrigation systems the following components were considered:

Cost component of irrigation systems: Assuming the life of diesel pump of 20 years with its maintenance cost of ₹ 1890 per year, working hours (6 hours per day minimum and 300 days in a year) and price of fuel (₹ 70 per litre). It has also been assumed that the initial cost of diesel system of ₹ 25000 minimum. Similarly, the life of solar irrigation system was also assumed twenty years with its maintenance cost of ₹ 150 per year considering the 6 hours per day accounted of 300 days of working in a year. The initial cost of solar system was ₹ 106595 with its salvage value of ₹ 28500 (Table 2).

Life cycle of irrigation systems

The life cycle cost of diesel system for 20 years has been estimated of ₹ 3859480 by taking in account of capital cost or initial cost of ₹ 25000, maintenance cost of ₹ 37800 and fuel cost of ₹ 3780000. The replacement and salvage cost of diesel system has been accounted of ₹ 21680 and ₹ 5000, respectively. Contrary to diesel irrigation system, the life cycle cost of solar irrigation has been estimated of ₹ 81095 for 20 years of its useful life by taking in account of its cost of capital, maintenance and salvage and amount of ₹ 106595, ₹ 3000 and ₹ 28500, respectively (Table 3).

Hence, the solar irrigation system found to be cost effective (lesser cost) in its maintenance (Singh *et al.* 2017). The comparison of the life cycle cost like operational,

maintenance and fuel costs were higher on diesel than the solar (Zieroth 2005, Narale *et al.* 2013). Consequently, considering the increase in price of fuel in future; the life cycle cost will also go up of diesel irrigation system (Wahyuni *et al.*, 2015). In present era of climate change the diesel irrigation system should be avoided for neat and clean environment (Armanous *et al.* 2016). Further, it is concluded that life cycle cost analysis of solar system was found to be more long lasting and economical choice over the diesel irrigation system (Reca *et al.* 2016, Singh and Mishra 2015).

Economic viability of irrigation systems

For obtaining logical inferences the sampled orchards have been appraised over 17 years taking into account various components of costs and returns. The costs and return estimates were discounted at an annual rate of interest of 12 per cent for the medium term investment for each year (Table 5 and 6). Comparative returns under solar irrigation orchard estimated to be higher side than the diesel irrigation system due to the merit of solar system which supplies energy to pump water un-interrupted as the water is required to maintain fertility of soils in Rajasthan at regular and continuous basis (Hossain *et al.* 2015 and Singh *et al.* 2017).

The Net Present Value (NPV) of diesel and solar irrigation estimated to be of ₹ 349214, ₹ 842521, respectively in kinnow orchard. The Benefit Cost Ratio has been estimated to be at higher (2.36) than diesel (1.31) irrigation system (Khan *et al.* 2013). The break-even point estimated to be less on solar irrigated orchard (4.16 ton) than the diesel irrigated orchard (5.04 ton) which shows the ability and efficiency of solar system for more production. Similarly, the payback period under solar system also worked out to be of lower (7.1 years) than the diesel (8.7 years) irrigation system (Table 4). Hence, the analysis of different economic indicators showed the solar powered irrigation system as more economically feasible than diesel. The higher returns in solar system proved the merit of solar system under orchard has been irrigated without using any fuel which saved huge amount of operational cost. Consequently, returns of solar irrigated orchard increased compared to diesel irrigation system (Singh *et al.* 2016 and Kaur and Singla 2016).

Conclusions and policy implications

From the analysis of irrigation systems it was apparent

Table 2 Cost component of different irrigation system

Particulars	Irrigation systems	
	Diesel	Solar
Life (Years)	20	20
Maintenance cost (₹/year)	1890	150
No. of days system work	300	300
No. of hours/day	6	6
No. of units	1.5 l/hr	-
Price of per unit (₹)	70/l	-
Initial cost of systems (₹)	25000	106595

Table 3 Life cycle cost of irrigation systems (₹)

Particulars	Irrigation systems	
	Diesel	Solar
Capital cost (CC)	25000	106595
Maintenance cost (MC)	37800	3000
Energy cost (EC)	3780000	-
Replacement cost (RC)	21680	-
Total cost (₹)	3864480	109595
Salvage cost (SC)	5000	28500
Life cycle cost (LCC)	3859480	81095

Table 4 Economic feasibility analysis of different irrigation system

Feasibility indicator	Irrigation systems	
	Diesel	Solar
Net present value (₹)	349214	842521
Break-even point (Ton)	4.26	5.04
Pay-back period (Year)	8.7	7.1
B:C ratio	1.31	2.36

Table 5 Cash flow analysis diesel system irrigated kinnow orchard

Year	Cost	Return	Discounted cost at 12% discounted rate	Discounted benefit at 12% discounted rate	Discounted net return at 12% discounted rate
1	142291	0	127046	0	-127046
2	136088	0	108489	0	-108489
3	135914	0	96741	0	-96741
4	141961	153600	90219	97616	7397
5	151114	172800	85746	98051	12305
6	159746	192000	80932	97273	16341
7	174056	245760	78734	111169	32435
8	174536	303360	70492	122522	52030
9	174177	376320	62810	135705	72895
10	175187	384000	56405	123638	67232
11	175339	433920	50406	124742	74336
12	176069	430080	45192	110391	65198
13	176615	464640	40476	106483	66008
14	176881	480000	36193	98218	62024
15	176942	483840	32327	88396	56069
16	177012	491520	28874	80178	51303
17	177034	492288	25784	71699	45915
Total	2800960	5104128	1116866	1466080	349214

Table 6 Cash flow analysis of solar system irrigated kinnow orchard

Year	Cost	Return	Discounted cost at 12% discounted rate	Discounted benefit at 12% discounted rate	Discounted net return at 12% discounted rate
1	93237	0	83248	0	-83248
2	80969	0	64548	0	-64548
3	80175	0	57067	0	-57067
4	81591	145920	51853	92735	40882
5	83747	153600	47520	87157	39637
6	85749	180480	43443	91437	47994
7	87527	253440	39593	114643	75051
8	87306	307200	35261	124073	88812
9	87830	345600	31673	124627	92954
10	88549	384000	28510	123638	95127
11	89092	445440	25612	128053	102441
12	89935	456960	23084	117290	94206
13	90843	476160	20819	109124	88305
14	91136	480000	18648	98218	79569
15	91647	499200	16744	91202	74458
16	90528	503040	14767	82057	67290
17	90402	506880	13167	73824	60658
Total	1490262	5137920	615555	1458077	842521

that the solar irrigation system was only long lasting, portable, sustainable and eco-friendly and economically feasible and viable device for irrigation. Further, economic feasibility analysis like pay-back-period, break-even-point, BC-ratio and cash-flow has proved that solar irrigation system has enhanced the returns of farm and played a partial catalyst role to enhance the income of the farm. Hence, provision of incentives on solar devices should be made to the farmers.

Solar energy requires no energy cost for pumping water and is a onetime investment reaping long term benefits and maintaining eco-friendly management strategies. The income and profitability of farmers will be enhanced and also attracts youth into agriculture. Thus further research in the field will be helpful to the researcher, extensionist, policy makers, teachers, scholars, bankers and industrialist to decide their way forward regarding solar use to enhance the life of farmers in rural areas thereby reducing the dependency on electricity of farmers for irrigation and other activities requiring electricity.

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