Catalysing Competitive Irrigation Service Markets in North Bihar: The Case of Chakhaji Solar Irrigation Service Market

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Competitive Irrigation Service Markets (ISMs) have bypassed Bihar due to lack of affordable electricity. Even though past and present governments promised affordable electricity for irrigation, it seems a distant dream given that the state is still struggling to provide reliable electricity to even the domestic sector. In the wake of climate change, lack of affordable irrigation increases the risk associated with agriculture as a livelihood and makes resource poor farmers even more vulnerable to its impacts. Solar pumps if promoted by catalysing competitive irrigation service markets can not only generate climate proof income for the Solar Irrigation Service Providers (SISP) but can have large distributive benefits for the water buyers. The current case presents one such Solar Irrigation Service Market (SISM) catalysed by supporting five solar entrepreneurs in Chakhaji village and discusses its relevance in the present times and its contribution to agriculture growth of the village.

1. Background

Despite having deep and under-developed aquifers, the eastern region of India, comprising of eastern Uttar Pradesh, Bihar, Jharkhand and Assam has not been able to utilize the irrigation potential and yield benefits of the same, primarily because of lack of affordable and reliable irrigation options (Shah 2009). Even today, most of the irrigation in Bihar is done through diesel pumps and majority of farmers buy expensive irrigation from these diesel pump owners (Durga et. al. 2016). This lack of access to affordable irrigation makes their livelihood more vulnerable to climate change. Affordable and reliable irrigation can provide the bare minimum resilience needed in times of climate change.

High cost of irrigation not only inhibits the adoption of high value water intensive crops but also leads to lower productivity of wheat-rice systems as farmers under-irrigate their crops. This is evident from the fact that despite having similar soil quality and water resource endowment, the productivity of paddy in Bihar is 64 per cent of what it is in the neighbouring state of West Bengal, primarily because majority of farmers in West Bengal have shifted to Boro (summer) paddy that gives much better yield but has high irrigation requirement. Farmers could shift their production as the agriculture power supply scenario in West Bengal was significantly better than in Bihar and has improved even further in the recent years (Shah *et. al* 2017). The well-developed infrastructure and reliable electricity supply provided farmers the option of shifting the crop to the dry season. In contrast to this, most of Bihar does not even have a summer crop season. Historically, it was argued that the reason for not having summer crops stems in cultural factor, as summer is the wedding season in Bihar. During a fieldwork, some farmers told the authors that onset of regular floods was also one of the reasons for not growing any crop in summers, as it would get washed away.

But researchers have argued that it is the lack of affordable irrigation, an absolute necessity for growing a summer crop, which has resulted in a cropping calendar in Bihar which cannot accommodate an additional crop (Shah 2009, Kishore 2014, 2015) in a year. Negligible area is cropped under summer paddy despite having higher yields of the crop compared to Kharif paddy in Bihar and UP (Table 1)

Table 1: Yield, cropping months and area under paddy in different seasons for Bihar, Uttar Pradesh (UP) and West Bengal (WB)

	Monsoon/Kharif (Paddy)			Summer Paddy		
	Cropping Months	Average Yield (1990-2000)	Yield (2015-16	Cropping Months	Yield (2015-16)	% Area of Kharif grown in summer
Bihar	July-Dec	1170	2258	April-June	2472	3.1
UP	May-Oct	1935	2130	April-June	2728	.4
WB	June-Nov	2094	2743	March-June	3375	33

The role of competitive groundwater ISMs in democratising affordable irrigation is well researched (Shah 1993, 2009, Mukherjee 2004). ISMs did flourish in Bihar owing to high land fragmentation and very high marginal productivity gains due to irrigation, but they largely remained monopolistic in nature (Shah 1997). In his field study of seven villages in Muzaffarpur district in 1997, Shah described that despite being inefficient, where in pump owners generated large monopoly rents, the overall impacts of ISMs were highly beneficial which was explained by the increased crop yield and cropping intensity achieved by water buyers viz-a-viz non-irrigators. Lack of reliable power supply and affordable fuel (diesel) were found to be the main reasons inhibiting expansion of efficient ISMs. Primarily, because the incentives of water sellers using diesel pumps to extract water are much lesser to sell irrigation aggressively compared to water sellers who face much lesser marginal cost for pumping. As the marginal cost of operating diesel pump is very high given the high maintenance cost and lesser life span of the machine, diesel pump owners largely sold irrigation to cover the cost of irrigating their own land. Therefore, higher the price charged per irrigation by the water seller, lesser number of transactions were required to cover the cost. Since, land fragmentation, land scarcity and poverty has remained historically higher in the state, not every farmer owned a well or could afford to dig a well, therefore monopolistic ISMs remained a way of irrigation in Bihar.

In other parts of the country, especially in western India, ISMs became highly efficient owning to subsidized farm power policy which not only led to mushrooming of electric pumps, but zero to negligible marginal cost of pumping incentivised electric pump owners to take up water selling as an income generating side business alongside farming (Shah 2009). Farmers invested in long underground pipelines and outlets to increase the command area, which was possible with submersible electric pumps unlike diesel pumps, that are usually used to extract water from shallow depths. The flat tariffs of electricity which were fixed monthly or annual charges based on the size of the pumps boosted ISMs. The experience from Gujarat, where ISMs thrived and became indispensable village institutions, shows that when farmers were under pressure of paying high annual flat tariff, they tried to maximize the utilization of pumping capacity (Shah 1993). They invested in water distribution systems to reach more number of buyers. During fieldwork in 1980s in Naveli village in Gujarat, Shah found 60 km of buried pipeline constructed in the village. Such extensive water distribution network created with farmers' private finance served farmers having no wells or electricity connections with with affordable irrigation. As applying for an electricity connection was easier, many farmers applied and got electric connections in Gujarat. As per 4th minor irrigation census (2006-07), there was one pump in every 3 hectares of irrigated land in Gujarat. This must have increased with one lakh pumps being added every year, especially after the expansion of Jyotirgram Scheme in 2005 (Shah & Verma 2012).

But Bihar did not see this farm power revolution even though tube-well revolution did happen and the density of tube-wells increased in 1980s which did contribute to increase in cereal yields. But this growth was short lived and despite the aggressive shallow tube-well expansion policy, the agricultural growth stagnated in 1990s (Kishore 2004). Unlike the experience of Punjab, Haryana and western UP; even though tube-wells became ubiquitous, lack of investments in infrastructure such as electricity grid and generation, inhibited their use to full potential (Kishore 2004). The steady increase in diesel prices and constant prices of output increased the unaffordability of irrigation and therefore vulnerability of agriculture as a livelihood in the state. Thus, when private cost of irrigation was falling in other states of India on account of free and subsidised power supply in 1980s and 1990s, farmers in Bihar incurred increasingly high cost for irrigation and higher risk of reduced yields and crop failure. Therefore, unlike in other parts of the country competitive and pro-poor ISMs nearly bypassed the state because of lack of affordable and reliable farm power supply and so did the incentives for pump owners to aggressively expand their market and compete in ISMs.

2. Will Solar Pumps Break the Agrarian Impasse in Bihar?

The reduced cost of Solar PV panels increased affordability of solar pumps drastically in the last few years. Also, under the National Solar Pumping Program, different state governments have been topping up the Ministry of New and Renewable Energy sponsored 30 per cent capital cost subsidy to promote solar irrigation. In Bihar, the scheme is called Bihar Saur Kranti Sinchai Yojna (BSKSY), which started in 2012 and offers 2-3 HP/kWp solar pumps at 90 per cent subsidy (Durga et.al 2016). Till 2017, close to 1800 solar pumps have been installed in the state under different MNRE sponsored schemes (MNRE 2017) including BSKSY.

Substituting solar pumps with diesel pumps reduces the cost of irrigation drastically for pump owners therefore, it is not very difficult to find their takers in electricity scarce or diesel pump dominated areas; especially when the capital cost subsidy is to the tune of 80-90 per cent. But there are multiple issues with high capital cost subsidy driven promotion scheme. Firstly, high capital cost subsidy limits the number of pumps to be allocated, which self-selects more influential farmers who are well connected with the district administration[1]. Secondly, higher subsidy limits the size of the pump, which can be acquired. This in turn limits the use of solar pumps and often they are not able to substitute diesel pumps and end up being back-up pumps with low utilization rate (SSEF 2018) in pre-monsoon season when irrigation requirement is highest. Thirdly, smaller pumps do reduce the cost of irrigation for pump owners, but the small size and less surplus energy left after fulfilling their own irrigation needs, fail to incentivise pump owners to invest in water distribution/sale network or aggressively participate/catalyse ISMs. So, the benefits of high capital subsidy remain concentrated with the pump owners. But logistically, it is convenient for the government to offer higher subsidy to smaller number of beneficiaries, compared to lower subsidy to a large number of beneficiaries, even though the benefits of the latter will be much spread out.

Deviating from the government scheme, IWMI-Tata Program[2] designed a Solar Irrigation Entrepreneurs Scheme, which was implemented in partnership with Aga Khan Rural Support Program (India) in Chakhaji village of Samastipur block and district, towards the end of 2016.

3. The Chakhaji Model: Solar Entrepreneurs Catalysing Competitive Solar Irrigation Service Markets

Members of Kushwaha community, who are well known for vegetable farming, constitute majority of the population of Chakhaji village. Earlier a predominantly diesel irrigated village, it has close to 65 hectares of cultivated land, divided into more than 2,400 smaller parcels. Average landholding per household in the village is around 0.5 acre in 7 to 8 parcels in different locations in the village. Due to high land fragmentation, even the well owners are water buyers for some of their parcels, which is a usual trend in North Bihar. Owing to smaller land holdings, there is a common trend of leasing in land and about one third of total cultivated land is exchanged through different type of leasing agreements. The terms of exchange (primarily leasing in rates) depend on multiple factors such as elevation of land, irrigation facility, and proximity to village etc.

There were only diesel pumps for irrigation before December 2016 in Chakhaji village. Even today, 18 pumps, mostly Chinese made are operational in the village. Having a life of not more than 3-4 years, that too with high annual maintenance cost of around

[1] The solar pumps are allotted on first come first serve basis so, a more informed and connected farmer, usually the sarpanch or the elite of the villages get the information and apply for the pump before others. The poor targeting of solar pump beneficiaries has been reported in a recent evaluation done by Shakti Foundation (SSEF 2018)

[2] A coequal partnership between International Water Management Institute and Tata Trusts

INR 5000, they are an expensive water extracting mechanism. The farmers who buy water from diesel pump owners, are worse off than the pump owners as they have to pay around INR 120-150 per hour of irrigation which translates to INR 2600-3300 for irrigating an acre per season. Annually, diesel irrigation expenditure amounts to 20 per cent of the annual revenue generated per acre. Also, lack of reliable (even though expensive) irrigation in pre-monsoon season (as diesel pumps cannot pump water from greater depths) not only exposes crops to production risks but also discourages farmers doing pre-monsoon sowing of kharif crop.

In December 2016, IWMI-Tata Program along with AKRSP(I) offered five solar pumps of desired size[3] (5 HP) at 60 per cent subsidy to farmers who were willing to contribute 10 per cent upfront payment and also agreed to pay 8 per cent of the capital cost each year for four years. Also 1000 ft of buried pipeline was to be given in the desired direction to the interested farmers. The cost of 5 HP solar pump was around INR 5 lakh[4], which meant farmers who were willing to become solar irrigation service providers (SISP) had to contribute 50,000 as upfront payment and INR 30,000-40,000 annually for four years. The hypothesis behind the offer was that an adequately sized pump with buried pipeline network could not only offer a farmer an opportunity to sell irrigation and earn a decent income but may also catalyse an equitable and competitive irrigation market (Durga et. al 2016). It was expected that upfront cost and annual payment would mimic a high flat tariff to be paid by the SISPs, which will push them to earn enough from the irrigation sale, in order to pay the annual instalment of the pump. They could increase revenue by charging much higher price than their marginal cost (which is negligible in case of solar pumps) but since it was not just one farmer having a solar pump but few more farmers and all with buried pipeline network to reach longer distances, they could compete with each other. Thus, it was expected that competition among SISPs to acquire more market share to maximise revenue would keep the irrigation prices low, hence resulting in a pro-poor irrigation service market.

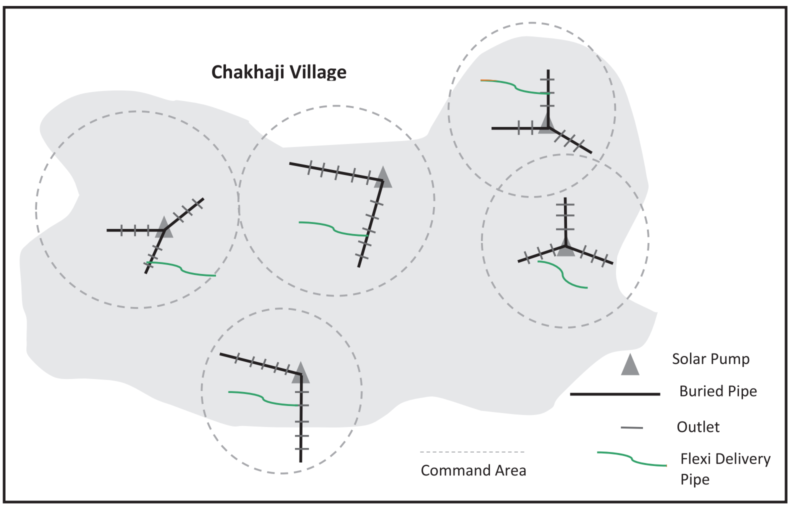

Figure1: Schematic diagram of Chakhaji ISM

[3] The subsidy offered was INR 40,000/kWp and farmer could opt for higher size (7.5 HP) pumps also but they opted for 5 HP pumps

[4] 1 Lakh = 0.1Million

Five farmers namely Neelkamal, Sanjeet Singh, Yatin Kumar, Rajkishore and Lalan Singh formed the first cluster of SISPs in Chakhaji village. They paid upfront payment of INR 50,000 in two instalments and gave an undertaking that they will be paying annual instalments for the coming four years. They also finalized the network of 1000 -1200 ft pipeline (Fig 1) and began operations in mid-December 2016.

Table 2 lists different parameters showing the individual performance of SISPs and also provides a snapshot of the ISMs in Chakhaji. The five SISPs are serving close to 400 farmers and providing irrigation to close to 75 Ha of area against the designed command of 55 Ha. Together they have earned a revenue of INR 9,34,291 by providing 9,497 hours of irrigation. This also includes their self-consumption which is less than 5 per cent for four SISPs and 8 per cent for the fifth one.

Table 2: Solar irrigation service market at Chakhaji

	Designed/ Expected Command Area (Ha)	Net Area Served (Ha)	Total Customers/ Water Buyers	No. of Operational Days b/w 31st Dec'16 to 30th Sep'18	Total Hours of Irrigation Sold (Hr)	Average Hours/ Day	Area (Ha irrigated once)	Total Revenue Till 30th Sep'18	Rs/Ha/ Watering	Asset Utilisation
Yatin Kumar	10	14	100	461	1463	3.2	83	1,41,140	1,700	56%
Lalan Singh	9	13	104	322	1490	4.6	70	1,44,724	2,077	57%
Sanjeet Singh	10	15	91	398	2527	6.3	142	2,48,981	1,753	96%
Rajkishore Singh	12	17	132	400	1783	4.5	100	1,77,989	1,778	68%
Neelkamal Prasad	14	15	124	422	2234	5.3	147	2,21,457	1,509	85%
Total	**55**	**75**					**542**	**9,34,291**		

The asset utilization is arrived by assuming the standard value of 1500 kWh/kWp of annual solar electricity production in a year as the maximum possible use of the solar pump. We can see that Sanjeet Singh has performed the best and Yatin Kumar has performed the poorest in terms of asset utilization and therefore revenue realization, even though the latter operated his solar pump for a greater number of days. But since Yatin Kumar's average hours of operation per day are half of Sanjeet Kumar's, he is earning much lesser than him. But if we see the number of farmers served, Yatin Kumar served more farmers than Sanjeet Kumar who served the least number of farmers. This is because the plots around Sanjeet Kumar's pump are relatively larger and the soil is dryer compared the plots and soil around Yatin Kumar's pump. The other reason is that Yatin Kumar is also engaged in other livelihood activities unlike Sanjeet Kumar who is full time doing farming and irrigation selling. Lalan Singh has performed marginally better than Yatin Kumar. He is the only one charging significantly higher rates of watering per hecatre. As per the fieldwork done by Kumar and Goel in June 2018, it came across that Lalan Singh has been losing his customers to the neighbouring Sanjeet Singh and Neelkamal due to his poor yet expensive service. Neelkamal is the second-best performer and the one who is charging least per hectare for watering. He is involved in irrigation service business full time and does little farming. He admitted that earlier he was not utilizing his time well for generating income as there were not many avenues or options in the village but after becoming an SISP, he has secured a reliable income which is proportional to the time and hard work, which he is ready to put in. Yatin Kumar realized over time that he was losing on an opportunity therefore he hired an operator to run his irrigation service business. The operator charges INR 20/hr for his time and labour in servicing the customers, which includes turning the pump on and off, opening the valve of specific outlets, laying down the delivery pipes from outlets to the buyer's field and rolling back the delivery pipes when the watering is done. The practice of keeping an operator was slowly adopted by all SISPs except Neelkamal as they figured out that day time is an important resource in solar irrigation and having an operator hedges the risk of losing the productive time due to any reason.

Also, the operator is usually a local farmer, who can spare his labour and earn close to INR 160-180 per day.

As still the density of solar pumps is low in the area, the competition between the SISPs is negligible. Each SISP has enough untapped market to expand into, and are not bothered about the little overlaps in command areas. As the density of the solar pumps will increase[5], the competition between the SISPs will increase and the service may improve further for buyers.

4. Subsidy Trickle Down to Buyers

By the end of June 2018, solar irrigation operation completed four agriculture seasons and resulted in multiple changes in the agriculture practices and income from the same, for SISPs and their customers. Even though, the five farmers got subsidy in acquiring solar pumps and water distribution network, the benefits were not concentrated in their livelihoods but they got distributed among all their customers, who are largely resource poor and marginal farmers. The diesel irrigation costed the buyers close to INR 120/hr and they could irrigate only two katha[6] in an hour due to poor efficiency of diesel pumps. Also, diesel pumps could not provide reliable irrigation during the pre-monsoon time, when sometimes the water table drops below 30 feet. With solar pumps, they could irrigate close to 5 katha in one hour which costed them INR 90-100. Therefore, a decrease of 60-70 per cent in the cost of irrigation happened for the water buyers. If they had to buy diesel pump irrigation for the area they had irrigated with solar pump, they would have had spent INR 21 lakh since January 2017; when they actually spent INR 9 lakh. They also saved on time as

[5] In 2017 and 2018, three new solar pumps have been added and eight more are in the pipeline.

[6] 22 Katha = 1 acre

they could irrigate twice as much land as they were irrigating earlier in the same time. And all of it in the day time which is a luxury for farmers who having subsidized grid electricity in the electrified regions of the country.

The other major benefit accrued to water buyers was availability of irrigation on credit which was not possible with diesel irrigation because of the marginal cost of running diesel pumps. Water sellers, in case of diesel pumps, usually transfers the cost to water buyers because the fuel cot is high. But with solar pumps, since the fuel cost is zero, water sellers are able to provide credit to the marginal farmers who are unable to prepay for the irrigation. This way solar pump-water sellers expand their market further since their capacity of holding larger account receivables is better than diesel pump- water sellers.

The other component of the Chakhaji model which impacted the livelihoods of the marginal farmers positively, is the buried pipeline network, which each SISP possesses. The buried distribution network has relatively much lesser chance of leaks compared to the delivery pipes. These leakages increase the time for water supply time, which has to be borne by the water seller as the irrigation pricing is on hourly basis. Delivery pipes are still used as the last leg in the distribution network but the initial network of 1000-1200ft is of PVC pipe buried underground. Owning to the large fragmentation and smaller sizes of the plots, delivery pipes will remain to be the essential component of a water distribution network. But lesser their length in the network, lesser would be leakages and faster and more efficient would be the irrigation service.

5. Early Impacts Reported at Village Level

Fieldwork done by Goel and Kumar in July 2018, revealed positive early impacts of Solar Irrigation Service Markets at village level. Two major impacts, which are somewhat cascaded and related, are increased cropping intensity and increased gross value of output from agriculture in Chakhaji village.

5.1 Increase in Cropping Intensity

Increased cropped area, especially in the summer season, is a direct result of availability of affordable and reliable irrigation. In figure 2, we can see that the irrigation cost in each season has almost halved after the solar irrigation service market was catalysed in Chakhaji. Still the area cropped in summer is least because i) the relative cost of irrigation is higher in summer than is 44 per cent higher than in Kharif and ii) the cropping calendar in the village has been such that it could not accommodate an additional crop (see Figure 3)

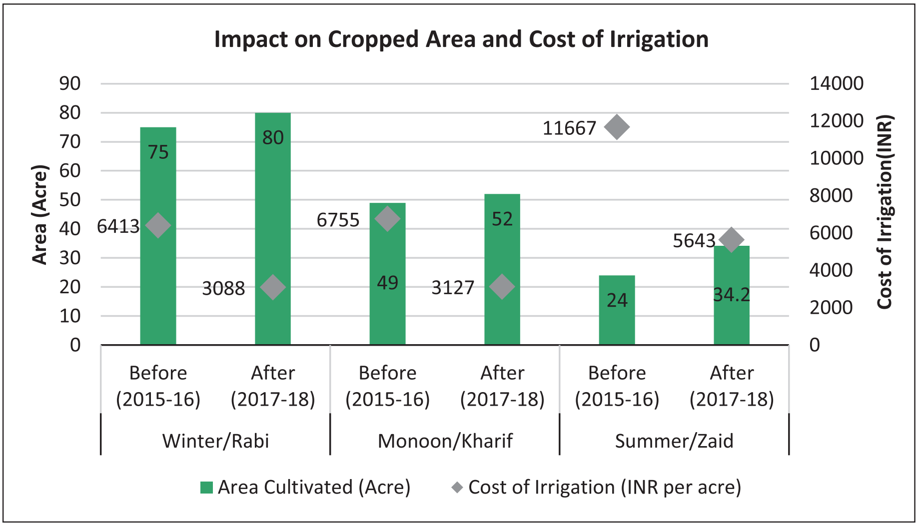

Figure 2: Impact of solar irrigation service market on village cropped area and cost of irrigation in different seasons

Earlier, when farmers were using expensive diesel irrigation, they could not do pre-monsoon sowing, as irrigation requirement is critical and high in that practice, and relied on rains for sowing paddy. This resulted in late harvesting of the kharif crop and therefore later sowing and harvesting of rabi crop leaving no room for a summer crop and farmers left the land fallow for a month or longer. But as the access to affordable and reliable irrigation improved, few farmers did pre-monsoon sowing in 2017 resulting in some room in 2018 to take a summer crop, which resulted in increased cropped area in summer.

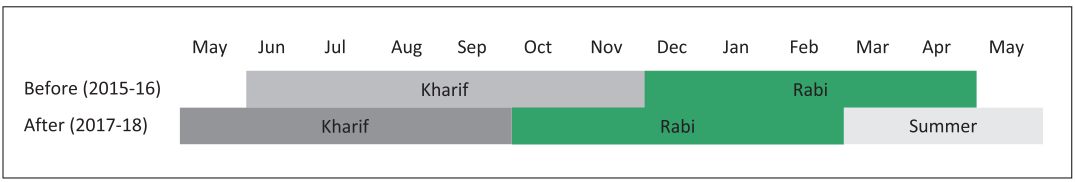

Figure 3: Cropping calendar of Chakhaji village pre and post solar irrigation service market

5.2 Increase in Gross Value of Output

Yields of major crops across the village improved with the increase in access to affordable irrigation, with maximum increase of 30 per cent in potato crop, primarily because of timely and adequate irrigation.

As a result of increased yields and areas across crops and seasons, the gross value of the output for all the seasons cumulatively increased by 46 per cent with maximum per cent and absolute (change in INR) change in the summer season. We envisage that this will further increase because of the shift in the cropping calendar and already established skill of the farmers as vegetable growers.

Table 3: Increase in yield(kg/acre) of different crops

Yield (Kg/Acre)	Before (2015-16)	After (2017-18)	Percentage Change
Paddy	1496	1804	21%
Wheat	1386	1518	10%
Maize	1672	2244	34%
Potato	7370	9592	30%
Cauliflower	6754	8316	23%

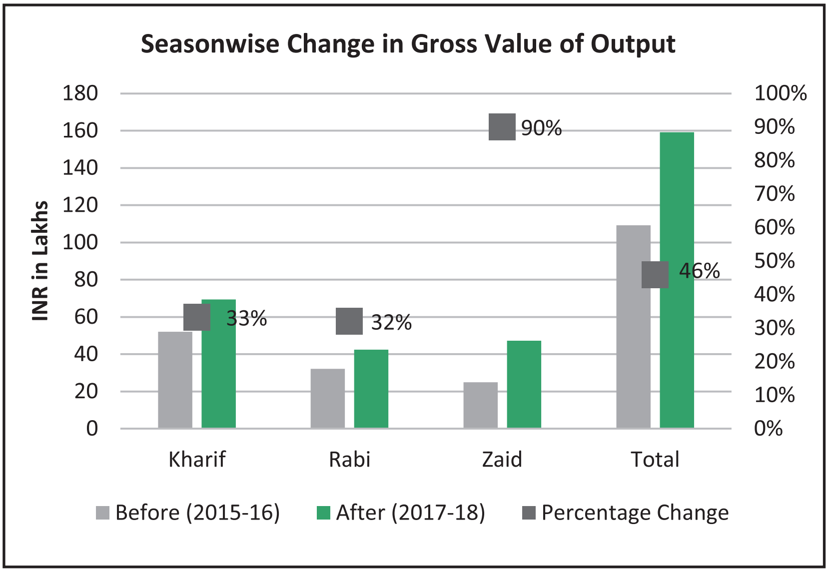

Figure 4: Season-wise and total gross value of output before and after the intervention

6. Conclusion

A competitive ISM catalysed by supporting multiple SISPs has shown positive early changes in the Chakhaji village and the adjoining area. It has boosted the income of both water sellers and buyers by allowing them to produce more from the scarce land resource they possess. Also, solar pumps provide an irrigation assurance for many years and is free from market risks of prices like diesel pumps. This strengthens the resilience of farmers in the times of climate change i.e. in case of less rainfall, they can irrigate their crops more without increasing the expenditure exorbitantly and therefore maintaining the crop viability.

Also, the distributive impacts of ISMs will make agriculture more viable as farmers having access to market will be able to change crops frequently given that irrigation will be assured.

Thus, framers will have more flexibility is choosing the crops. Also, the increase in cropping intensity because of affordable irrigation will result in more labour requirement throughout the year, thus generating more employment for the landless farmers also.

At the same time, farmers who have lesser land and entrepreneurial capability can become an SISP. Providing irrigation service can be a full-time employment but there will some seasonality affects as the water requirement reduces in the rainfall season. Also, there is some surplus energy generated in solar pumps in the monsoon season as the irrigation requirement is high. There can be additional ways of using this additional energy. One of the SISP used the monsoon season to provide pumped water for fisheries at a bulk rate which was lesser than the usual charge (INR 100/hr). More such innovative ways can be devised to tackle the lack of demand in the monsoon season.

Catalysing competitive irrigation service market requires a lucrative financial deal which can be/should be offered to around 5-8 farmers (or more) in village. Promoting SISPs in a clustered approach not only provides climate-smart employment to the farmers owning the pump but also generates jobs across the value chain. As it becomes viable for the solar pump companies to invest in building the capacity of local technicians and providing them employment to deliver the O&M services if a greater number of solar pumps are located near each other. In the current scheme, the solar pumps are so sparsely located, that companies not only find it difficult to provide after sale service (Durga 2016) but also hesitate in employing a local individual (as usually the number of solar pumps in a village is not more than 2).

Competitive and effective SISM can transform the energy-irrigation of the Ganga-Brahmaputra-Meghna basin and can impart the much-needed dynamism in its agriculture which will have multiple cascading benefits. In-fact this model of catalysing ISM by supporting multiple SISPs is relevant for all the regions having scarcity of affordable electricity and abundance of groundwater. Expanding grid electricity and supplying high quality electricity to agriculture at tariffs viable for both farmers and electricity utilities is a long-standing dream and the political economy associated with tariffs make it even more distant. SISPs can bypass the messy and slow route of electrifying agriculture, as the ultimate objective is to provide affordable and reliable energy and therefore irrigation to farmers which bolster their capabilities to adapt to climate change.

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