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Impact of Conjunctive Use of Water Resources on Crop Production in Canal Command Area- A Case Study

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ABSTRACT: The study is carried out for Jamuniya, Jhansi and Khulri Minor of Left Bank Canal network of Rani Avanti Bai Sagar irrigation project. It constitutes impact of conjunctive use on water resource utilization pattern, irrigation depth, changes in cropping pattern, effect on yield of crops, water table depth and net farm return. The results indicated in Jamuniya minor have the use of surface water for irrigation is more than ground water in last 10 years. In Jhansi minor, the use of surface water for irrigation was maximum in year 2001-02 (114.88 ha) and then continuously decreased during last 10 years reached to 50.55 ha. Reverse trend was observed in Jhansi minor with use of ground water for irrigation and similar pattern was found in Khulri minor. The depth of irrigation for wheat, gram and green pea was observed the highest in Jhansi head reach 26.5 cm, 10.6 cm and 25.8 cm, respectively and the lowest in Khulri middle reach as 12.5 cm, 5.0 cm and 15.0 cm for wheat, gram and green pea, respectively. The wheat area intensity continuously increased in all minors during 2003-04 to 2009-10. The yield of wheat registered the highest (38 q/ha) in head reach of Jamuniya minor and the lowest (27.7 q/ha) in middle reach of Jamuniya minor. The yield of gram was maximum (18.21 q/ha) in tail reach of Jhansi minor and minimum (14.0 q/ha) in middle reach of Khulri minor.

Key words: Water resource utilization, cropping pattern, water table, net farm return

Increasing water demand poses new challenges for water resources planners and managers. The world population is increasing rapidly and expected to touch the 9.30 billion mark by 2050 from the 7 billion in 2011 (United Nations, 2010). Agricultural production needs to be increased in order to provide food and fibre for the burgeoning global population (Singh and Panda, 2012a). To keep pace with the increasing population, agricultural production needs to be increased along with irrigation. This is possible through development of new water resources projects (supply management) or efficient water management of available resources. Conjunctive use of surface and groundwater is one of the most effective water management alternatives, to deal with increasing irrigation demand and inadequate surface supplies. It is necessary to achieve maximum returns from cropping activities and to resolve the problems of water-logging and water table depletion. The conjunctive use of surface water and ground water resources is necessary because the availability of one source of water may not be sufficient to fulfill the entire irrigation requirements (Nevill, 2009; Harmancioglu *et al.,* 2013). The conjunctive use improves the water use efficiency and regional environment of irrigated areas (Cosgrove and Johnson, 2005; Cheng *et al.,* 2009) by increasing the reliability of supply when a single source of water is inadequate to meet the demand with sustainability (Singh, 2012b; Liu *et al.,* 2013). The increase in agricultural productivity by minimizing the crop stress is the major benefit of conjunctive water use (Fredericks *et al.,* 1998). Conjunctive use also allows the use of poor quality water for irrigation (Prendergast *et al.,* 1994; Datta and Jong, 2002; Kaur *et al.,* 2007; Mandare *et al.,* 2008). Oster and Grattan (2002), Malash et al. (2008), and Rasouli *et al.* (2013) have demonstrated the successful utilization of conjunctive use of poor quality water for crop production. Since no attempt was made toward the impact assessment of conjunctive use of water resources and it's after effects in canal command area in Jabalpur. Therefore, this study focuses on the study of comprehensive effect of conjunctive use of water resources in Jamuniya, Jhansi and Khulri Minor of Left Bank Canal network of Rani Avanti Bai Sagar irrigation project in Jabalpur district of Madhya Pradesh.

Materials and Methods

The study in the command area of Jamuniya, Jhansi and Khulri minor (LBC) of Rani Avanti Bai Sagar irrigation project, located in the village Bijora that is about 43 km from the Jabalpur city, india. The command area of Jamuniya minor lies between the North latitude 23º 2' 27" to 23º 3' 40" and East longitude 79º 41' 9" to 79º 41' 35", command area of Jhansi minor lies between the North latitude 23º 3' 40" to 23º 4' 45" and East longitude 79º 41' 35" to 79º 42' 5" and Khulri minor command area lies between the North latitude 23º 4' 34" to 23º 5' 52" and East longitude 79º 47' to 79º 48' 14". Average annual rainfall is 1350 mm about 80% of which is received during the monsoon period (July to September). The average annual evaporation recorded during the month of May is about 350.46 mm whereas minimum evaporation of 70 mm is observed during the month of December. The mean maximum temperature ranges between 42.2ºC and 25.8ºC and mean minimum temperature ranges between 26.7ºC and 9.2ºC. As the project area lies in hot zone, the variation in humidity is quite large. The soil of the study area is clay-loam and has low phosphorous, medium nitrogen and medium potassium. Daily records of supply head in main canal were obtained from the Department of Irrigation, Government of Madhya Pradesh. Based on cross sectional area, slope and outlet conditions, the discharge delivered to the command area was estimated. Operation hours of selected minor and schedule of operation for main canal during the irrigation season were observed to estimate the volume of water delivered to the study area. The cropping pattern and detailed land use data for 2000-01 to 2010-11 were collected personally through field visits and contact with the farmers. In order to assess the impact of canal irrigation on cropping pattern, intensity of cropping, land use and agricultural production, a pre-decided and pre-tested Performa was used. Farmers were contacted personally to collect the desired information. Representative farmers within the command area as well as in the immediate vicinity were selected from different categories of landholding namely marginal, small, medium and big. Farmers were selected using random sampling technique. The selected farmers were interviewed and the information on their agricultural practices, land use, crops grown, irrigation sources, fertilizer and irrigation practices were obtained. The data were tabulated and analyzed to determine the impact of conjunctive use of canal water resources on crop production. Table 1 presents the size of land holding in head, middle and tail reaches of the study area.

Table 1 : Farmer's classification and size land of holding in different canal reaches of study area

Canal Reach	Marginal (0-1 ha)		Small (1-2 ha)		Semi-medium (2-4 ha)		Medium (4-10 ha)		Large (> 10 ha)	
	N	**A**	**N**	**A**	**N**	**A**	**N**	**A**	**N**	**A**
Head	1	0.8	3	4.80	1	3.20	2	10	2	24.80
Middle	4	3.20	3	5.20	1	3.60	2	11.60	0	0
Tail	0	0	2	3.80	4	11.20	3	16.40	1	24

N- Number of farmers, A- Area

Field observations

Field observations were carried out to determine the discharge of minor, canal, tubewell, centrifugal pump and number of tubewells in different minors at different reaches.

Table 2 : Characteristics of selected minors in left bank canal (LBC) of Rani Avanti Bai Sagar irrigation project

Location	Bottom width (m)	Side Slope (H:V)	Top width (m)	Depth of flow (m)	Velocity offlow (m/s)
Jamuniya	0.30	1:1.5	1.40	0.38	0.263
Jhansi	0.30	1:1.5	1.40	0.40	0.454
Khulri	0.30	1:1.5	1.40	0.50	0.1086
Main	9.14	1:1.5	17.24	2.70	0.1052

To determine the ground water irrigated area in command area at different reaches, the following method was adopted.

$$V_1 \quad \frac{(QX3600XT)}{1000} \qquad \text{... (1)}$$

$$V_2 = V_1 \times \text{Irrigation interval (in days)} \qquad \text{... (2)}$$

$$D \quad \frac{V_2}{10000} \quad 100 \qquad \text{... (3)}$$

Area irrigated (ha) = D/ADI ... (4)

Q = Discharge from tube well (lps)

T = Time of tube well pumping (hrs)

V_1 = Volume of water in one day (m^3)

V_2 = Volume of water available in irrigation interval days (m^3)

D = Total depth per hectare (cm)

ADI = average depth of irrigation water (cm)

Measurement of depth of irrigation water

To determine the depth of irrigation water in command area of different minors at different reaches, information on horse power of motor, discharge of motor, operating hours, method of irrigation and head loss of system are required.

H.P.	=	$(Q \times Hn) / (75 \times Ep)$ … (5)
Q	=	maximum flow rate of the system or pump capacity, lps
Hn	=	total dynamic head, m
Ep	=	pump efficiency, %
H.P.	=	horse power

To test the significant difference among the treatment means, SE(m), SE(D) and CD were determined.

Results and Discussion

Water resource utilization pattern

Surface water started with the introduction of canal in the year 1989 and the amount of water delivered in to the area as well as the area irrigated by canal water were found increasing. The canal water or surface water was used mainly through flood irrigation and lift irrigation through pumps. Table 4 shows the utilization pattern of ground water and surface water in different commands of minors at different reaches like head, middle and tail with different years since 2001. In Jamuniya minor out of total canal command area of 208 ha, the use of ground water has increased with time. The area of surface water irrigation was converted in ground water in last two years presented in Table 3. In Jhansi minor, yearly increase in surface water was maximum in year 2007-08 then decreased in last three years and ground water area increased. In Khulri minor, the use of ground water in last ten years was higher than surface water use and the surface water use is mostly constant.

Table 3 : Resource utilization pattern of surface water (SW) and ground water (GW)

Minors	Area irrigated, ha								
	Jamuniya			Jhansi			Khulri		
Year	SW	GW	Total	SW	GW	Total	SW	GW	Total
2001	24.36	0.00	24.36	114.88	14.40	129.28	79.20	115.70	194.90
2002	18.77	0.00	18.77	106.64	14.40	121.04	78.20	117.70	195.90
2003	25.14	4.70	29.84	107.25	23.60	130.85	77.20	122.60	199.80
2004	16.10	21.90	38.00	17.80	38.40	56.20	64.20	124.60	188.80
2005	26.54	21.90	48.44	76.78	48.80	125.58	73.20	124.60	197.80
2006	55.39	36.90	92.29	94.89	85.20	180.09	71.76	131.50	203.26
2007	71.52	61.30	132.82	106.55	101.00	207.55	71.20	135.40	206.60
2008	134.00	74.00	208.00	83.00	129.76	212.76	73.00	142.00	215.00
2009	115.00	93.00	208.00	53.63	158.78	212.41	71.00	144.00	215.00
2010	112.00	96.00	208.00	50.55	168.45	219.00	71.00	144.00	215.00

Table 4 : Characteristics of resource utilization pattern of surface water (SW) and ground water (GW) at different reach of minors

Reaches	Area irrigated, ha																	
	Jamuniya Minor						Jhansi Minor						Khulri Minor					
	Head		Middle		Tail		Head		Middle		Tail		Head		Middle		Tail	
Years	SW	GW	SW	GW	SW	GW	SW	GW	SW	GW	SW	GW	SW	GW	SW	GW	SW	GW
2001	13.46	0.00	2.50	0.00	8.40	0.00	39.55	4.00	59.33	10.40	16.00	0.00	41.20	11.70	31.00	64.00	7.00	40.00
2002	7.87	0.00	2.50	0.00	8.40	0.00	38.71	4.00	61.93	10.40	6.00	0.00	42.20	11.70	29.00	66.00	7.00	40.00
2003	14.24	0.00	2.50	0.00	8.40	4.70	44.59	8.00	59.66	15.60	3.00	0.00	42.20	15.60	29.00	66.00	6.00	41.00
2004	5.20	6.00	2.50	11.20	8.40	4.70	7.80	8.00	10.00	26.00	0.00	4.40	31.20	15.60	27.00	68.00	6.00	41.00
2005	13.54	6.00	2.50	11.20	10.50	4.70	32.83	8.00	43.95	36.40	0.00	4.40	40.20	15.60	27.00	68.00	6.00	41.00
2006	25.49	6.00	11.00	16.80	18.90	14.10	37.03	20.00	50.68	52.00	7.18	13.20	41.76	19.50	25.00	70.00	5.00	42.00
2007	30.62	6.00	22.00	22.40	18.90	32.90	44.37	20.00	52.00	59.00	10.18	22.00	41.20	23.40	25.00	70.00	5.00	42.00
2008	53.00	6.00	55.00	31.00	26.00	37.00	39.00	28.00	35.64	75.36	8.36	26.40	44.00	29.00	24.00	71.00	5.00	42.00
2009	53.00	6.00	37.00	49.00	25.00	38.00	24.41	36.00	19.22	91.78	10.00	31.00	43.00	30.00	23.00	72.00	5.00	42.00
2010	53.00	6.00	34.00	52.00	25.00	38.00	27.87	39.13	16.68	94.32	6.00	35.00	43.00	30.00	23.00	72.00	5.00	42.00

Depth of irrigation water in different minors at different reaches

The uniformity of application describes how evenly an application system of distributed water over the field. Depth of water supply in different reaches and different minors is presented in Table 5 for different crops like wheat, gram and green pea. In Jamuniya minor, the tail reach has the highest depth of water (23.0 cm) for wheat crop whereas in Jhansi and Khulri minors, the head reach has the highest depth of irrigation (26.5 and 24.5 cm, respectively). This pattern is true for other crops like green pea and gram. The depth of irrigation water is the lowest in middle reach of Khulri minor.

Changes in cropping pattern

Cropping pattern in canal command area depends on the certainty and timely availability of irrigation water. It also gets affected by drainage conditions and maintaining healthy environment around root zone of crops. Conjunctive use of surface and ground water has got its significant effect on crops and cropping pattern in the area. Wheat requires assured irrigation, increases in acreage and replaces gram which needs only single irrigation. Wheat area intensity (WAI) shows spread of wheat. Its change with respect to change in ratio of surface and ground water depicts the impact of conjunctive use. Wheat area intensity (Table 6) in all the minors increased from 4.87 to 64.8 during 2003-04 to 2009-10. This is a significant change statistically. On an average, the WAI has increased from 28 to 56% during this time period, whereas intensity of gram has reduced from 45 to 33% (Table 7). This change can be attributed to a rise in ground water use which has reduced surface and ground water ratio from 3.5 to 0.70 (Table 8).

Effect on yield of crops

Table 9 presents the yield of wheat and gram obtained in different reaches of the three minors along with the ratio of surface and ground water utilization. Highest yield (38 q/ha) of wheat was obtained at Jamuniya with higher SW: GW ratio of 8.83, whereas it was 36.45 q/ha in Jhansi minor with a SW: GW ratio of 0.71. Similarly, lowest SW: GW ratio of 0.12 was in Khulri minor tail end with an yield of 33.34 q/ha which is on par with yields at other SW: GW ratio in the Khulri minor itself.

Similar trend has been observed with yield of gram as 14.17-17.50 q/ha in Jamuniya, 15.71-18.21 q/ha in Jhansi and 14.00-15.83 q/ha in Khulri minor with a variation of SW: GW ratio from 8.83 to 0.12. This also shows a mix trend in yields obtained in various reaches with various SW: GW ratio. This may be attributed to the management applied to different source of water apart from quantity of irrigation water.

Water table depth

Table 10 presents the depth to water table in different minors at different reaches in rabi season. The Jamuniya minor has

Table 5 : Depth of irrigation in different reaches for wheat, gram and green pea crops

Minor	Depth of irrigation (in cm)								
	Wheat			Gram			Green pea		
	Head	Middle	Tail	Head	Middle	Tail	Head	Middle	Tail
Jamuniya	18.0	19.25	23.0	7.2	7.7	9.2	15.6	17.1	21.6
Jhansi	26.5	20.5	24.75	10.6	8.2	9.9	25.8	18.6	23.7
Khulri	24.5	12.5	22.0	9.8	5.0	8.8	23.4	15.0	19.8

Table 6 : Wheat area intensity in different minors

Year	Jamuniya	Jhansi	Khulri	Avg.		
2003-04	4.87	26.94	52.30	28.04	S.E(m)	4.04
2004-05	7.54	24.24	48.16	26.65	S.E(d)	5.72
2005-06	15.53	25.93	57.20	32.89	C.D	13.16
2008-09	33.89	58.17	62.62	51.56	C.V	18.09
2009-10	35.53	63.4	64.8	54.58		
Total	97.36	198.68	285.08			
Mean	19.47	39.74	57.02			

Table 7 : Gram area intensity in different minors

Year	Jamuniya	Jhansi	Khulri	Avg.		
2003-04	51.50	53.65	31.16	45.44	S.E(m)	4.56
2004-05	39.51	50.41	34.57	41.50	S.E(d)	6.45
2005-06	62.29	49.40	28.28	46.66	C.D	14.83
2008-09	50.38	31.91	21.86	34.72	C.V	19.66
2009-10	49.38	27.35	20.93	32.55		
Total	253.06	212.72	136.80			
Mean	50.61	42.54	27.36			

Table 8 : Ratio of surface water and ground water (CU) in different minors

Year	Jamuniya	Jhansi	Khulri	Avg.		
2003-04	5.35	4.54	0.63	3.51	S.E(m)	0.60
2004-05	0.74	0.46	0.52	0.57	S.E(d)	0.85
2005-06	1.21	1.57	0.59	1.12	C.D	1.97
2008-09	1.81	0.64	0.51	0.99	C.V	76.43
2009-10	1.24	0.34	0.49	0.69		
Total	10.34	7.56	2.74			
Mean	2.07	1.51	0.55			

significant difference over Jhansi and Khulri minors when mean of minors are compared and also significantly different in mean of reaches. In case of reaches, only middle reach of Jamuniya minor is not significant and has the large difference over the all reaches.

Net farm return affected by conjunctive use

Table 11 presents the net returns obtained in various reaches of Jamuniya, Jhansi and Khulri minors. The mean values of farm returns ranged from ₹ 22324/ha to ₹ 26321/ha. There is no significant difference among mean returns of different

Table 9 : Comparison with SW: GW area and yield (q/ha) of wheat and gram

Minor	Jamuniya			Jhansi			Khulri		
Reaches	SW:GW	Wheat	Gram	SW:GW	Wheat	Gram	SW:GW	Wheat	Gram
Head	8.83	38.00	17.50	0.71	36.45	17.50	1.43	35.91	15.83
Middle	0.65	27.7	14.17	0.18	37.17	15.71	0.32	33.37	14.00
Tail	0.66	32.93	15.00	0.17	35.14	18.21	0.12	33.34	15.00

reaches as well as different minors. However, in Jamuniya minor command, the middle reach returns was minimum (₹16499/ha).

Table 10 : Depth of water table (m) in different minors and reaches in rabi season during 2010-11

Minor	Jamuniya	Jhansi	Khulri	Mean
Head	11.43	7.64	9.14	9.40
Middle	24.38	11.15	4.97	13.50
Tail	19.4	9.63	3.05	10.69
Mean	18.40	9.47	5.72	11.19
	Minor	Reach	Minor * Reach	
SEm±	0.441	0.441	0.764	
CD (P = 0.05)	1.438	1.438	2.492	

Table 11 : Net farm returns in ₹/ha from wheat crop in different minors at different reaches with conjunctive use

Minor	Jamuniya	Jhansi	Khulri	Mean
Head	25444.63	25905.73	27614.19	26321.51
Middle	16499.62	26527.11	23946.62	22324.45
Tail	25323.28	21967.3	26004.09	24431.56
Mean	22422.51	24800.05	25854.97	24359.17
	Minor	Reach	Minor * Reach	
SEm±	1737.46	1737.46	3009.37	
CD (P = 0.05)	5208.96	5208.96	9022.09	

Conclusions

The ground water irrigated area is more in tail ends than head reaches due to the reason of non-availability of canal water. Since the availability of surface water as compared to ground water in head reaches of all the minors was much higher, a marked difference was observed in yields of wheat and gram. Conjunctive use has distinct advantage in improving the cropping pattern, yield, production and water table.

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