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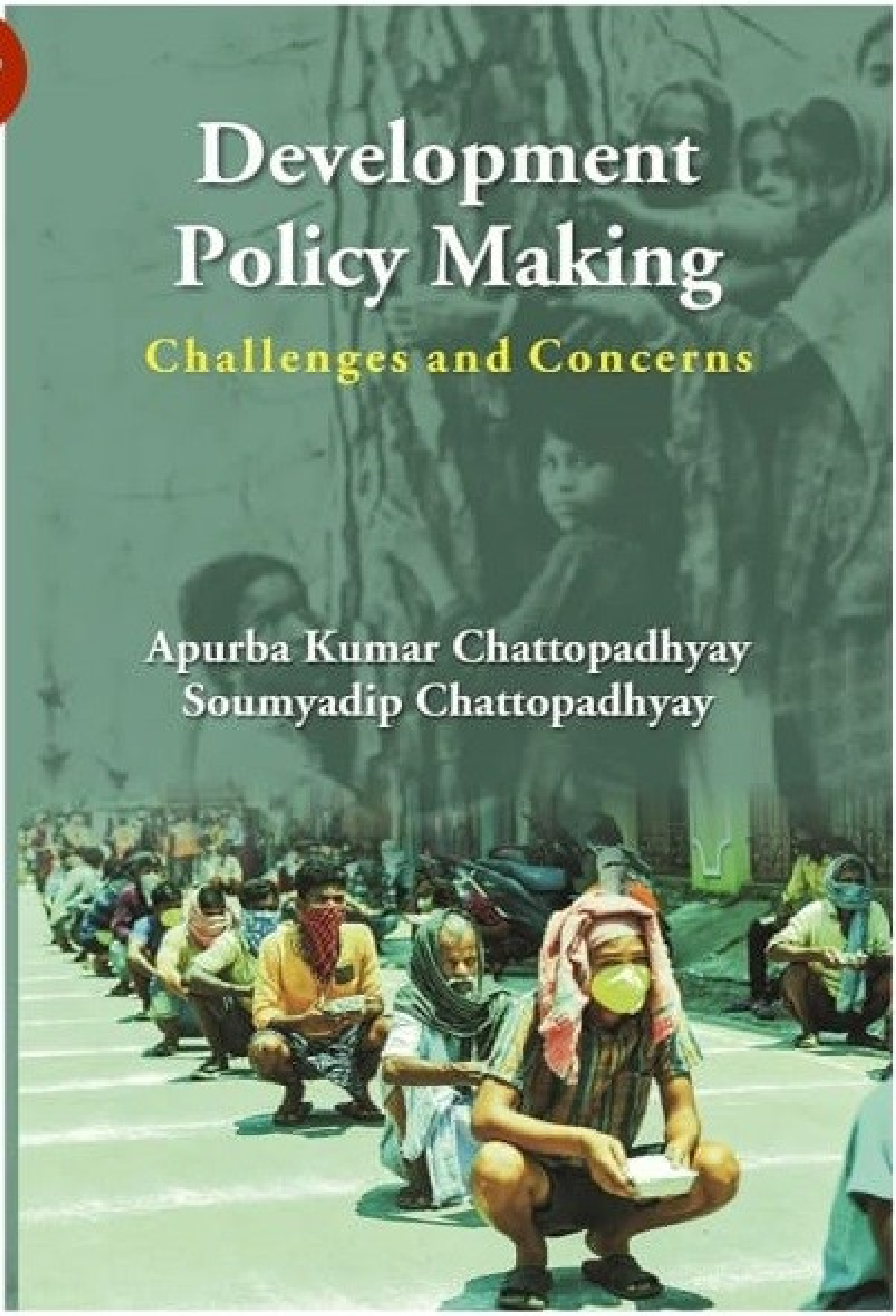

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Looking into the Efficiency and Productivity of Major Irrigation Projects in West Bengal, India with Special Reference to the DVC Irrigation Project

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Abstract

In West Bengal, about 66 percent of total canal irrigated area has been covered by the Damodar Valley Project (DVC) and Kangsabati Reservoir Project. These two major irrigation projects are structurally different—the DVC irrigation project is a single-barrage-multi-reservoir type project but the Kangsabati irrigation project is a multi-barrage-single-reservoir type project. The objectives of this study have been to make a comparative analysis of the irrigation efficiency of these two types of major irrigation projects and also to find out the possible reasons for their variations over time. We have also attempted to make a zone-wise (head-reach, middle-reach and tail-end-zones) comparative analysis of the irrigation performance in the DVC command area using primary data collected during 2013-14 through field survey. This study reveals that the multi-barrage-single-reservoir irrigation projects (Kangsabati) is more efficient than the single-barrage-multi-reservoir irrigation project (DVC). Further, it has been found that the summer (boro) paddy productivity is higher in the plots of the head-reach zone compared to that in tail-end zone because of their respective locations vis-à-vis canal water availability and furthermore, this location factor is important in determining crop pattern and crop diversification in the respective zones.

Key Words: *Irrigation Efficiency, Potential Created and Utilised, Water Supply, Productivity Variation.*

1. Introduction

Agricultural growth in India is greatly dependent on the monsoon rainfall because it is largely rain-fed. Irrigation, thus, is an important input for increasing agricultural productivity and it is required at different critical stages of plant growth. What is true for the country as a whole is also true for the state of West Bengal. The surface irrigation and ground water irrigation are the two available sources of irrigation. In West Bengal, the ground water irrigation potential was only 16 percent up to 1982 (Boyce, 1987), which increased to about 56.08 percent in 2007 (Ray, *et. al.,* 2009). On the other hand, in 1975-76 canals irrigated area was 47.6 percent (Rawal, 2001), which declined to about 23.78 percent in 2007(Ray, *et. al.,* 2009). These explain declining importance of surface water for irrigation purpose. However, it has been emphasised by the researchers that excessive dependence on groundwater has caused depletion of ground water at a rate greater than the rate of its recharge. This has threatened the water table and also has raised questions about the sustainability of such use in the long run (Dhawan, 1987; Gulati, et al, 2005; Chattopadhyay, 2014). These studies further emphasised on the conjunctive use of both ground water and surface water (whose main constituents are canals) for the purpose of irrigation.

West Bengal has seven major irrigation projects. Among these irrigation projects, Teesta and Subarnarekha Barrage projects have not yet been completed. Damodar Valley Project, the Kangsabati Reservoir Project, the Mayurakshi Reservoir Project, Hinglow Reservoir Project and the Medinipur Canal are the other major projects. The reservoirs or the dams of the projects in South Bengal are located either along the western border of the State or beyond that i.e. within the territory of the adjacent State of Jharkhand.

Among the major irrigation projects, the Damodar Valley Corporation (DVC) project and the Kangsabati Reservoir Project together have covered about 66 percent of total canal irrigated area of West Bengal in 2009-10. Further, these two major irrigation projects are structurally different in that while the DVC irrigation project is a single-barrage-multi-reservoir type project; the Kangsabati irrigation project is a multi-barrage-single-reservoir type. We have taken up these two major irrigation projects for our study for these two reasons. The DVC project has five reservoirs (Tilaiya, Maithon, Panchet, Konar, and Tenughat) and one barrage (Durgapur) while the Kangsabati project has three barrages (Silabati, Bhairabanki, and Tarafeni) and one reservoir or dam (Mukutmanipur). The net irrigated area of DVC project is 3.94lakh ha (covering parts of Burdwan, Hooghly, Howrah and Bankura districts) and the net irrigated area of the Kangsabati project is about 3.41 lakh ha (covering Bankura, West Midinipur and Hooghly districts). We have examined these two major irrigation projects in terms of (a) irrigation efficiency, (b) depth of water supply,

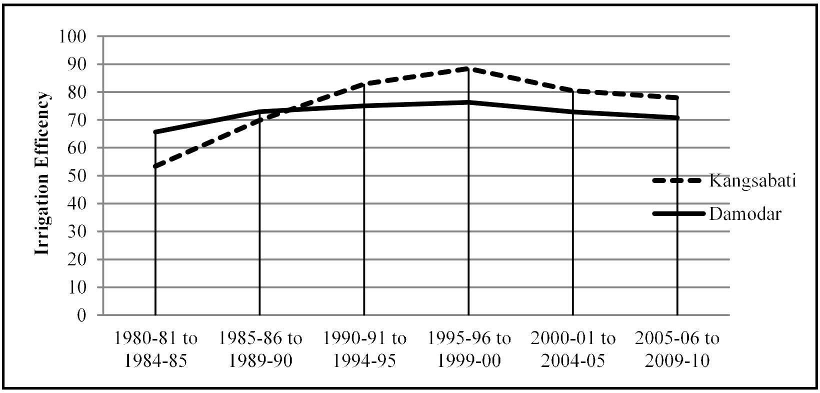
(c) nature of irrigation in all seasons and (d) performance of Command Area Development Authority (CADA). The period of our study is 1980-81 to 2009-10. Further, by using primary data collected from the command area of the DVC project which is the largest among the major projects in West Bengal, we have tried to explain zonal variations in farm productivity and cropping pattern [in respect of head reach (HR), middle reach (MR) and tail end (TE) zones of canal course].

We have structured our article in terms of the following sub-sections. We discuss comparative performance of these two major irrigation projects of West Bengal in Section II and in Section III we will make an appraisal of zone-wise irrigation performance and water use efficiency of the DVC project; and finally, in Section IV we make concluding observations.

2. Comparative Performance of the two Major Irrigation Projects

In this section we make a comparative study of the DVC project which is a single-barrage-multi-reservoir type project with the Kangsabati Reservoir Project which is a multi-barrage-single-reservoir type project in terms of irrigation efficiency (IE) and depth of water supply per ha, in different seasons by using secondary data for the period 1980-81 to 2009-10. Irrigation efficiency of any project is calculated in terms of utilisation and creation of irrigation potential of the concerned project. Thus, Irrigation efficiency = [(irrigation potential utilised ÷ irrigation potential created) × 100] (GoWB, 2013a). We have presented the computed values of irrigation efficiency of these two major projects in Figure-1. It reveals that irrigation efficiency (IE) is higher for the Kangsabati irrigation project, during most of the period of our study compared to the DVC project.[1] Further, in the Kangsabati project, IE has been increasing at a faster rate till 1999-00 and then it is gradually declining but still remains at the higher level compared to that of DVC project. We may now seek to explain the reasons behind higher IE of the Kangsabati irrigation project.

The irrigation efficiency of any irrigation project depends on two factors: (i) gross water supply and (ii) construction of field channels in the command area of the concerned project. That the gross water supply (GWS) is a positive and significant factor of IE of any project can be shown using a single linear regression model: IE = f (GWS). When we run this model separately to the time series data of DVC and Kangsabati irrigation projects the regression coefficients of GWS are found to be positive and statistically significant in both cases.[2] On the other hand, several studies have revealed that under-utilisation of irrigation potential (or low irrigation efficiency) is due to lack of sufficient field channels in the command area of the concerned irrigation project (Kumar, 1978; GOI, 1972; Pant, 1992; Vaidyanathan, 1999 and Viswanathan 2001). Now we can explain why Kangsabati irrigation project is more efficient than DVC in respect of IE by using these two factors.



Source: Annual Report of CADA of DVC and Kangsabati Reservoir Project, Govt. of West Bengal (2011-12).

Figure 1: Overall Irrigation Efficiency of Two Major Irrigation Projects during1980-81 to 2009-10.

Water Supply: From the available data (Table 1) we have found that the depth of water supply per ha of the Kangsabati Project is greater than the DVC Project (about 17 percent) during *rabi* & *boro* seasons when the demand for irrigation water is maximum as there is no scope of having normal rainfall. This make the Kangsabati project relatively more irrigation efficient. It may, however, be noted that during the *kharif* or monsoon season the depth of water supply per ha is higher in DVC project (about 45 percent). But, lower depth of water supply per ha in any command area during monsoon does not cause concern because of availability of rain water. This explains differences in the irrigation efficiencies between two major irrigation projects.

Further, the structural differences of the two water projects also make Kangsabati Project more efficient than the DVC which may be explained in terms of the dynamic use of rain water. The Kangsabati project is a multi-barrage-single-reservoir type and thus it can store monsoon rain water in the existing barrages. This stored rain water is distributed as *kharif* irrigation which requires release of less water from Mukutmanipur reservoir. In this way multi-barrage-single-reservoir type irrigation project may be able to store higher level of water in the connected reservoir for *rabi* &

boro seasons and provides higher amount of water for irrigation purpose. It is to be noted that percolation rate of river connected with barrage is relatively higher than reservoirs. On the other hand, the Damodar irrigation project is a multi-reservoir-single-barrage type for which procedures for storage of rain-water and release of it are completely different. In the latter case, rain water gets stored in dams and then distributed through the barrage in need or under compulsion. This implies that dynamic-use-of-rain-water for irrigation is substantially higher in the Kangsabati project than DVC project. It is to be noted that for dynamic use of rain water Kangsabati project has been providing about 25.02 percent more irrigation water than their actual storage capacities, while for DVC project this is only about 17.90 percent[3]. There are certain other factors which resulted in lower IE of the DVC projects. They are: (i) Kangsabati project is entirely meant for irrigation purpose while DVC project is for both power generation and irrigation purpose; (ii) During last 30 years no new reservoir was constructed by DVC but 16 new thermal power plants have been built up (GOI, 2013); (iii) the water supply for industrial and municipal uses has also increased rapidly during last couple of years[4].

Table 1: Depth of Water Supply in the Damodar and Kangsabati Irrigation Projects

Year	***Kharif (Cu. M / Ha)***		***Rabi & Boro (Cu. M / Ha)***	
	Kangsabati	***Damodar***	***Kangsabati***	***Damodar***
1980-81 to 1984-85	3100	6288.15	10933	8562.49
1985-86 to 1989-90	3920	5448.56	11950	8125.37
1990-91 to 1994-95	2800	4901.32	7060	9747.37
1995-96 to 1999-00	3750	4556.47	10100	8916.58
2000-01 to 2004-05	3120	4687.35	8625	8033.72
2005-06 to 2009-10	3340	3221.24	11200	7764.31
Average	3338	4851	9978	8525

Source: Annual Report of CADA of DVC and Kangsabati Reservoir Project, Govt. of West Bengal (2011-12).

Field channel area: In a study relating to Hirakud irrigation project, Kumar (1978), has found that field channels have significant role in increasing the overall irrigated area and raising cropping intensity. Further, Pant (1992) in his study in the command area of Sharda Sahayak irrigation project has found that absence of efficient field channels and field drains within the command of outlet have been responsible for underutilisation of irrigation potential and on-farm development is marginal. In the Kangsabati project field channel area is comparatively higher in both absolute (70,811.3 ha till 2009-10) and relative senses (20.78 percent of net irrigated area) (GoWB, 2014) than the DVC project (47,300 ha and 12.01 percent, respectively, till 2009-10) (GoWB, 2013). These imply that field channel area has played a significant role to enhance irrigation efficiency or performance of the Kangsabati project compared to that of DVC project.

3. Zone wise irrigation performance and water use efficiency of the DVC project

In this section, we have tried to examine zone-wise irrigation performance on farm productivity in the summer season and irrigation efficiency of this project as revealed by crop pattern in different segments of the canal course. For the purpose of primary survey we selected samples from the Left Bank Main Canal command area of DVC that has originated from Durgapur Barrage. It covers three districts of West Bengal namely, Burdwan, Hooghly and Howrah. The entire area has been divided into three zones, namely, Head Reach (HR), Middle Reach (MR) and Tail-end (TE) zones. These divisions have been made on the basis of water availability and physical structure of canal network and follow the procedure adopted in previous studies pertaining to DVC canal network (IIMC, 2008; Kundu and Chattopadhyay, 2017).

In our study area, summer paddy (*boro*) has been the main crop during summer and it is cultivated in most of the arable land in HR and MR zones of the canal course but in the TE zone less than 40 percent of land is used for *boro* paddy production. This follows the pattern of availability of the irrigation water in the land corresponding to different zones of the canal course. Thus, while the plots of land served by HR zone and large part of the MR zone get required canal water for irrigation there are always uncertainty about the availability of canal water in the TE zone. The data from our primary survey has revealed that productivity of *boro* paddy is the highest in the HR segment and it is lowest in the TE segment. Previous studies have also revealed similar outcome (GOI, 2003; Hussain, 2004). Further, we have used the multiple-regression model to ascertain if the supply of canal water has been a major factor in determining differences in productivity across lands corresponding to different zones of the canal network. Regression results are presented in the Appendix Table 1. It clearly reveals that supply of canal water is highly significant factor to explain differences of productivity across different zones. Other important factors are type of the soils, participation of adult family members, cost of other factors of production and techniques of production.

It may be noted that the farmers in the TE zone incurs substantial cost on underground irrigation to neutralise the uncertainty and uneven supply of canal water. Excessive storage of canal water by the farmers in the HR and MR zones making use of their location advantages vis-à-vis TE farmers has led to the uneven distribution of water and thereby making the latter farmers dependent on other costlier sources of irrigation. This inefficient management of canal water is one of the factors which explain lower *boro* paddy productivity in the TE zone.

Further, this uneven distribution of canal water leads to create different types of cropping pattern across HR, MR and TE zones of the DVC command area, which is shown in Table 2. From this table we can observe that about 92 percent and 73 percent of gross cultivated land has been used for paddy cultivation only in the HR and MR areas, respectively. While in the TE area this figure is about 44 percent and remaining part of land is used to produce less water intensive crops like, potato (29%), *til* (12%), vegetables (7%), mustard (3%) and other crops (ground nut, pulses, etc.) (5%). This indicates that location advantages of the farmers in the HR and MR zones lead to over use of canal water and cultivation of water intensive crop like paddy while TE farmers are compelled to use major portion of their land for production of less water intensive crops. Wade (1976) in his study have reached similar conclusion. This means, water use efficiency is relatively lower in the HR and MR zones compared to TE zone.

Table 2: Inter-segments Variation of Cropping Pattern in the DVC Command Area

(Area in hectare)

Types of crop area	*Head Reach*	*Middle Reach*	*Tail-end*
kharif Paddy	133.40	112.97	79.44
boro Paddy	92.91	76.03	18.34
Potato	0.93	44.12	63.65
Mustard	16.60	6.53	5.62
Wheat	1.87	0.00	0.00
Til	0.00	15.39	26.14
Jute	0.00	0.00	4.00
Vegetable	0.00	3.64	15.45
Ground nut	0.00	0.00	1.28
Pulses	0.00	0.00	0.11
Others #	0.00	0.00	7.35
Gross cultivated area	245.71	258.68	221.38
Net cultivated area	135.13	113.56	82.54
Cropping intensity (%)	181.83	227.79	268.21
Crop diversification*	0.51	0.64	0.74

Notes: # Others consist of fruit (cucumber and water-melon), turmeric, etc.

* It has been calculated based on Transformed Herfindahl Index formula[5].

Source: Primary Survey.

Our study has revealed the following reasons for uneven water distribution of canal water in different segments of the canal course (HR, MR and TE zones): (i) Area under field channels is relatively higher in the TE area compared to the HR area which results in greater seepage loss in the HR area compared to TE area; (ii) Further, due to lack of proper management by the authority there occurs huge loss of precious irrigation water through unmanaged canal outlets mainly in the HR area; (iii) The method of flood irrigation is adopted for paddy cultivation, where each plot needs to be irrigated before passing onto the subsequent plots. This results in wastage of water since a part of the flooded plots might not be used for cultivation that season or around the same time. Had there been more field channels in the HR area; this wastage of canal water could be avoided; (iv) It may be noted that if plots are flooded by the farmers themselves at the time of paddy cultivation, the amount of water use would be relatively lower than when irrigation water is supplied by the irrigation authority who generally does not have knowledge about quantum of water requirements at different stages of plant growth within huge command area for irrigation; (v) Further, the huge length of channel network proves to be a classic example of managerial diseconomies of scale to deliver water successfully till the end point of the channel network; (vi) Furthermore, absence of continuous supervision of water delivery in the channel network also leads to uneven distribution of irrigation water.

4. Concluding Observations

Our study has revealed that multi-barrage-single-reservoir (MBSR) type irrigation project is relatively better than single-barrage-multi-reservoir (SBMR) type irrigation project in respect of irrigation efficiency or potential utilisation of their targeted area of irrigation. We have also found that expansion of gross field channel area play a significant role in enhancing irrigation efficiency in the command area. Further, dynamic use of rain water is considerably higher in the MBSR type of project compared to the SBMR type project. Therefore, when additional water is required for cultivation (i.e., in the *rabi* & *boro* season), depth of water supply per hectare is higher in the MBSR type project than SBMR project. Thus, DVC project is required to build additional barrage to improve irrigation efficiency, dynamic use of rain water and depth of water supply per hectare in winter and summer (*rabi* & *boro)* seasons.

Our analysis of primary survey data collected from the DVC command area reveals that water availability is relatively higher in the HR zone compared to the MR and TE zones. This has influenced the cropping pattern in the three segments of the canal course. As a result, the TE farmers use their land to produce less water intensive crops while the farmers of HR area mainly cultivate water intensive crops. This implies that water use efficiency is relatively lower in the HR and MR zones compared to TE zone. Further, average summer paddy productivity is relatively higher in the HR area followed by MR and TE areas. This variation is also due to uneven water distribution of canal water among farmers in the HR, MR and TE zones. Thus, DVC is required to improve management in the DVC canal network during water delivery and also it is required to construct additional field channel area to distribute canal water equally among farmers in the HR, MR and TE zones. Further, there is an urgent need of transforming old method of irrigation (flood irrigation) to new method of irrigation (SRI, drip, spring, etc).

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Notes

1. Gross irrigation efficiency of Kangsabity, and DVC Projects during 1980-81 to 2009-10.

Irrigation Projects	*1980-81 to 1984-85*	*1985-86 to 1989-90*	*1990-91 to 1994-95*	*1995-96 to 1999-00*	*2000-01 to 2004-05*	*2005-06 to 2009-10*	*Average*
Kangsabati	53.35	69.89	82.88	88.39	80.42	77.92	75.47
Damodar	65.64	72.95	75.03	76.33	72.83	70.73	72.25

Source: Annual Report of CADA of DVC and Kangsabati Projects, Govt. of West Bengal (2011-12).

2. The regression coefficients of GWS are 0.06* (0.01) and 4.89*** (2.80), respectively for DVC and Kangsabati Projects. The asterisks '*' and '***' indicate 1% and 10% level of significance, respectively and values in parentheses are corresponding standard errors.

3. The storage capacity of five reservoirs of the DVC project for irrigation and power generation purpose is about 1829.33 MCM (GoWB, 2013). The storage capacity of Kangsabati reservoir is about 917 MCM where storable water is used only for irrigation. The yearly average water supplies for irrigation from these projects are about 2066.83 MCM and 1146.39 MCM, respectively. Additionally, DVC provided 90MCM water for power generation purpose in 2009-10. The calculation of dynamic use of rain water of DVC project is [(2066.83 + 90) ÷1829.33] × 100 = 117.90 i.e., 17.90 percent more than their actual storage capacity.
4. The DVC water supply for industrial and municipal uses increased from 73.35 MCM to 1408.77 MCM during 2005-06 and 2015-16 (DVC Annual Report 2005-06, p.44 and 2015-16, p. 37). Further, the present water supply for industrial and municipal uses is more than half of average water supply per year for irrigation (2066.83 MCM).
5. For a detailed discussion of the nature and extent of crop diversification in the study area, please see, Kundu and Chattopadhyay (2018).

Appendix

Table 1: Regression Results Explaining Zonal Differences of the Summer Paddy (*Boro*) Productivity

Explanatory Variables	*Values of Regression Coefficients*			
	All zones	*Inter-zonal*		
		Head Reach (HR)	*Middle Reach (MR)*	*Tail-end (TE)*
Participation rate of adult family member in agriculture (X^{PRA})	3.76* (0.56)	4.35* (1.33)	4.14* (0.77)	4.43* (0.87)
Soil types (D^{ST}) (1- sticky, 0 – loamy)	3.74* (0.60)	-	2.10** (0.75)	-
percentage of canal water availability (X^{CWA})	0.24* (0.01)	0.26* (0.04)	0.22* (0.01)	0.19* (0.05)
Technique of paddy cultivation SRI ($D^{TC\text{-}SRI}$): (SRI=1 and 0, otherwise)	11.24* (1.40)	-	-	10.51* (1.49)
Fertilizers cost (X^{FC})	0.04 (0.03)	0.08 (0.06)	0.01 (0.04)	-0.05 (0.06)
Seed cost (X^{SC})	0.23** (0.09)	0.13 (0.17)	0.17 (0.16)	0.27*** (0.15)
Pesticides cost (X^{PC})	0.02 (0.06)	0.005 (0.07)	0.09 (0.12)	0.30 (0.19)
Constant	10.91* (1.61)	12.86* (3.45)	13.60* (2.98)	9.75** (4.54)
R^2	0.76	0.53	0.79	0.86
Adj R^2	0.75	0.51	0.78	0.84
F value	88.63*	18.78*	48.15*	30.22*
Observation	204	88	81	35
Irrigation cost (X^{IC}) #	-0.50* (0.06)	-2.36* (0.52)	-1.44* (0.23)	0.59** (0.28)

Note: Here (-) means no change of the respective value of variable in the respective areas and *, ** and *** imply statistical significance at 1%, 5% and 10% levels, respectively.

The linear regression model is: $\mathbf{Y_j^s = \alpha_s + \beta_{ks}(\sum_{j=1}^{ns} X_i + \sum_{j=1}^{ns} D_i) + u_j}$

Where Y_j indicates summer paddy productivity (kg/*katha*) in the s = zone (all zones, HR, MR and TE). j = 1, 2, 3,..., n indicate number of observation (204, 88, 81 and 35 respectively for different zones). Independent variables and regression results are given in the above Appendix Table 1. Regression coefficient of fertiliser cost is positive in HR (0.04) and MR (0.01) zones but it is negative in the TE zone. In the TE area, impact of fertiliser cost is negative because about 69% plots are used to cultivate *boro* paddy after potato production and there is a tendency to apply less fertiliser (since farmers apply huge amount of fertiliser per unit of land for growing potato and part of it stays in the field) while the farmers apply relatively higher amount of fertiliser in those plots which are used only for paddy cultivation (both *kharif* and *boro*).

Irrigation cost (X^{IC}) is not an explanatory variable in our model since it produces multicolinearity problems with other variables. This row depicts the result of single linear regression model (last row of the above table), where irrigation cost is the only explanatory variable.

Source: Primary Survey.