

Impact assessment of water savings technologies for bridging the gap from lab to land

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Rajasthan is the largest state of the country having more than 10.4% of the country's geographical area, supporting more than 5.5% of the human population and 18.70% of the livestock with 1.16% of the total surface water available in the country. More than 60% of the gross sown area in the state falls under arid or semi-arid zones, agriculture in the state continues to be largely rainfed. Management of water resources helped to achieve "per drop more crop and har khet ko pani" at the field level. Technological interventions namely laser levelling, raised bed technology, biogas slurry application, micro-irrigation, SPV energy in irrigation, sensor driven irrigation system and construction of water storage reservoir were made in the district Alwar of Rajasthan to enhance the water and energy efficiency at the field level in selected 34 villages.

Key words: Impact assessment, Lab-to-land, Water saving technologies

EFFICIENT utilization of available water and energy resources is crucial for a country like, India, which shares 17% of the global population with only 2.4% of land and 4% of its water resources. The current Indian population of 1.2 billion may stabilize at 1.64 billion by 2050, implying a gradually increasing demand for food. To meet the food security, income and nutritional needs of the projected population in 2050, the food production will need to be almost doubled. Rajasthan is the largest state of the country having more than 10.4% of the country's geographical area, supporting more than 5.5% of the human population and 18.70% of the livestock with 1.16% of the total surface water available in the country. As more than 60% of the gross sown area in the state falls under arid or semi-arid zones in the state, agriculture in the state continues to be largely rain fed. Management of resources in agriculture may help in savings of significant amounts of water to achieve 'per drop more crop and har khet ko pani' at the field level. Technological interventions namely

laser levelling, raised bed technology, biogas slurry application, micro irrigation, SPV energy in irrigation, sensor driven irrigation system and water storage reservoir were made in district Alwar of Rajasthan to enhance the water and energy efficiency at the field level in selected 34 villages.

Study area

Alwar has an important place in agriculture production in Rajasthan. Total geographical area of the district is 7,82,897 hectares which is about 2.5% of the state. The net cultivated area is 5,09,107 hectares from which about 83% is irrigated and remaining 17% is unirrigated. Double cropped area is 2,72,508 hectares of which 32,230 hectare (12%) area is irrigated and remaining 2,40,278 hectare (88%) area is unirrigated. In *kharif* Bajra, maize, jowar, *kharif* pulses, arhar, sesamum, cotton, guar etc. are sown in about 3,29,088 hectare (42%) and in *rabi* wheat, barley, gram, mustard, taramira and *rabi* pulses

etc. are sown in about 4,52,527 hectare (58%). The main source of irrigation is tube wells. In Alwar district, 68% of the working population is employed in the agriculture sector. In this district, 82% of the farmers come under small (1-2 ha) and marginal (<1 ha) land holding categories. The main source of irrigation is wells and tube wells having 35470 electric motors and 66502 diesel pump sets. The normal rainfall for the district is 657.3 mm. The rainfall distribution in the district is uneven and scattered which resulted sometimes flood problems and some time drought position which affect the agriculture production as well as cropping pattern in *kharif* and *rabi* season. There are no canal irrigation facilities in the study area. The climate of the area is semi-arid type. Technological interventions namely laser levelling; raised bed technology, micro-irrigation and biogas technologies were made in district Alwar of Rajasthan state to enhance the water and energy efficiency at the field level in 34 selected villages each representing the normal irrigation



Table 1. Existing crops and irrigation technologies in the villages

Season	Crop	Methods of water application	No. of irrigations
Kharif	Bajra	Furrow	3
	Jwar	Furrow	3
	Gwar	Furrow	3
	Till	Furrow	3
Rabi	Cotton	Furrow	4
	Wheat	Check basin	5
	Barley	Furrow	5
	Mustard	Check basin	5
	Tomato	Check basin	3
	Chilli	Check basin	3

practices in vegetables–wheat cropping system of the area.

Participatory Rural Appraisal (PRA) techniques were conducted in the villages to get an insight in to the farmers' perceptions. Lack of awareness among farmers about the consequences of inefficient water application and the lack of appropriate technologies for regulated application of the desired quantity of water at appropriate time are among the major causes of low water use efficiency at the field level. Water productivity can be enhanced by adopting a good water application method along with laser leveling, raised bed technology, biogas slurry application, micro-irrigation, SPV energy in irrigation, sensor driven irrigation system and water storage reservoir. Daily values of meteorological data comprising maximum and minimum temperatures, average relative humidity, wind speed, rainfall and sunshine hours were collected. These

data were analyzed to obtain their monthly average values. Physico-chemical properties of soils, quality of irrigation water, source of water, duration of irrigations, crop details were monitored in the farmers' fields. Fields were surveyed with the help of dumpy level and the reduced levels at a square grid of 10 m × 10 m were determined. Grid survey data were analyzed to prepare the topographical maps.

The average values of field capacity and wilting point moisture content of the soil were determined and were 21.3 and 9.8%, respectively. To determine nutrients status of soil, analysis of soil samples were done. Soils of these villages were nitrogen deficient (av. 151.9 kg/ha) but having very high phosphorous (54.2 kg/ha) and potassium (430.1 kg/ha). The average bulk density of soil was 1.46 g/cm³. All the cultural practices followed by the farmers were maintained. A total of 3-5 post sowing irrigations were applied in tube well irrigated fields (Table 1).

Most farmers expressed that their land is not leveled and needs further leveling. Before leveling, contour interval of 1 meter resolution was prepared as it is necessary for foot hill area like Ramgarh because it helps to understand the slope of the each agricultural field. Existing slopes of agricultural field was assessed and fields were selected for further study.

Capacity building of farmers

Capacity building through training of farmers, field visits and institute

visit on various technologies and their interaction with other progressive farmers to motivate the farmers for large scale adoption of water saving technologies were done throughout the study period.

Based on PRA and field observations on different cultural practices, gaps between the existing and appropriate technologies were established. The interventions included laser leveling to improve water application and biogas technology for saving of energy and fertilizer besides enhancing the crop yield, low cost bucket drip system, micro-irrigation at the field level to improve overall irrigation efficiency.

Laser land leveling technology

Farmers traditionally have been practicing land levelling in their fields using animal drawn patta or wooden planket or tractor driven ordinary levellers consisting of a blade and a small bucket for shifting the soil from higher spot to the low laying areas. These traditional methods of land levelling are not designed to match the stream size, soil type, field size and slope and moreover they are tedious, time consuming, uneconomical and inaccurate. Significance amounts (10-25%) of irrigation water are lost during application at the farm due to poor management and uneven fields. Excessive irrigation at low lying areas leaches soluble nutrients from the crop root and makes the soil less productive. On the other hand, germination and crop stand are



Training of farmers



Laser levelling of field

constrained by low soil moisture at higher levels.

Fields of 136 selected marginal farmers were laser leveled to evaluate its impact on water and labor saving and yield increase in Alwar. The average yield of 5.25 t/ha was recorded from all the laser-leveled fields (Table 2). The cost of precision leveling at farmer's fields through laser leveler varied from ₹ 3729 to 5748 per hectare, depending upon the undulations in the field. Significant changes were observed in the average basin sizes that the farmers adopted before and after the laser leveling. Significant savings of water (30%), energy (33.3%), and labor (2%) with increase in wheat production (18.2 to 25%) was resulted from this intervention in the selected villages besides 26% increase in grain yield of wheat by laser leveling of fields as compared to traditionally leveled field. This is because of better distribution and less loss of irrigation water as reflected by higher irrigation efficiencies.

Raised bed technology

Raised bed-planting system with a number of defined rows (usually two to four rows) planted on top of the bed with furrow irrigation offers great potential to avoid wastage of water and soil nutrients. The technology can also reduce water logging through improved surface drainage, and the opportunity to diversify for the crops sensitive to water logging. Raised beds enable crop flexibility, rapid response to

market opportunities and intercropping along with improving soil organic matter status. Raised bed technology was evaluated in 72 farmer's field covering an area of 34.75 ha. The benefits of the raised bed technology resulted in the savings of cost of seed (25%), fertilizer (20%) and irrigation water (25-30%) (Table 3).

Biogas technology

The amount of biogas produced and nutrients supplied to crop was assessed for fifteen (15) farmers to meet the energy requirement for cooking and enhance the soil fertility with improvement in the soil health. For biogas production, average summer air temperature above 20°C yielded mesophilic conditions, and average winter temperature below 20°C lead to psychrophilic conditions. Thus, mesophilic conditions dominate from April to November and psychrophilic conditions from December to March. The rate of gas production was taken as 0.067 m³/kg during summer and 0.045 m³/kg during winter. The Indian rates of energy consumption mirror those set by the FAO/CMS for India, which assume a daily biogas energy need of 1.5-2.0 m³ for a household of six people (FAO 1996). It was observed from our study that biogas was sufficient to meet the energy needs of 6-8 family members throughout the year.

Slurry produced from biogas plant was mixed with irrigation water and applied to crop at the rate of 30 t/ha.

Addition of 30 t/ha biogas slurry provided 36 kg nitrogen, 26.8 kg phosphorous and 34.1 kg potassium per ha besides other micro nutrients. Biogas technology resulted in reduction of irrigation demand, water and energy requirement for pumping irrigation water to the tune of 5.9, 15.8 and 20 % besides 15.2 % increase in wheat yield (Table 4). Application of fly ash and biogas slurry reduced bulk density and increased saturated hydraulic conductivity and moisture retention capacity of soil, which increased short term and long-term benefits in terms of production increase and soil amelioration.

The digested slurry can be directly applied in the field using a bucket or drum. An alternative to this is to discharge the slurry into an irrigation canal. However, these methods of direct application have some

Table 2. Impact evaluation of laser levelling on water and energy and wheat yield

Parameter	Laser levelled field	Control plot	Saving (%)
No. of irrigations	6	6	0.00
Total time of irrigation (h)	144	216	33.3
Irrigation cost	21600	32400	33.3
Total irrigation water (m ³)	4200	6000	30.0
Yield (t/ha)	5.25	4.20	25.0
Total income (₹/ha)	44708	35765	25.0
Energy (kWh/ha)	1074.24	1611.4	33.3
IWP (l/kg)	398.0	740.0	46.2



Application of biogas slurry with irrigation water

Table 3. Impact of raised bed technology on water savings in onion (District Alwar)

Particular	Raised bed technology	Conventional practice	Input savings and increase in yield (%)
No. of irrigation	5	5	0.0
Irrigation water (m ³)	6300	8400	25.0
Irrigation cost (₹/ha)	1620.00	2160.00	25.0
Fert./Manure cost (₹/ha)	2626.67	3421.82	23.24
Yield (q/ha)	130.00	110.00	18.1
Total income (₹/ha)	65000	55000	18.1
Energy (kWh/ha)	671.40	895.20	25.0
IWP (l/kg)	124.62	196.36	36.6

Main product: ₹ 500/quintals

limitations. Firstly, not all farmers have irrigation facility throughout the year and digested slurry is in a liquid form, it is difficult to transport it to farmers located far from the biogas plants. Farmers realized savings of 1 irrigation and additional yield of 25-30%, energy savings of 16-30% and fertilizer savings of 20% over the conventional water application in wheat. In paddy crop, there was savings of 100% fertilizer means no additional fertilizer was applied. In several cases, relatives of participating farmers have also got constructed their biogas plants. Biogas technology saves fuel and fertilizer can be of great use for the farmers (Table 4).

Low cost family drip system

A low head bucket drip system was designed and standardized for kitchen gardening (25 to 50 m²). This system consists of a bucket, portable laterals, and drippers.

System cost (varies from ₹ 750 to ₹ 21,000 having 5 years life) and benefits of ₹ 1800 to 24000 per year, under different designs, were determined to illustrate a benefit cost ratio of 1.8 to 2.2. Family drip systems (low cost) for farmers were designed to provide them firsthand experience. Different bucket kits produced 150 kg of bottle gourd, 90 kg of bitter gourd, 75 kg of okra in one season (March to June). Cropping systems brinjal-carrot-

radish/ coriander; bottle gourd-tomato; papaya intercultural with early cauliflower and lettuce/spinach were standardized to get round the year vegetables. Forty (40) low cost drip systems were installed in Alwar, Rajasthan where farm women were keen to maintain.

Micro-irrigation and fertigation

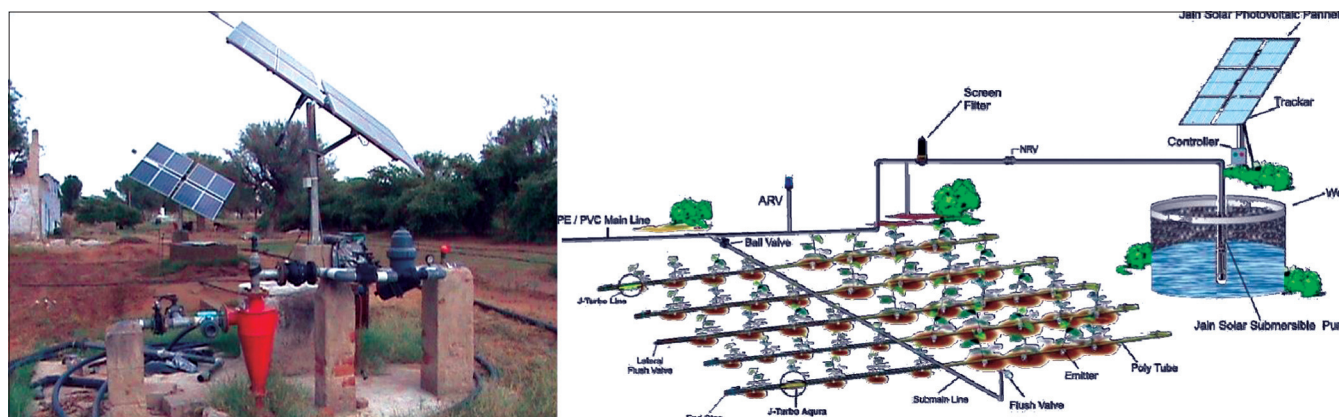
Micro irrigation is used more often for horticultural crops but water requirement of horticultural crops under drip were not available. The water requirement of horticultural crops was estimated through water balance studies in the field and was later compared with modified Penman Montieth method (cauliflower, cabbage, tomato, okra, potato, onion, broccoli, bottle gourd, ridge gourd, bitter gourd, wheat, pigeon pea, mung bean, brinjal, garlic, pomegranate, sugarcane, papaya, kinnow). Micro-irrigation system resulted in 30 to 70% water savings in various orchard crops and vegetables along with 10 to 60% increase in yields as compared to conventional methods of irrigation (cauliflower, cabbage, tomato, okra, potato, onion, broccoli, bottle gourds, ridge gourd, bitter gourd, wheat, pigeon pea, mung bean, brinjal, garlic, pomegranate, suagarcane, papaya, kinnow).

Small farmers solar initiatives, Alwar (Rajasthan)

Rajasthan is blessed with one of the best solar insolation on earth (6-7 kWh/m²/day) with about 325 sunny days in a year, which makes it one of the most attractive destinations to harness solar energy. Rajasthan has disadvantage by factor of ten for supply of irrigation water

Table 4. Impact of biogas slurry on water savings and yield in Wheat (District Bulandshahar)

Particular	Biogas slurry applied with water	Conventional practice	Input savings and increase in yield (%)
No. of irrigation	5	5	0.00
Irrigation water (m ³)	5600	6650	15.6
Fert./Manure cost (₹/ha)	3045.2	3886.5	21.7
Yield (q/ha)	72.56	55.64	30.4
Total income (₹/ha)	111380	85407	30.4
Energy (kWh/ha)	477.4	566.9	15.8
IWP (l/kg)	436.6	676.1	35.4



Solar water pump system—with drip irrigation

vs. agriculture area. Acute water shortage, erratic rainfall and recurring droughts have exacerbated the situation. About 70% irrigation is done through wells/ tube-wells energized mainly with grid-power/ diesel-generators. There is a long queue of farmers seeking grid-based electricity connections for irrigation; approximately 60,000 farmers are waiting. Expansion of electric-grid is not feasible in far-flung areas; almost 70% area in the State is characterized as desert. Out of 249 blocks, nearly 200 are in the highly critical zone. Almost 90% of groundwater withdrawal in the State is utilized through flood/furrow-irrigation methods with mere 35 to 45% water-use-efficiency.

Field study was done in the three farmer's fields having four solar pumping systems belong to small and marginal farmers those who are growing onion in *kharif* and wheat in *rabi* using solar water pumping system, connected to drip irrigation system. Study was done considering different economic parameters as the maintenance and operation costs, fuel costs, salvage costs, initial costs. Subsidy on installation of SPV system decreased from 86 to 50%, and also the cost of solar water pumping system was reduced (Tables 5 and 6). Water table also goes down in that area but the solar water system was working properly giving adequate water. Table 5 shows the technical specifications of PV panel of 3000 Wp while PV pump specifications are provided in Table 6. In the study SPV submersible pump with AC, DLS (domestic lighting system) and an auto tracker is used.

Soil moisture sensor based automated irrigation system and linking with DSS

A decision support system (DSS) was developed using real time online sensors namely soil temperature, soil moisture, ambient temperature, humidity, leaf wetness, solar insulation to estimate crop water demand. The ET_0 and crop water requirement was estimated from developed DSS and compared with CROPWAT model. Sensors application in estimation of crop water demand could save 24.4 and 33.8% of water in comparison to CROPWAT and US class evaporation pan, respectively. Developed DSS was integrated with a soil moisture sensor designed by us

during the years 2013-15 and tested in six vegetable crops, viz. okra, tomato, brinjal, broccoli, potato, and knol-khol. Water savings of 39.62-48.67% was achieved using automated drip irrigation over manually controlled check basin irrigation for all the six vegetable crops.

SUMMARY

Significant savings of water (30-60%), energy (30-40%), and labor (20%) with increase in production (18.2 to 50%) was resulted from technological interventions. Fifteen farmers were encouraged to install biogas plants (2-6 m³ capacity) with a view to use biogas slurry directly to field along with irrigation water to

Table 5. Farmers who adopted solar pumping system linked with drip system

Farmer name	Shri Karan Singh	Shri Ratiram	Shri Jugmaal
Village/Mandal	Pehal	Pehal	Pehal
District	Alwar	Alwar	Alwar
Crop sown	Onion, Wheat	Onion, Wheat	Onion, Wheat
Variety	Arjun, HD-3059	Arjun, HD-3059	Arjun, HD-3059
Area under drip irrigation	5.50 ha	1 ha	2.2 ha
Type of drip system used	0.4 m × 2.4 lph	0.4 m × 2.4 lph	0.4 m × 2.4 lph
Year of installation of drip system	2011	2011	2014

Table 6. Information about solar photo voltaic system

Farmer's name	Shri Karan Singh	Shri Ratiram	Shri Jugmaal	
Solar pump (hp)	3	5	3	5
Installation year	2012	2014	2013	2018
Subsidy (%)	86	60	86	50
Farmer's share (US\$)	900	2700	900	2560
Average discharge (Lph)	8000	12000	10000	15000
Method of operation	Direct from bore well	Direct from bore well	Direct from bore well	Direct from bore well
Bore well depth (ft)	600	600	650	850
Depth of submersible pump (ft)	150	170	220	230
Area irrigated (ha)	1.50	2.25	1.0	2.2
Saving of energy (%)	100	100	100	100



improve water holding and release properties of soils besides substantially reducing the use of water and fertilizer. Biogas technology resulted in reduction of irrigation demand, water and energy requirement for pumping irrigation water to the tune of 5.9, 15.8 and 20% besides 15.2% increase in wheat yield. A low head bucket drip system was designed for kitchen gardening (25 to 50 m²) and 40 family low cost drip systems were installed in the backyards of homes in the selected

villages. Bucket kit produced 150 kg of bottle gourd/ 90 kg of bitter gourd/ 75 kg of okra in one season (March to June). Drip systems helped in motivating the farmers to install drip system in regular fields. Consequently, in a span of just two years time, 90 farmers were convinced who adopted drip irrigation in their fields covering about 75 ha area. Increased vegetable production in the villages has generated secondary employment for land less women in picking, sorting

and grading of vegetables. The interventions made in the project are of very basic nature and there is a large likelihood of harvesting the similar benefits in terms of water and energy saving and increased yields by implementing the suggested interventions in the entire district.

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Success Story

Managing localized water stagnation and improving groundwater quality by harvesting excess rain water

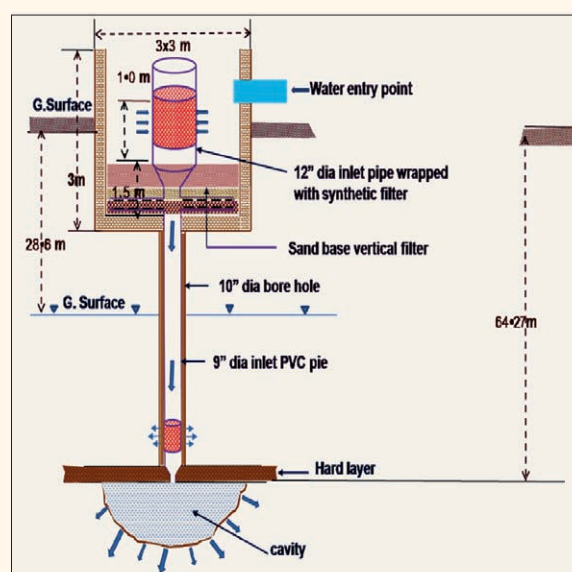
The average groundwater level in Kaithal block (Haryana) during the last 10 years (2005–15) has gone down by more than double (–1.33 m/year) in 10 years compared to last 40 years average data (–0.61 m/year) owing to excessive pumping to fulfil water requirements of predominant rice-wheat cropping system. Poor quality groundwater causing soil sodicity results in low soil infiltration rate and crop failure due to continuous water stagnation/submergence is a common feature during the periods of intense rains. Such extreme rainfall events are likely to occur more frequently in future due to climate change effects. A total of 6 recharge structures with integrated filtering unit were constructed in masonry chamber. The total cost of each structure was estimated to be ₹ 1200/feet approximately, depending upon lithology of the area.



Flood condition due to heavy downpour



Crop condition after receding of flood volume due to drainage-cum-recharge structure



Recharge structure with integrated filtering unit

Installation of recharge structures managed localized water stagnation vis-a-vis rise in groundwater table (up to 1 m), improved underground water quality with concomitant reduction in residual alkalinity in irrigation water (RSC: 1.5–2.5 meq/l) and enhanced farmers' income by saving submerged rice crop during intense rains. Heavy downpour (150 mm on a single day) immediately after rice transplantation result in complete crop submergence. The installed structure reduced flood volumes through drainage-cum-recharge structure and saved transplanted rice crop in lowest 5 ha area, though low to modest impact was clearly visible in the surrounding areas.

Considering the re-transplantation cost for rice in 5 ha area and 15–25% potential yield reduction under delayed transplanting conditions, the tangible benefit through direct crop saving was estimated to be ₹ 30,000–35,000 in lieu of transplanting (nursery + labour cost) and income loss of approximately ₹ 80,000–90,000 in the absence of recharge structure. The payback period for the localized drainage system to disposed off accumulated runoff volume in low lying area and saving standing crop which otherwise be damaged very badly was estimated to be 2–3 years with the net present value (NPV) of approximately ₹ 1.34 lakh. Benefit-cost ratio of 1.25 and internal rate of return (IRR) of 19% indicated desired economic feasibility of investment on drainage-cum-recharge structure.

Source: DARE-ICAR Annual Report 2018-19