COST AND BENEFITS OF INTERMEDIATE WATER STORAGE STRUCTURES: CASE STUDY OF DIGGIES IN RAJASTHAN

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Abstract

This paper assesses the cost and benefits of "diggies", the intermediate water storage structures in the Indira Gandhi Nehar Pariyojana project in Rajasthan. A diggi helps provide reliable water deliveries to farms and that in turn expects to increase crop production. Our analysis shows that through better water control, farmers with diggi's have increased cropping intensity, input application and crop productivity. The net value of crop production per ha of irrigated area of farms with diggi's is 68% higher than that of farms without diggi. A cost-benefit analysis shows that diggi is a financially viable intervention for farms with size larger than 4 ha.

1. INTRODUCTION

Unreliable water supply associated with rigid schedules of water delivery is a major constraint for increasing the performance at farm level in the canal irrigation commands. Often, the schedules of water delivery do not match the periods of crop water stress at field level. They result in, at times delayed sowing and often improper input application leading to low productivity. The canal irrigation through the warabandi system in north-western India is one in which farmers often complain of unreliable water supply. The major objective of the warabandi system is to distribute the scarce water resources to as many farmers as possible through a system of rotational water supply. So, untimely water delivery is an inherent feature in the warabandi system.

The Indira Gandhi Nehar Pariyojna (IGNP) project in Rajasthan, which uses warabandi system of delivery of water, envisages irrigating 1.9 m.ha of crop land. It off takes from the Harike barrage, located a few kilometers downstream of the confluence of the Sutlej and the Beas rivers in Punjab, and takes water along 650 km long main canal and terminates near Jaisalmer in Rajasthan. Water scarcity is an in-built feature of irrigation distribution in the IGNP canal system. The warabandi in IGNP has promoted equitable water distribution, but water deliveries at times become unreliable or inefficient. Farmers do not receive water at a time when the irrigation is critical even for the survival of crops or for higher yields.

A diggi, intermediate storage or surface water banking, is a farmers intervention to mitigate the effects of scarce and unreliable canal water supply in the IGNP. Through this intervention, farmers first construct a small pond, called a diggi, in their farm to store the canal water supply. Next they pump the water out from a diggi to irrigate the crops, through field channels or micro-irrigation technologies. With increase in control of the water management, farmers meet the crop-water requirement as best as possible. In fact, a diggi addresses the reliability issue through a self enforcement mechanism and corrects the allocative inefficiency of water use. In the end, the society achieves both equity and efficiency. The cost of achieving efficiency is reflected in the cost of diggi.

This report assesses the impacts of the "diggi" intervention on the irrigation performance at the farm level, and estimates the incremental value of the net income benefits. The study has significant policy relevance. The results suggest how a farmer in canal command system can achieve a Pareto improvement through saving of water. The specific objective of the report is to assess

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- the extent that "diggi" helps increase the irrigation performance, which include increasing the crop area, crop yield, crop diversification and net value added economic benefits at the farm level, and
- to evaluate cost and benefit of "diggi" intervention in the IGNP,

The report is organized into five sections. Section two gives a brief description of how "warabandi" and "diggi" perform. Section three describes the methodology of impact assessment of Diggi. Section 4 shows the cost and benefits of introducing a "diggi". Section 5 discusses the up scaling and possible impacts. And we conclude the paper with a policy discussion and implications to further development of IGNP in the second phase.

2. WARABANDI AND DIGGIES IN IGNP

The main goal of the IGNP canal system was to provide irrigation to a major part of the Thar Desert in Rajasthan. Located in the north-west, Rajasthan is the largest state in India, covering 10 per cent of the total land area in India. Two-thirds of the land area of Rajasthan is covered by the Thar Desert. This includes 85 out of 142 desert blocks in whole of India. Moreover, a major part of the state of Rajasthan is covered by the arid to semi-arid climates. The rainfall patters are highly erratic, and they vary from low rainfall in north-east region to high rainfall in south-west region (Khan, 1998). Most of the rain falls from June to September. On an average Rajasthan, receives 560mm rainfall annually. So, without irrigation, crops cannot survive in many parts of the state. In fact, irrigation covers about one-third of the net sown and gross cropped area, 15.5 and 19.3 million ha, respectively in 1999-2000.

Tubewells and canals are major sources of irrigation in the State of Rajasthan. Of the net and gross irrigated area (5.61 and 6.93 million ha), tubewells and canals provide, 64 and 33 per cent, respectively. Groundwater is virtually the only source of irrigation in the southern plateau and arid region of the west (93 and 92% respectively) and dominates irrigation in southern and eastern plain regions (79 and 65% respectively). However, canals provide almost all the irrigation in the arid north region. The IGNP project, popularly known as the Rajasthan canal, is the largest surface irrigation projects in arid north-west. The warabandi is the system of water deliveries in the IGNP project.

3. WHAT IS WARABANDI?

In warabandi, "wara" means turn, and "bandi" means fixed. According to Malhotra (1982), "warabandi is a rotational method for equitable distribution of the available water in an irrigation system by turns fixed according to a predetermined schedule specifying the day, time and duration of supply to each irrigator in proportion to the size of his landholding in the outlet command".

The warabandi system, mainly practiced in semi-arid and arid north western India for more than 125 years, rotates irrigation supply according to a predetermined schedule, where one cycle generally last for 7 days. It allocates the irrigation quantity proportion to farm area. The higher water-use efficiency and equitable water distribution are prominent goals of a Warabandi system (Malhotra 1982). The water-use efficiency is to be achieved through the imposition of water scarcity on each and every user, and the equity in distribution through enforced equal share of scarce water per unit area among all users. The key features of warabandi system are:

- Individual farms are aggregated into hydrologic units (chaks) of 100-400 ha (50-200 farms),
- Each chak is served by a water course whose capacity is proportional to the size of chak;
- Each farm holding in the chak is entitled to take full supply in watercourse during a specified period proportional to its size. Since the watercourse flow is proportional to the size, each farm in a command area of distributaries is ensured a uniform volumetric allocation per hectare per week,
- Watercourses are un-gated and are served by parent channels (minor canals) that at any given chainage has capacity exactly equal to the sum of the discharges of the watercourses offtaking at downstream points.

- ✍ Minor canals in turn are usually gated and are served by a distributary whose capacity at any given chainage is exactly equal to the combined capacity of offtaking minors and watercourses downstream).

For more information of warabandi, see Reidinger (1971), Malhotra (1982), and Berkoff and Huppert (1987), Sakthivadivel et. al. (1999).

Throughout IGNP, the canals operate on the warabandi scheme due to variation in water availability at the Harika barrage in the river Sutlej. The demand for irrigation water throughout the year is met by changing the days on which each branch canal is operated. Water flows in canals for one week, and then the canal is dry for a week. This water distribution system forces all minor and branch canal, distributaries, water courses to share the deficit of water supply in the IGNP system. This means that farmers, in general, get their quota of irrigation at fortnightly intervals.

4. WHAT IS A DIGGI?

"Diggi", a "surface water bank" is an intermediate water storage tank between the watercourse and the farm. It is a farmer's response to water scarcity and unreliable canal water supply in the IGNP. The canal irrigated area in the IGNP command has gradually increased over the last 15 years. Accordingly, the frequency of canal water releases to the farms in the command area has decreased. Initially, the number of turns into the field was 4 turns a month, and 4-5 hours per each turn. Today, with increasing command area, the number of turns has decreased to two times a month and 2-3 hours per each turn. The reduction of duration of water supply had many negative implications, which includes decreased irrigated area; crop failures; and in some cases where the supply was not adequate or available to meet crop requirement at the critical stages of growth. The IGNP farmers responded to the water stress and unreliable water supply by constructing diggi's.

The diggi stores the canal water supply from watercourses in allotted turns to the fields. Water from the "diggi" is then pumped from an electric motor and applied to field by micro-irrigation devices such as sprinklers (typically with 20-25 nozzles). In the IGNP canal commands, the sprinklers are used not to save irrigation water, but to irrigate more area. A diggi combined with the sprinkler irrigation increases the number of irrigation and the irrigated area; provides a reliable water supply to meet the cropwater requirements; increases the crop yields; helps diversify to high value cropping patterns; and reduces land leveling requirements of the uplands, and allows irrigating the undulating lands through sprinklers, where normal canal water courses cannot.

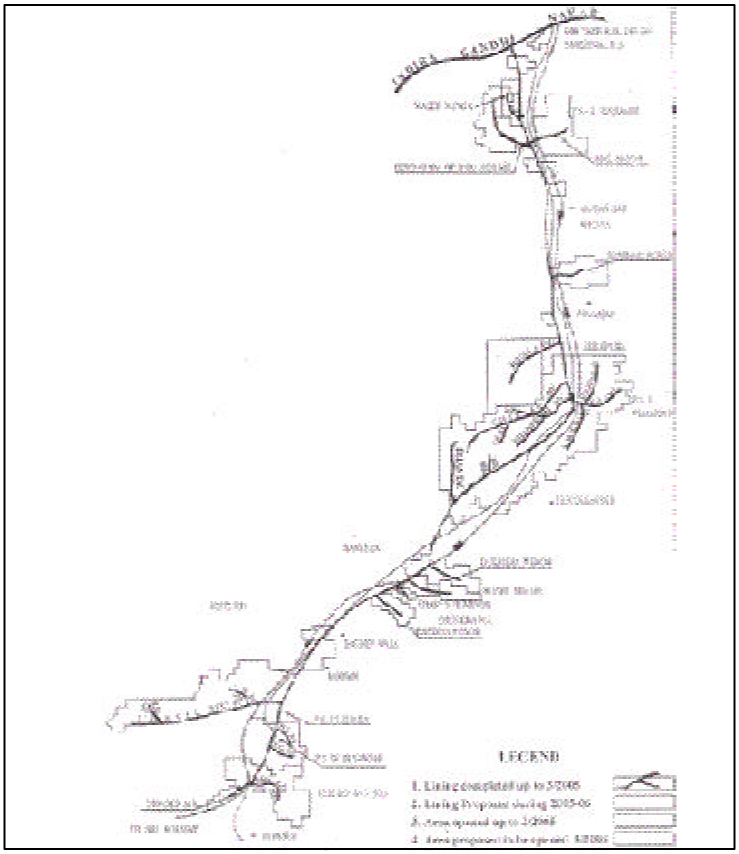
Initially, the IGNP farmers constructed diggis from their money. Now, the Government of Rajasthan provides a 20 percent subsidy of the total cost. The average cost of constructing a diggi is RS 172,710 or US$ 3111 (at 2006 prices). The cost is based on the primary survey.

Although it is not as prevalent as in the canal command areas, the diggis are also being constructed in the groundwater irrigated area. The primary reasons for constructing diggis in groundwater irrigated area are the low yields in tubewells and unreliable electricity supply. Due to these constrains, farmers are unable to apply irrigation when the cropwater requirement is most critical. So, first they pump groundwater into the diggi and then pump out to irrigate the crops. Although this practice is highly energy expensive, farmers claim that without diggis farming is not effective or is not possible in many of groundwater irrigated areas.

5. STUDY LOCATION AND METHODOLOGY FOR IMPACT ASSESSMENT

A distributary of the IGNP canal, the Kanwarsain lift Canal, is the location of this study (Figure 1). The canal offtakes at Birdhwal in the IGNP main canal and stretches about 200 km to Bikaner.

Figure 1: Study Location- Kanwarsain Lift Canal of IGNP project



5.1 Sampling Plan

A stratified random sampling scheme is used for assessing the benefits from diggi. First we identify the watercourses with and without diggi across head, middle and tail sections of the canal and also across the tube-well irrigated areas. From the watercourses with diggis, 31 watercourses were selected, with 10 each from the head, middle and 11 from tail end of the canal command area. From each selected watercourse, two farmers were selected with one having a diggi and the other without a diggi. We also selected 10 farmers from the groundwater irrigated area, with five each having diggi and irrigating their crop directly from tube-wells. Both groups of farmers in groundwater irrigated areas used sprinkler for irrigating their crops. In all, 72 sample farmers were selected for in-depth survey.

5.2 Methodology and Data Requirements

The hypothesis which is being tested in the study is that adoption of diggi helps the farmers to expand the irrigated area; increase the crop yield diversify cropping patterns; improve input application; and increase the gross and net value of crop output.

These hypotheses are tested using simple statistical techniques-- two sample or paired t-tests. We collect the primary data from the selected samples, which include total land holding size, irrigated area and irrigation paterns, seasonal cropping patterns, crop inputs and outputs. The data related to diggi were also collected, which includes the year of construction of a diggi, physical details, fixed and working cost of diggis, tube-well and sprinklers.

We also estimated the cost:benefit ratio (CBR) and the internal rate of return (IRR) from diggis. The benefit is estimated as the net value added after the construction of a diggi. The cost includes the capital investments for a 'diggi, sprinklers, electricity connection and electric or diesel motors, and the operational and maintenance cost. In groundwater irrigated areas, the capital cost includes the cost of installing a tube-well. For estimating the benefit:cost ratio, we assumed the useful life of all structures as 20 years..

6. RESULTS AND DISCUSSIONS

The decreasing and reliability of canal water supply to the farm are the main reasons for constructing a diggi. Over the time, water supply has decreased in the IGNP canal system. We observe a similar pattern from the data. On an average, farmers received 20 hours less canal water supply as compared to that prior to constructing diggi when water supply was initially started in their watercourses. Today, the number of hours of canal water supply is even less. Farms with a diggi receive on average only 65-68 hours canal water supply in kharif (July-October) and rabi (October-March) seasons, as against 148 to 129 hours water supply at the time of construction of a diggi. Farms without a diggi receive only about 32 hours of water supply in each season. The difference of duration of water supply to farms with and without a diggi is due to farm land holding size.

In general, diggi is constructed in farms of larger size. The average size of farms with a diggi is about twice the size of the farms without a diggi (Table 1). The farm size decreases from head to the tail reach of the canal command. This seems to indicate that diggi is not a viable option in smaller farms and also when the distance from the main offtake from distributary increases.

The portion of land holding that is cultivated decreases from head to tail reach of the distributary. This is clearly related to inequitable water supply between the head end and tail end, and similar situation exists in farms with and without diggi. The inequity in water supply is very prominent in farms without diggis, where

Table 1. Average land holding size and the area of cultivation in farms with and without diggis

	Land holding size of farms with and without diggis (ha)		Cultivated area- % of land holding size Cultivated area of farms with and without diggis (%)		Number of hours of canal water supply in farms with and without diggis in 2006 (Hours)	
	With	Without	With	Without	With	Without
Canal command area						
Head	13.7	7.7	83	89	164	108
Middle	12.9	5.6	77	66	128	35
Tail	10.3	4.5	59	59	102	52
All	12.3	5.9	73	70	135	64
Groundwater irrigated area	10.2	11.9	67	46	-	-

Source: Authors' estimates based on the primary survey

head end farms receive water supply for greater duration than that in middle and tail reaches. Of course, land holding size is a determinant of the duration of water allocation in warabandi system. But our sample shows, the duration of water supply per unit area of farms in head end of the distributary is significantly higher than that at the tail end farms. The average durations of water supply per ha in the head end farms with and without diggie were 12 and 14 hr/ha of land holding size respectively. The middle and tail end farms with diggie receive about 9 hr/ha of water supply; and farms without diggie received 6 and 12 hr/ha, respectively.

The average land holding size of farms in groundwater irrigated areas showed insignificant difference between farms with diggis and farm without diggis. But they have substantially lower percentage of cultivated area, and similar to tail end farms with diggie.

6.1 Expansion of Irrigated Area

Irrigated area expansion was a major goal of farmers in constructing a "diggi". We explore here the extent to which diggi helps increase the irrigated area in farms. With diggis farmers were able to irrigate all their cultivated area compared to only two-thirds of the area before diggi construction (Table 2). This increase is significant and is uniform across reaches in canal command and groundwater irrigated areas.

Farms without diggis, except those in the middle reaches, irrigate almost all their cultivated land. Due primarily to significantly lower number of hours of canal water supply (see Table 1), the farms without diggis in the middle reach irrigate only 79 per cent of the cultivated area. Farmers with diggis uses sprinkler irrigation

Table 2. Irrigated area (%) of cultivated area in farms with and with-out diggis

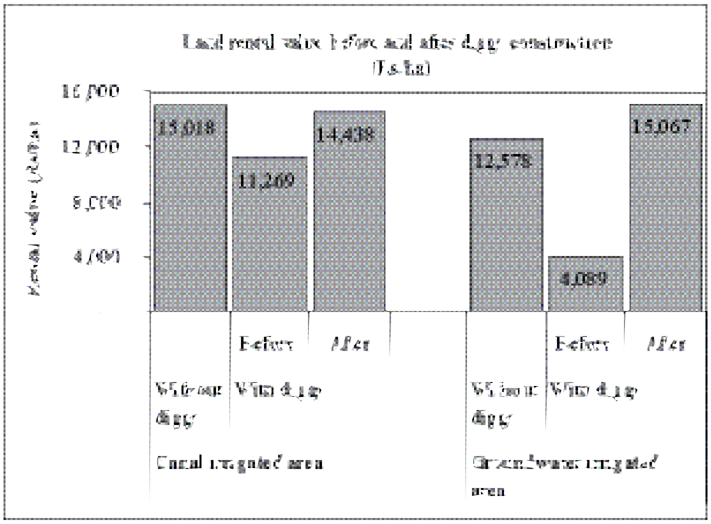
	Irrigated area (%) of cultivated area		
Command area	Farms with diggis		Farms without diggis
	Before	After	
Canal irrigated area			
Head	61	100	100
Middle	66	100	79
Tail	67	100	100
All	67	100	93
Groundwater irrigated area	63	93	96

to irrigate their crops, and this allows them to irrigate even the undulated land, which the direct canal irrigation did not allow, and as a result it increases the irrigation coverage substantially. Overall, the crop area has increased by 33 percent with diggi construction. A similar increase is evident in groundwater irrigated areas. In groundwater irrigated areas, farms without diggis irrigate almost all their cultivated area. However, the farms with diggis only now mange to irrigate 93 per cent of the cultivated area, whereas they irrigate only 63 per cent crop area before construing diggis.

6.2 Increased Land Rental Value

The construction of a diggi has also brought many changes to the irrigated lands. An immediate impact was the increase in land rental value. As per the response survey, the rental value of agricultural land in canal irrigated area before construction of diggi was Rs 11,269/ha/year (US$ 269 in 2006 prices, US$ 1= Rs. 43). But after the construction, the rental value has increased to Rs 14,438/ha/year (US$ 335). The value addition owing to extra infrastructure is more than Rs 3,000. Although not significantly different, the higher rental value of the lands without a diggi was because the land was more suitable for irrigating from canal. In fact, the overwhelming response of the farmers for investing in diggi was the poor irrigable conditions of their land.

Figure 2. Land rental value before and after diggi construction

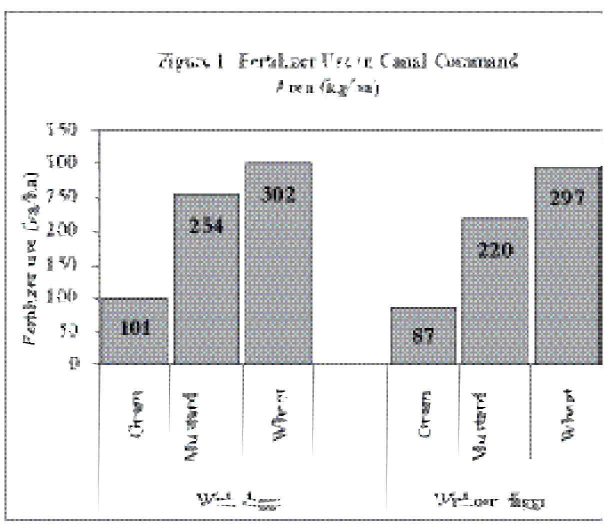


The general trends of increase in land rentals in the groundwater irrigated areas are similar. The rental value of lands after constructing a diggi is vastly different from land before construction and also lands without a diggi.

6.3 Increased Input Application

With diggis, now farmers have the ability to apply irrigation to crops, when the crop demands the most. With a reliable irrigation supply, farmers in general manage their input application better. This is evident in fertilizer application of some crops (Figure 3). Farmers without a diggi in canal command areas did not take an undue risk of applying more fertilizer with an unreliable canal water supply. However, a significant increase in fertilizer application can be seen for gram and mustard crops, which have relatively higher value than cereal crops. The fertilizer application of wheat crop, which is already high before the construction of diggi, shows non significant change.

Figure 3: Fertilizer use in canal command area for selected crops (kg/ha)



6.4 Increased Crop Yields

In the IGNP canal command area, diggi helps farmers to irrigate crops through sprinklers, and when the crop demands the most. Microirrigation technologies, in general, seems to have a positive effect on increasing the yield of many crops (Narayanmoorthy, 2006, Kumar et al., 2008). The data also show a similar trend. In the canal command areas, almost all farmers with diggis irrigates their crops using sprinklers, whereas only one farm out of 30 sampled without a diggi used sprinklers. However, in groundwater irrigated areas, both farms with and without diggis use sprinklers. So, yield increases in groundwater irrigated areas did not show any apparent pattern. However, yield increase in canal command area is very significant. There is difference in crop yields in canal command area with and without diggis.

The crop yields are significantly higher in areas with diggis than those without diggis' (Table 3). The increase in yield is significant in all canal reaches, from head to tail end. Kharif crop yields of farms with diggis are 18 and 39 per cent higher for guar and groundnut, respectively. In Rabi season, crop yield of gram, mustard and wheat in farms with diggis are 30, 29 and 7 per cent higher than those in farms without diggis, respectively. The difference between the main crop yield and their byproducts between farms with and without diggis are statistically significant.

The diggis with sprinklers have helped farmers not only meet the crop water requirements better, but also increase the input application. So diggis have directly and indirectly increased the crop yields.

6.5 Increased Gross Value of Crop Production

The average gross value of output of farms with diggi is significantly higher than that without diggis (Table 4). It is 39 per cent higher in kharif season, and 21 per cent higher in rabi season. There are significant differences of increments in different canal reaches. In the kharif season, the farms in head reach had a significantly higher increment than farms in middle and tail reaches. In rabi season, farms in head and middle reaches had significantly higher increments in gross value of outputs.

The difference in gross value of output per ha of land between head reach and tail reach could be due to the differential access to water supply. Although,warabandi is supposed to ensure equitable distribution, our results show otherwise. We have earlier shown that water supply to farms in head reach is significantly better than that in middle and tail reach. So, these farmers have more gains by storing them in diggi's and distributing them among different crops. In fact, many farmers with high gross value had high yields and also high value crops.

Table 4: Gross value of output per ha of irrigated area

Location	Gross value of output[1] per ha of irrigated land (Rs/ha, Rs 43 = US$ 1 in 2006)			
	Kharif season		Rabi season	
	Without *diggi*	With *diggi*	Without *diggi*	With *diggi*
Head	23,915	42,416[2]	19,843	25,857
		(77%)		(30%)
Middle	23,414	31,355	18,855	24,474
		(34%)		(30%)
Tail	20,188	29,672	21,755	24,586
		(47%)		(13%)
All	22535	34207	20109	24956
		(52%)		(24%)

[1] Values within the parenthesis are the percentage differences of the average gross value of output with and without a *diggi*.
[2] This average for the head end farmers is based on 9 observations, and has highly skewed distribution. Only two farms in this group have higher than average gross value of outputs, Rs 87,000/ha and Rs.54,000/ha. This is mainly because significantly higher yields of these farms.

Table 3: Yields of selected crops in canal command areas with and without *diggis*

	Yields in canal command area (kg/ha)											
	Without *diggi*		With *diggi*		Without *diggi*		With *diggi*		Without *diggi*		With *diggi*	
	Main	By-product	Main	By-product	Main	By-product	Main	By-product	Main	By-product	Main	By-product
***Kharif* season**	Guar				Groundnut							
Head	562	924	684	902	2,435	2,950	3,156	4,067				
Middle	711	1,089	975	1,550	1,765	2,080	2,422	3,511				
Tail	556	889	540	900	1,667	2,367	2,267	3,311				
All	610	967	717	1,093	1,982	2,475	2,615	3,630				
***Rabi* Season**	Gram				Mustard				Wheat			
Head	740	1,060	1,120	1,560	1,200	2,000	1,300	1,600	2,711	7,600	2,700	3,820
Middle	600	800	900	1,250	1,020	1,560	1,345	1,836	2,340	2,860	2,850	4,700
Tail	800	1,200	624	920	800	1,120	993	1,444	2,356	3,111	2,400	6,667
All	723	1,031	943	1326	976	1,482	1,206	1,650	2,464	4,464	2,644	5,030

Source: Author's estimates using the sample survey

6.6 CROP DIVERSIFICATION

To what extent does a diggi help crop diversification? Our sample suggests no major differences of cropping patterns between the farms with and farms without diggis (Table 5). The only exception is bajra and narma (cotton) area in the Kharif season and gram and mustard in the Rabi season. While the area under narma (cotton) and bajra is higher in farms with diggis, the area under gram and mustard is lower.

Table 5: Cropping pattern in farms with and without *diggi*s

Crop	Cropping paattern - % of total irrigated area	
	Without *diggi*	With *diggi*s
Kharif season		
Bajra	13	7
Cotton	3	3
Narma (cotton)	13	5
Gawar	13	16
Groundnut	9	9
Green gram (moong)	3	0
Rabi season		
Gram	15	22
Joi	4	4
Mustard	11	14
Taramira	7	4
Wheat	8	9
Total	100	100

6.7 Benefit Cost Ratio of Diggi Intervention

The annual net value added through diggi construction is the increase in net value of agricultural output in farms with diggis over those without diggis. The net value of agricultural outputs is the value of production of crop and livestock minus the cost of inputs, interest of the capital expenditure, and variable cost (operation and maintenance cost) of diggi, sprinklers and electric or diesel motors.

6.7.1 Cost of Construction, Operation and Maintenance of a Diggi

The operationalization of a diggi in canal command area includes: constructing a diggi, installing diesel/electric motor for pumping water from a diggi, and then installing sprinklers for irrigation. Installing tube-well for pumping groundwater to diggi is an additional investment in groundwater irrigated areas. These are the capital investment involved in diggi operations. The variable cost include the cost of electric/diesel for pumping water from diggi and pumping groundwater to diggi; and the operation and maintenance cost for diggi, sprinkler and electric/diesel pump. The capital cost and variable cost of a diggi operation in the canal and groundwater irrigated areas are given in Table 6.

The average size of a diggi in canal command areas is generally larger than those of groundwater irrigated area. In fact average storage of a diggi in a canal command area, 2,877 m^3 (29 m * 29m * 3.4m), is three times more than that of a diggi in groundwater irrigated area, 944 m3 (16.9m * 16.3m * 3.4 m). The

Table 6. Capital and operation cost of *diggi* and sprinklers

Items	Cost[1] (Rs/year)		
	Canal irrigated areas	Groundwater irrigated areas	
		With *diggi*	Without *diggi*
Capital cost of construction of *diggi*[1]	1,49,912	96,526	-
Subsidy	35,041	-	-
Net cost of construction of a *diggi*	1,14,871	96,526	-
Cost of maintenance (Rs/year)	11,113	9,200	-
No. of sprinklers	21	37	39
Capital cost of sprinklers	35,602	74,800	58,955
Cost of maintenance of Sprinklers (Rs/year)	6,071	3,600	2,100
Capital cost of electricity connection and			
electric/diesel engines	25,902	79,602	77,302
Cost of electricity/diesel cost (Rs/year)	19,513	43,000	36,800
Capital cost of installation of tube-well	-	2,03,488	3,44,567
Cost of maintenance of tube wells (Rs/year)	-	4,800	4,800
Electricity charges (Rs/year)		40,560	33,600
Fixed cost	1,76,375	4,54,416	4,80,824
Variable cost			
Operational cost (Rs/year)	19,513	83,560	70,400
Maintenance cost (Rs/year)	17,184	17,600	6,900

Government of Rajasthan has provided a subsidy, o InRs 35,000, for construction of a diggi in canal command area, while farmers have borne the full cost of diggi construction in groundwater irrigated area.

In groundwater irrigated areas, a sprinkler irrigates only half the area than in the groundwater irrigated area. As a result, number of sprinklers required to irrigate the farm land and the capital cost for installing them are significant in the canal command areas than in the groundwater irrigated areas. Additionally, the groundwater irrigated areas require tube wells for pumping water into the diggi. Therefore the capital and the operational cost are significantly higher in the groundwater irrigated areas.

6.8 Net Value of Crop Production

The net value of crop production is the difference between the gross values of crop production and the cost of production. The cost of production includes the cost of labour, seeds, fertilizer, insecticide, and ploughing, threshing, machinery and water charges. In canal command area, the net value of crop production of farms with a diggi is significantly higher than in the area without diggi's (Table 7).

The incremental benefits from kharif crops are much higher than the incremental benefits from Rabi crops. This is because of the reason that farmers in IGNP command tend to allocate more area under wheat in Rabi season, and difference in wheat yield is not significantly high between the areas with and with diggis.

[1] Cost estimated on the basis of 2006 constnat prices

Table 7: Net value of crop production and the net value of output per ha of irrigated area per year (Rs/ha)

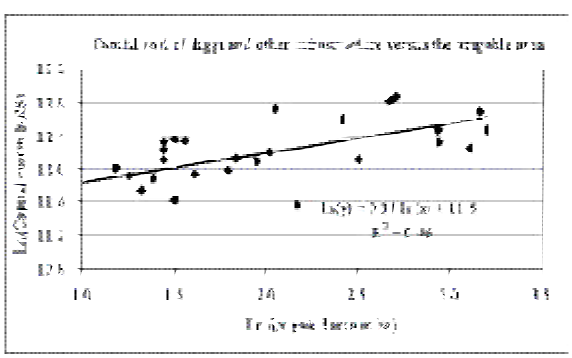
Canal reach	Average net value of crop production per ha in farms *with* and *without diggi*s					
	Kharif		Rabi		Annual	
	Without *diggi*	With *diggi*	Without *diggi*	With *diggi*	Without *diggi*	With *diggi*
Head	14,776	34,860	11,755	20,114	16,778	34,847
		(136%)		(71%)		(108%)
Middle	12,573	23,077	9,553	16,891	16,678	27,814
		(84%)		(77%)		(67%)
Tail	12,141	19,508	12,407	15,288	21,139	29,137
		(61%)		(23%)		(38%)
All	13,144	25,503	11,191	17,413	18,152	30,509
		(94%)		(56%)		(68%)

However, value of incremental output varies substantially across the canal reaches. The head reach farmers have more than doubled their net value of crop production, and have more than three times the incremental benefits that the tail reach farmers secure. While the head reach has increased the annual benefit, by 108 per cent by introducing a diggi, the tail reach farmers have increased only by 38%. This has to do with the available water supply for diggis. As we have shown earlier, the diggis in tail reach receives on an average 60% less water supply than diggis in head reach. So, opportunity for tail end farmers to increase cropping intensity and yield through diggis is much lower.

6.9 Benefit:Cost Ratio for Diggi Investment in Canal Irrigated Area

The cost of diggi operation in a farm in canal irrigated area includes cost of constructing a diggi, installing sprinklers and required electric and diesel motors, and investment for electricity connection. An average sized diggi in IGNP costs about Rs 176,000. But capital cost is related to irrigable area. Our sample shows that 1 per cent increase in irrigated area results in 0.31 per cent additional capital cost of diggi and other infrastructure (Figure 4). We estimated the required capital investment for different irrigable areas using the equation in Figure 4 (Table 6).

Figure 4: Capital cost of diggi, sprinklers and electricity connection and electric/diesel motors vs irrigable area



[1] Net value of crop production is gross value of crop production minus cost of inputs (US$1=Rs 43 in 2006).
[2] Values within parenthesis are incremental average net value of output of the farms with *diggi*s.

In estimating the cost and benefits, we assume useful life time of diggi and other infrastructure as 20 years. The cost of diggi and related infrastructure (in 2006 prices) for different irrigable area is given in Table 8. The operation and maintenance cost of an average size diggi and other infrastructure, with a capital cost of Rs 1,76,000, is about Rs 36,000. There is variation in operation and management cost for diggis with different size. On the benefit side, new infrastructure brings an additional benefit of Rs 12,257/ha/year independent of size of irrigable land. The annualized cost, benefits: cost ratio for diggis for different farm sizes are given in Table 8.

Table 8: Annualized cost, benefits, and benefit:cost ratio of a *diggi* and other infrastructure

Irrigable area (ha)	Capital cost (Rs)	Annualized cost and benefits (Rs)					Benefit-cost ratio
		Interest on capital @ 6%	Depreciation @ 5% discount rate	Operation and managem-ent cost	Total cost	Total benefits	
1	98,716	4,936	5,923	20,619	31,477	2,357	0.4
2	122,379	6,119	7,343	25,561	39,023	24,714	0.6
3	138,770	6,938	8,326	28,985	44,249	37,071	0.8
4	151,714	7,586	9,103	31,688	48,377	49,428	1.0
5	162,580	8,129	9,755	33,958	51,842	61,785	1.2
6	172,034	8,602	10,322	35,933	54,856	74,142	1.4
7	180,454	9,023	10,827	37,691	57,541	86,499	1.5
8	188,081	9,404	11,285	39,284	59,973	98,856	1.6
9	195,075	9,754	11,705	40,745	62,203	111,213	1.8
10	201,552	10,078	12,093	42,098	64,269	123,570	1.9

The analysis shows that diggis are economically viable for farms with large holdings. The benefit:cost ratio is more than one for farms with size more than or equal to 4 ha. In fact, the average land holding size of the farms with diggis in the command area is 8.7 ha. A farmer with an irrigable land of more than 7ha can recover the full investments for the new infrastructure in 6 years.

Due to variation in the net crop production benefit across the canal reach, the benefit:cost ratio of new infrastructure is much higher in the head reach. For example, the incremental value of the crop production benefit from irrigated lands in head reach from diggis is about Rs 18,100/ ha. Thus, the incremental value of the output from an irrigated land holding of 4 ha in head reach is about Rs. 72,000, and is 1.5 times the total cost. In fact, a diggi and other infrastructure in the head reach area can be cost effective even for an irrigable land holding size equal to 2 ha.

6.10 Benefit: Cost Ratio in the Groundwater Irrigated Area

The average size of land holding of diggi owners in groundwater irrigated areas does not vary much. It varies from 10.2ha for diggi owners to 11.9ha for those without diggi. We have estimated the benefit cost ratio of a farm of average size 10 ha, and the results are provided in Table 7.

In groundwater irrigated areas, farmers have already installed tubewells and sprinklers for irrigating their fields. We assumed that in groundwater irrigated areas, only additional cost that farmers have to incur with new infrastructure is that of diggi. The capital cost of the diggi is Rs.96000. The annual operation and maintenance cost is Rs.17400. The change in net value of crop production through a diggi in groundwater area is about Rs

Table 9: Benefit and cost of adopting a *diggi* in groundwater irrigated area

Cost and benefit items	Without *diggi*	With *diggi*
Cost of a *diggi* construction (Rs)		96526
Interest on capital at 6% (Rs)		5792
Depreciation cost @ 5% discount rate (Rs)		4826
Operational and management cost (Rs)	41,700	59,180
Change in total annualized cost (Rs)		28,098
Net value of crop production (Rs/ha)	22,867	26,893
Change in net value of crop production for a 10 ha land		40,257
Benefit-cost ratio		1.4

4,000, generating a net benefit of Rs. 40257 for a land holding of 10 ha. Thus, even in groundwater irrigated areas benefits of introducing a diggi is far out weigh the cost. A farmer can recover the full cost of constructing a diggi of a farm with land holding size 10 ha after 3 years.

7. OTHER BENEFITS OF DIGGIS IN THE CANAL COMMAND AREA

7.1 Addressing Water Logging and Salinity

The problems of water logging are increasing in the IGNP command area. The rise of water table leads to water logging and development of salinity in many parts. The soils of the IGNP command are calcareous, and the soils in the desert plains are underline by nodular lime horizon, consolidated gypsum and sand stone. Sandy soils have poor water holding capacity, are susceptible to wind erosion. The infiltration capacity of fine texture sandy soils is very poor. They are highly saline and sodic. With rising groundwater tables, these soils pose problems of drainage, salinity and alkalinity. In fact, a few villages in the IGNP area were abandoned due to unfavorable living conditions due to water logging and salinity.

Although characterized as water scarce, farmers in some regions of IGNP apply excess water to irrigate their crops. This is especially true in the head reaches of the canal command. Long periods of flood irrigation recharge the shallow aquifer, and due to poor vertical drainage conditions, the water table comes, which results in water logging and salinity. Thus, this can be decreased by lowering canal irrigation, increasing conjunctive water use, or increasing consumptive part of the total irrigated water applied in the command area. The diggi and sprinklers help overcome these problems. The diggi, which stores the water supply from the watercourse, address the increasing unreliability with decreasing canal water supply the warabandi system. Sprinklers help spread the irrigation into a large area, increasing consumptive water use. Thus diggi and micro-irrigation help avert water logging and salinity in long-run.

7. 2 Spreading Microirrigation Technologies

In general, canal irrigation does not support microirrigation technologies such as sprinklers and drips. However, water stored in a diggi facilitates microirrigation. Microirrigation not only improves the water-use efficiency, but also increases the crop yield. So spreading micro irrigation in canal command area will increase the crop productivity and ultimately benefits the farmers.

7.3 Increasing Crop Diversification

Crop diversification has a large potential for increasing the net value of crop production. With proper crop choice, crop diversification to high-value crops can especially, help the small to medium land holders in water scarce regions (Birthal et al., 2007). They need to increase the value of crop production from the same amount of consumptive water use. A reliable water supply is the critical requirement for high-value crops that require proper application of inputs, where some of them are expensive. The diggi is an ideal solution for unreliable water supply to farms. Farmers have full control of managing water stored in a diggi. But, why then it is not an economically-viable option for small farmers in the IGNP canal command area. It is precisely because of this reason that diggis have not brought about significant changes in the cropping pattern. However, by shifting to high value crops, it could be possible for small holders to significantly increase the value of crop production. In such cases, diggis can be an economically-viable intervention even for small land holders.

7.4 Increasing Multiple Use of Water

Diggis in the IGNP are so far being used only for enhancing the crop production. Can it also be used for raising fish? Since water is supplied round the year, certain level of water supply can be maintained in a diggi for raising fisheries also. According to farmers, this has not been practised in the IGNP due to: low local demand, poor facilities for marketing the produce outside; and limited knowledge for raising fish in conjunction with crop production. Raising fish means that farmers cannot empty there diggi for an extended period of time of the year. However, we do not know whether net benefit loss of crop production after retaining water in diggis for fisheries is less than the net value of production gain through fisheries. However, data show that fisheries in conjunction with crop production can increase the income of farmers from every drop of water used manifold So with proper extension, diggis can eventually become an even better economically viable enterprise for farmers in the IGNP command area.

7.5 Bridging gap between Potential and Actual Irrigated Areas

A major problem in IGNP command area is irrigating the undulating land. This is exacerbated by the differences of water supply between the farms in head, middle and tail reaches of the canal command. Our research show, that water distribution between head, middle and tail reaches are highly inequitable. Farmers in head reach may still be using large quantity of water for irrigating their crops with a diggi. Indeed, a proper water accounting study could assess the quantity of water needs to be diverted to a diggi for meeting the full requirement of crops and other multiple uses. The excess water can then be diverted to meet the requirements of tail end of the command area, which often suffers due to water scarcity. This additional water supply can make a diggi an economically-viable option even in tail end areas. And it can increase irrigated area and bridge the gap between potential created and actual irrigated area.

8. CONCLUSIONS

In this paper, we had evaluated the physical and economic performance of diggis with sprinkler irrigation for farmers of different land holding sizes in IGNP command area. The diggi combined with microirrigation has substantially increased the irrigated area, yield, with improved input management and finally the net income benefits from crop production.

The capital cost of diggi and other infrastructure can be recovered within 6 years in a farm of size 6 ha. At larger land holding sizes, the returns to investments are much higher, and the investment can be recovered quickly from increase in crop production itself. The diggi can also become a viable option for small land holders, if they grow high-valued crop or diversify their farming to include fisheries. Due to the vegetarian diet being followed in this region, whether this type of intervention would be successful or not is not clear. However, given the present trends in states such as in Andhra Pradesh, where most of the inland fish production is exported for consumption outside the state, it is likely that with proper marketing facilities this can be a viable option in the IGNP project in Rajasthan.

It is clear that a diggi can: 1) mitigate the waterlogging and salinity in canal command area, 2) spread microirrigation; 3) help promote crop diversification; and 4) mitigate water scarcity in tail reach. All these require further research and extension in the IGNP canal command areas.

The intermediate storage structures with micro irrigation technologies, such as diggi and sprinklers in the IGNP, can be a viable solution to water scarce areas in other parts of the country. While they increase the private benefits, they could mitigate the environmental impacts such as waterlogging and salinity in high water table areas and reducing groundwater overdraft in semi arid and arid areas.

We need to further explore whether the use of diggis in the head reach farms could mean making more water available to tail end areas. This is important for successful completion of Phase II and III of the IGNP. The reason is that completion of these phases of the project would depend largely on water availability in the main canal for delivery to downstream locations.

Although, size of the sample from g roundwater irrigated areas for this study is not large, the general patterns show that an intermediate water storage structures are economically viable there also, even though they are highly energy-intensive. However, more research is required to assess the impacts of these intermediate structures on energy requirements, or to know at what level of energy prices can these structures be viable.

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