CONJUNCTIVE USE OF SURFACE AND GROUND WATER FOR IMPROVING WATER PRODUCTIVTY IN COASTAL AREA OF ORISSA

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ABSTRACT

Groundwater being one of the most valuable resources of earth needs to be utilized properly for healthy and economic growth of any region. Present study on ground water and surface water use was carried out in Eastern part of India, where it is blessed with plenty of water resources but its utilization is very poor as compared to other part of India. Orissa, being one of the resource rich States in India still struggles with low crop production and cropping intensity status. The groundwater development of the State is only 18.31 % out of total replenishable groundwater resources of 21,00,928 ha-m.. The groundwater earmarked for irrigation is 16,78,038 ha-.m. For exploiting this quantity of groundwater during rabi season , ground water structure like open well and bore well is essential . Among 30 districts , groundwater development is maximum of 77.61 % in Baliapal block in Balasore district. This block is dominated with boro paddy(January to April/May), where the crop needs frequent irrigation water.

To exploit ground water and use during post rainy season, the district-wise as well as block-wise crop reference evapotranspiration was estimated with standard procedure (Penman Monteith 1998 , FAO56). The annual reference evapotranspiration of Orissa is 1658 mm, whereas total annual water supply through rainfall was 1492.8 mm. Thus there is annual water deficit of only 9.94 % (165 mm). Though the water availability through rain alone was sufficient to fulfill crop water demand for two-crop season, but due to its uneven distribution, the farmers of this state have been growing only one crop in most of the districts. As far as season-wise crop water demand and supply is concerned, on an average of all thirty districts, there was surplus of 106.55 % during wet season and deficit of 83.7 % and 76.9 % during rabi i.e.Nov. - March and April - May i.e dry season, respectively. During rabi and summer, the amount of rainfall was only 101.6 mm in 6.2 rainy days and 90.3 mm in 7.0 rainy days respectively, which is not enough to fulfill water needs of crop for more than fifteen days period . So it is important to make utilization of excess rainwater of wet season effectively. This excess water can be recharged in to the ground by various recharged techniques wherever it is feasible. This recharged groundwater can be further exploited during dry season i.e rabi and summer season and the cropping intensity and irrigated area can be increased as there is substantial deficit of water exists during rabi and summer season..

Considering low utilization of ground water in the state of Orissa, the ground water structures viz. bore wells and open wells were constructed on participatory mode during 2007- 08, and 18 farmers and 6-7 farmers were involved for exploiting ground water during rabi and summer season in Mahanga block of Cuttack district (coastal area) of Orissa. The result of 2009-10 presented on exploitation of ground water for growing two to three crops by the farmers. The results revealed that the availability of canal water was very much limited in tail reach farmers as discharge rate was 64.9 to 79.3 % less than head reach (0.699 to 0.775 cumec) which compelled to develop ground water structures on participatory basis and use during rabi and summer season.

Due to development of ground water structures, more numbers of the farmers have been benefited and they are now growing seasonal crops throughout the year without any depletion of ground water level as it remained at shallow depth (up to 2.73 m) during dry season (March-May) and at surface level during wet season. The economic return with two crops (paddy –brinjal) was maximum of Rs 90, 031/ha in open well command and Rs

92,187/ ha in bore well command area. Among all vegetable crops , the maximum water productivity was recorded in brinjal With the help of this structure, farmers have recovered the expenditure incurred in development of open well and bore well in first year itself. The cost benefit ratio was also very high with two crops as compared to one crop as most of the farmers were following before development of these structures.

INTRODUCTION

Groundwater is an important source of irrigation and caters to more than 45% of the total irrigation in India. The contribution of groundwater irrigation to achieve self-sufficiency in food grains production in past three decades is phenomenal. In the coming years, the groundwater utilization is likely to increase manifold for expansion of irrigated agriculture and to achieve national targets of food production. Although the groundwater is annual replenish-able resource, its availability is non-uniform with space and time. Hence, precise estimation and utilization in agriculture sector is a prerequisite for planning its development. In eastern states of India, the ground water development as on March, 2004 is only 18 % in Orissa, 21 % in Jharkhand, 39 % in Bihar, 20 % in Chhattisgarh and 42 % in West Bengal as compared to the national average of 54 %. In these states, rice is dominated and water exhaustive. However the productivity is quite low, though the amount of rainfall received is high as compared to other region of the country.

Orissa State lies within latitude 17^0 48' N - 22^0 34'N and longitude 84^0 24'E- 87^0 29'E. Out of total geographical area of 1,55,700 sq km, 1,18,800 sq. km area is suitable for groundwater exploitation (Anonymous, 2003). It has an annual replenish able net groundwater resource of 21,00,928 ha-m, out of which 1,22,126 ha-m is committed for domestic and industrial requirements for coming 25 years. The present demand for irrigation use is estimated to be 300901 ha.m(Pati, 2007). The area covered by hard rock and alluviums is 86444-sq.km and 32356-sq km, respectively. Major portion (about 85%) of state covered by hard rock area are normally compact and rendered groundwater bearing only when fractured and weathered.

With respect to rainfall status in this state , on an average of 50 years rainfall data (1901-1950) , the total rainfall received is 1492.8 mm rainfall in 73 rainy days. Out of this, 1295.7 mm (86.8%) is received during June- October, 98.6 mm (6.6%) during November to March and rest amount of 98.5 mm (6.6%) during April and May. However the annual crop evaporative demand is 1657.8 mm. This total annual crop evaporative demand (ETo) is more by only 11% over the rain fall received, but water supply through rain is highly erratic during different seasons. So to fulfill crop water demand during off season, it is highly essential to exploit ground water and improve cropping intensity and water productivity.

In coastal area of Orissa Sethi et al., (2002) made ground water balance model to estimate usable quantity of ground water in study area of 1066 sq. km (north latitude 21 ^{0} 27 ′ to 21 ^{0} 45′ 45″ and south longitude 86^0 56 ′ 15″ to 87 ^{0} 20′ 30″). They considered assessing optimal crop planning with linear model under various soil types, non –saline and saline ground water, irrigated and rainfed situation to make best use of available ground and surface water. The water balance model developed by them showed that additional water resources available is 400.84 Mm3(after withdrawing 255.03 M m3) for further use, is more than present demand due to more recharge from rainfall and base flow from river. In coastal area , though ground water is exploited during off season, it is again recharged with rain water and not depleted to that extent, as it occurs in other region of the country. This type of conjunctive use study of multi-sources and multi-quality water is being practiced in India and elsewhere to use the bad quality saline / alkali water for crop production and improve water use efficiency. Particularly in salt affected soils as well as the sodic water, the crop suffers due to excess salt, osmotic effect and specific ion effect in crop root zone (Kaledhonkar et al., 2001, Minas et al., 2004, , Rhoades et al.,1992 , Srinivasulu et al., 1997) .So application of such water by blending, alternate use with permissible limit is essential. Such type of irrigation water is available in northern region of India and it is followed in Punjab, Haryana and Rajasthan. In eastern region, only saline water exists but it is not being used intensively as sufficient quantity of good quality water is available for crop production.

Considering low utilization of ground water in the state of Orissa, the ground water structures viz. bore wells and open wells were constructed on participatory mode during 2007- 2008, and 18 farmers and 6-7 farmers were involved for exploiting ground water during rabi and summer season in distributor no. 5 of Patmundai canal in Mahanga block of Cuttack (Coastal) district of Orissa. The result of 2009-2010 are described on ground water and canal water use and improved the crop productivity in the selected command area.

MATERIAL AND METHODS

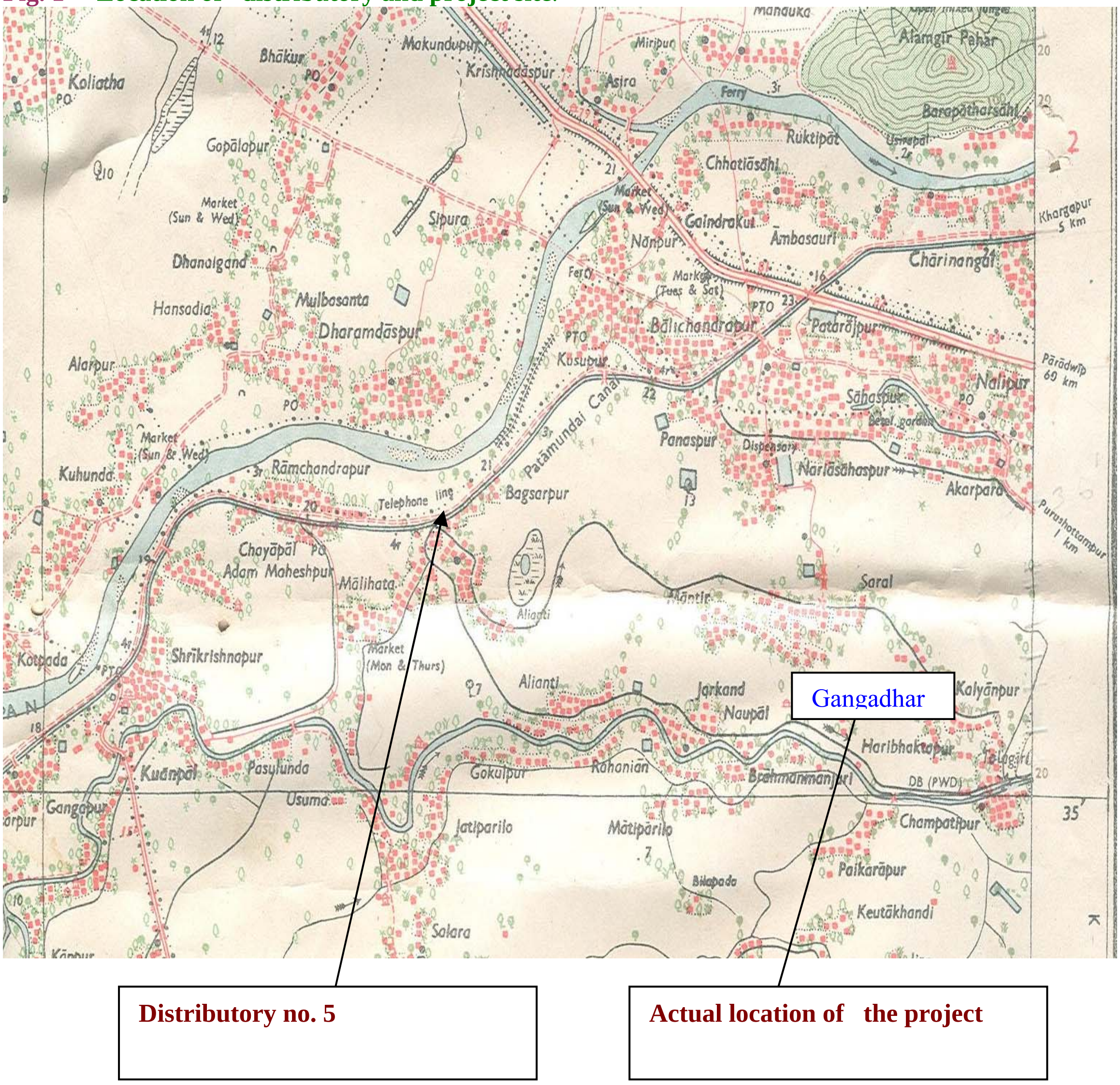
Location of Project:

The project was carried out in distributory no. 5 of Pattamundai canal command area (Mahanga block, Cuttack district) . Initially in this distributory, the water discharge rate was monitored at frequent interval during kharif and rabi season to assess actual availability of canal water for kharif and rabi crop and exploit ground water according to the need of crops grown in the command area. The actual design discharge of the dstributory is given in Table 1.

Table 1:- Details of Distributory no.5 of Patmundai canal

Name of distributory	Length, km	Design discharge, cumec	Outlet no.	CCA, ha)
No.5 a	5.56	0.386	34	272.353
No. 5b	5.59	0.738	39	388.903
No.5 b minor	2.76	0.08	8	92.673

Fig. 1 Location of distributory and project site.



General cropping pattern of selected distributory:

In the selected distributory (Mahanadi Delta I) about 12 villages are benefited by canal water but with varying magnitude as the distribution of canal water is erratic . The CCA of the distributory is about 752.929 ha. Rice is main crop of this area. In head reach and middle reach villages about 71 to 88 % area is occupied with kharif paddy and rest area is with jute, vegetable crops. But in tail reach villages the area occupied by *kharif* paddy is slightly less (54 to 74%) than middle and head reach villages. In such upland and medium land area in tail reach villages farmers are cultivating jute and vegetable crops and the area occupied by these two crops are to the tune of 6-13% and 13- 27% respectively.

After harvest of *kharif* crops, farmers are growing vegetable, pulses, and oil seed crops in the command area where irrigation facilities exists. In head reach villages, the major crops are green gram and black gram. The area occupied by these crops ranged from 22 % to 33%. In some of the villages, it was very low (4 to 8 % of the total cultivated area). The *rabi* ground nut was also dominated in this area and it was only 0.4% to 8.0% in different villages. In tail reach villages, green gram occupied 5 % to 49% of the cultivated area and black gram 7 % to 24% . These crops are grown on residual soil moisture due to non availability of canal water. The vegetable crops (tomato, brinjal) are also dominated and the area ranged from 9% to 50% of cultivated area.

General Climate of the Area during experimentation period:

The climate of summer season is hot and humid. The monsoon months are from June to October when the area receives most of its rainfall from the South West Monsoon. The winter season from November to February is characterized by mild temperatures and occasional showers. Temperatures may exceed 40°C during summer and may fall to below 10°C in winter.

During the experimental period, the water deficit was observed in the month of April –May 2009 and October 2009 to June 2010; however the magnitude of water deficit in these months varied considerably. The average monthly maximum and minimum temperature was 32.61^{0}C and 23.36 0C, respectively. The average relative humidity in the morning and evening was 90.88 % and 56.7 % respectively; the wind speed was 5.1 km /hr; bright sunshine was 5.96 hour per day and evaporation rate was 4.55 mm per day (fig. 2).

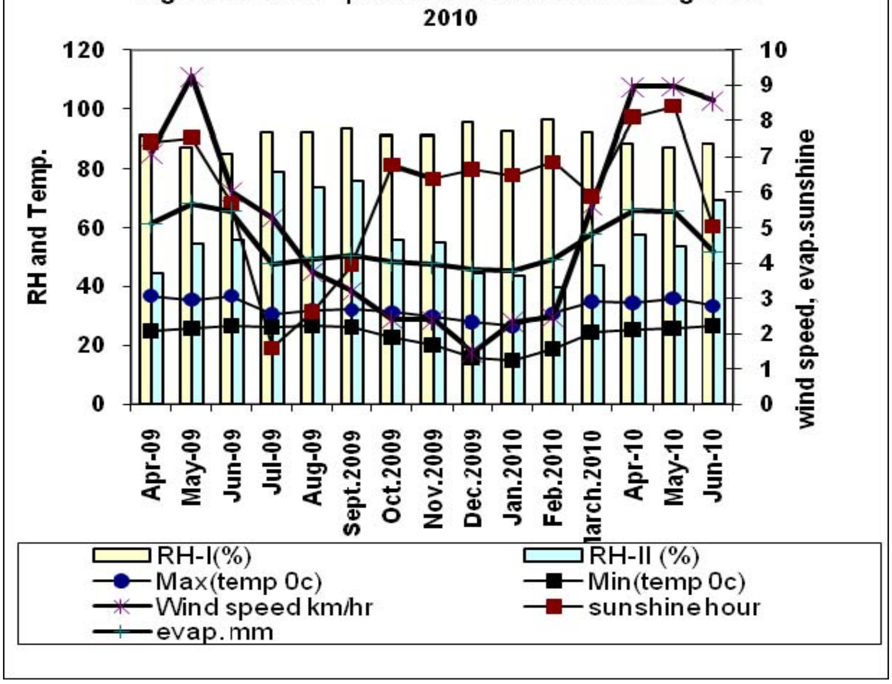


Fig. 2: Weather parameters observed during 2009-2010

Computation of Crop water Demand (Evapotranspiration):

For assessing crop ET demand of this command area, daily crop evaporative demand (reference evapotranspiration) for the period from April 2009- June 2010 was computed by Penman Monteith methods (FAO56) with meteorological data, which is widely adopted by irrigation engineers, agronomist and other researchers, engaged in planning and executing the programme for estimating crop water demand. Based on crop ET demand and the rainfall received and canal water discharge rate the availability of water was computed.

Water Productivity of command area:

Before initiation of the project, data on crop yield of different crops grown by the farmers in 12 villages were collected and economic returns were computed based on the price of the commodities and the expenditure incurred on cultivation of various crops. Thereafter the WP of different crops as per equation described by Dong et al.,(2001) were computed.

The WP per unit of evapotranspiration (WP_{ET}) is

= (mass of crop production /total mass of water transpired by the crop and lost from soil by evaporation).

i) The WP per unit of irrigation water is

= (crop production /irrigation water used)

ii) Based on net monetary return , the WP is

= (net return in Rs per ha/ crop ET or total water use in ha-m)

iii) Water use efficiency (WUE) as per irrigation agronomists it is

= crop yield/ total water use (irrigation + effective rainfall).

Monitoring of water discharge rate of distributory and ground water table

Every year the canal water is released in last week of July and it continues up to November first week for kharif paddy transplanting. During rabi season it is released in the month of January second week and continues up to February end. During our experimentation period, the discharge rate of canal water was measured at periodic interval. The ground water table fluctuation data of 61 observation wells were also monitored frequently and analyzed for its influence on water table depth for further irrigation during canal off period.

RESULT AND DISCUSSION

Water availability of canal water during kharif and rabi season 2009-2010

The canal water was released on 17.7 2009 and it was continued up to 15.11.2009. On an average of five observations on discharge rate of water, the discharge rate at head reach was 0.775 cumec in distributory 5 a, 0.699 cumec in 5b and 0.225 cumec in minor of 5 b. The flow rate was reduced as the distance from head reach increased. But at tail reach, the flow rate was very low even during August and September 2009. This clearly shows that the reduction in flow rate at tail reach is very high and it ranges from 8.5 % at 0.2 km away from main outlet to 79.3% at 5 km away from main outlet. In distributory no. 5 b and minor of 5 b, the reduction in flow rate ranged from 32.6% at 1.5 km away from main outlet to 64.9% at 4.5 km away from main outlet.

During *rabi* season the water was released on 12.1.2010 and closed on 27.2.2010.The total duration of water flow in distributor was 46 days. The flow rate on an average of three observations were 0.715 cumec at head reach and 0.090 cumec at 5km away from head reach in distributory no.5a and 0.735 cumec at head reach and 0.315 cumec at 4.5 km away from head reach in distributory no. 5 b. In minor of 5 b, it was only 0.218 cumec. Thus there was substantial reduction of flow rate in both the distributory as compared to head reach and the extent of reduction was 3.2% at 0.2 km away from source of outlet to 83.3 % at 5km away from source in distributory no. 5a and 24.4 % at 1.5 km to 47.2 % at 4.5 km away from source in distributory no.5b. In minor of 5 b, the reduction in flow of water was 55.7 %.

Water available from rainfall and water demand

During June to November, the crop water demand was only 553.4 ha-m. The water available through rainfall during above period was 1326.0 ha-m and through canal water at head reach it was 810 ha-m in distributory no. 5 a, and 669.1 ha –m in distributory no.5 b during canal operation period. However in tail reach, the availability of water was quite low i.e 166.2 ha-m and 223.7 ha-m in respective reaches.

During winter and summer season, the crop water demand was 535.6 ha – m and water available through rainfall water was only 114.1 ha-m. However the water available through canal operation period of 46 days was 284.2 ha –m in distributory no.5 a and 120.7 ha-m in distributory no.5 b at head reach point. At tail reach it was very low.

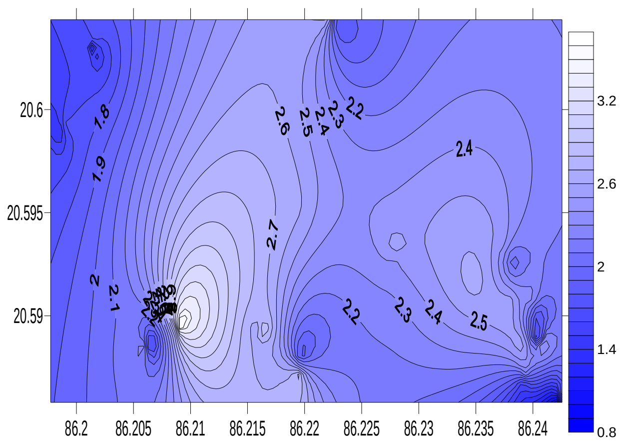
Ground water Fluctuation:

The groundwater fluctuation data of whole command area (61wells) comprising 12 villages was analyzed and categorized as pre-monsoon (March- May2009), monsoon (June- October2009), and post monsoon (November 2009-February 2010). The data on groundwater fluctuations showed that the groundwater table during the month of May was at deeper depth, thereafter due to receipt of rainfall and release of canal water, the groundwater table remained at shallow depth. During the post monsoon season also the groundwater table depth was at shallow depth because of release of canal water in the month of January 2010 and continued up to February 2010 (Table 2).

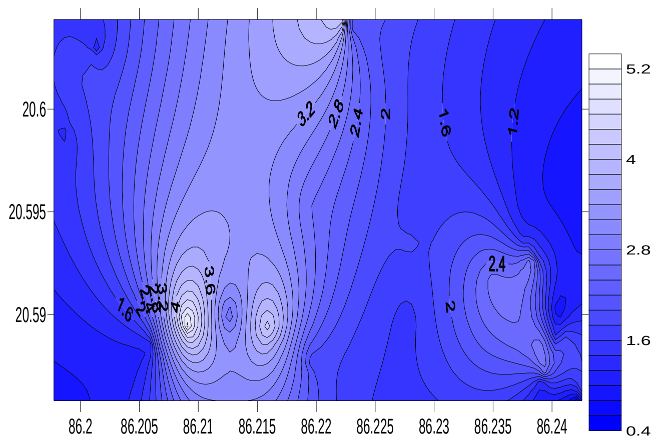
Table-2:- Statistical analysis of water table depth

Parameters	2009-2010		
	Mar-May (Pre-monsoon)	June-Oct (Monsoon)	Nov-Feb (Post monsoon)
Mean	2.73	2.10	2.08
Maximum	5.02	3.58	5.26
Minimum	0.61	0.69	0.26
SD (m)	0.95	0.61	1.02
CV %	34.8	29.1	49.0

Fig- 3. Contour map of groundwater table depth during monsoon periods



Water table fluctuation during June 2009-October 2009



Water table fluctuation during November 2009-February 2010

Water Productivity of Command area:

From each village, the yield data of *kharif* and *rabi* crops were collected and water productivity of important crops were computed by dividing crop yield and net return with crop ET. In this area farmers are cultivating paddy (high yielding, and local varieties), vegetables (turmeric, chilli, and gingers) during *kharif* season in upland area. The result presented in Table 3 revealed that in case of high yielding paddy varieties, the water productivity is 0.70 kg/m^3 ET, but in low yielding normal paddy it is only 0.50kg/m^3 ET crop. In vegetables, the yield potential is as high as 8.1 t/ha and hence the water productivity is as much as 4.14 kg/m^3 of ET crop. In other high value cash crop (turmeric, chili, and ginger), the water productivity is also very low due to very low yield. The WP was maximum in vegetables followed by ginger. In term of net return, the water productivity was maximum in vegetables.

Table 3: Water productivity (WP) of kharif crop

Crop	Yield, kg/ha	ET Crop, mm	ET Crop	WP based on yield	WP based on Net return	
					Net return	Rs/m^3 of ET

			m^3/ha	and ET (kg/ $m^{3)}$	(Rs /ha)	
H Y Paddy	2801.00	399.20	3992.00	0.70	5668	1.41
local paddy	1557.50	309.61	3096.10	0.50	2966	0.95
Vegetables	8100.00	195.54	1955.40	4.14	11075	5.63
Turmeric	777.50	540.95	5409.50	0.14	22000	4.07
Chilli	803.33	217.37	2173.70	0.37	14813	3.11
Ginger	1104.28	540.95	5409.50	0.20	25193	4.66

After harvest of paddy and other high value kharif crops , the farmers were taking *rabi* crops through supplemental irrigation from canal as well as from irrigation structures like open well, shallow tube wells . In rabi season majority of the farmers were growing *rabi* crops on residual soil moisture and harvesting very low crop yield. Based on crop yield data of the villages and crop ET, the water productivity of sugar cane, sweet potato, potato, garlic, onion, vegetables was very high as compared to oil seed and pulses crop. Some of the farmers had grown paddy crop and produced good crop yield (2789kg/ ha) from 334 mm of crop ET and hence water productivity was 0.84 kg/ m^3 of ET as compared to *kharif* paddy in which it was 0.50 and 0.7 kg/ m^3 crop ET. The WP during rabi season was highest in vegetables followed by garlic. Based on net return , water productivity was maximum in vegetables followed by garlic.(Table 4)

Table 4: Water productivity of rabi crops

Crop	Yield, kg/ha	ET crop, mm	ET crop m^3/ha	Water productivity (kg/ m^3)	Net return (Rs/ ha)	WP based on net return (Rs/m^3 of ET)
Groundnut	1215	248.24	2482.4	0.49	6248	2.52
Sugarcane	71000	836.53	8365.3	8.49	17250	2.54
Sweet potato	8550	238.11	2381.1	3.59	7150	3.10
Potato	9650	228.05	2280.5	4.23	6950	3.04
Onion	4862.50	238.09	2380	2.04	10514	4.43
Vegetable	9837.50	248.30	2483	3.96	18948	7.52
Chilli	780.00	232.11	2321	0.34	17000	3.01
Corriander	600.00	227.96	2279	0.26	6200	2.72
Garlic	2462.50	235.90	2359	1.04	13812	5.85
Paddy	2789.23	333.96	3339	0.84	2830	1.62
Maiize	859.00	231.94	2319	0.39	5326	1.07

Water Productivity In Open Well And Bore Well Command Area After Experimentation*:*

a) Construction of bore well and open well for exploiting ground water

The open well with diameter of 3 m and total depth of 6.65 m was constructed during 2007-2008. The total expenditure for developing ground water structure including capital cost in case of open well was Rs 33600.00. It included the cost of cement concrete ring and labour cost , 2 Hp electric pump and 2 % annual maintenance cost . In case of bore well, total expenditure including capital investment and maintenance cost was Rs 23918.00. After development of groundwater structures at project site (tail reach), irrigations through open well, bore wells were given as per schedule during *kharif*, *rabi* and summer season of 2009-2010.The experimental results on irrigation requirement, water use efficiency, water productivity, and overall economic return obtained by the farmers is summarized here.

Crop performance and economic returns of different crops:

During 2009-10 in total command area of 3400 m^2 different vegetables as well as one oilseed crop was grown after *kharif* paddy crop The short duration varieties i.e. *Satabdi* and *Khandagiri* was grown in open well command area during June 18 to October 11, 2009 under rainfed situation by broadcasting method as the farmers have been adopting since long before introduction of the project work. During above period in case of paddy, the ET crop was 464.03 mm and reference ETo was 454.59 mm. Since the soil profile was saturated with heavy rains most of the received rain water was not effective.

The data on crop yield and economic return revealed that there was rice grain yield of 2960 kg/ha (irrespective of crop varieties followed). However the variety Satabdi performed better than Khandagiri (Table 4). The net return from the paddy crop during *kharif* season was Rs. 11186/ha.

After harvest of *kharif* paddy crop, the different vegetable crops were grown and used open well water. The result showed that out of all vegetable crop, the brinjal gave maximum return of Rs. 78,845/ha (Table 5) followed by onion (Rs 55455/ha). The brinjal vegetable crop is very much common and most of the farmers are growing extensively in their field where irrigation facility is available with them. After harvest of radish and potato crop, being short duration, bitter gourd crop was taken in 440 m^2 area during February 2010 -June 2010. The bitter gourd yield was 4300 kg/ha with net return of Rs. 32060/ha.

Regarding irrigation requirement of crops, water use efficiency and water productivity, underground tuber (vegetable) crops as well as tomato had more water use efficiency, water productivity during *rabi* season. Among all vegetable crop brinjal had also high water use efficiency, when ETo, ET crop as well as irrigation + effective rainfall is taken for consideration. With respect to WP against the net return, obtained under various crops grown , the maximum WP was observed in case of brinjal followed by onion(Table 6).

The irrigation schedules were followed in different vegetable crops as per IW/CPE ratio. However for reference the irrigation schedule followed in brinjal crop is given in fig. 3

Table 5: Crop performance under open well command area (open well)

Open well	Crop name	Crop yield (kg/ ha)	Gross return Rs / ha	Total Expenditure Rs/ ha	Net return Rs / ha
Kharif crop	paddy	2960	28416	17230	11186
Rabi season crops	Raddish	19750	49375	19350	30025
	Potato	13100	78600	35078	43522
	Tomato	22750	91000	42350	48650
	Brinjal	16485	115395	36550	78845
	Chilli (dry)	1770	88500	37330	51170
	Onion	8345	91795	36340	55455
	G.Nut	2315	64820	31450	33375
Summer crop	Bitter gourd	4300	60000	27340	32860

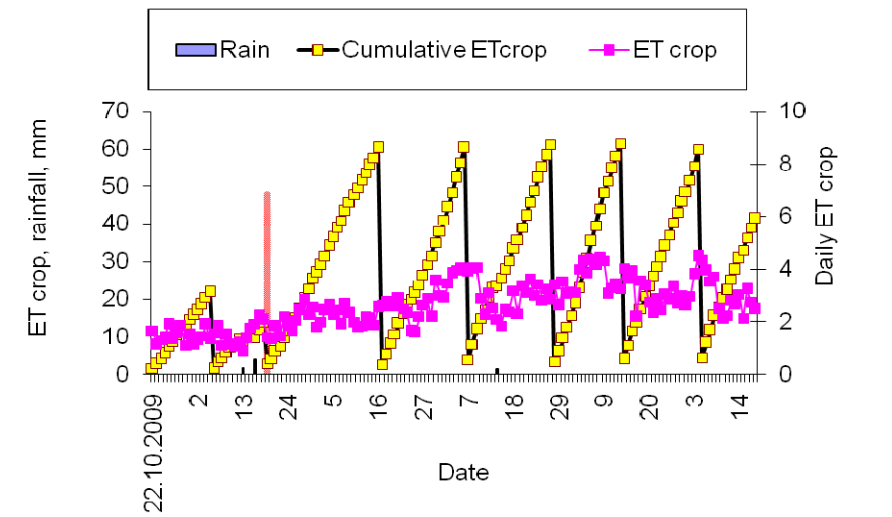
Table 6: Irrigation scheduling and water requirement of different crops under open well command area

Crops	ET0 mm	ET crop mm	Rainfall mm	Irrigation + effective rainfall mm	Water use efficiency (kg/ha- mm)			Water productivity (kg /m^3)		
					ET0	ET crop	I+ER	ET0	ET crop	I+ER
***Kharif* Rice**	454.59	454.59	1403.5							
***Rabi* crop**										
(Raddish)	320.35	239.53	53.6	319.6	61.65	82.45	81.8	6.2	8.25	6.10
Potato	379.87	294.31	53.6	363.6	34.48	44.51	36.02	3.45	4.45	3.06
Tomato	451.33	395.41	53.6	503.6	50.40	57.53	45.2	5.04	5.75	4.52
Brinjal	492.32	385.80	53.6	523.6	33.48	42.82	30.25	3.35	4.30	3.27
Chilli	431.31	346.40	53.6	484.91	4.10	5.11	3.65	0.41	0.51	0.41
Onion	391.37	347.50	53.6	433.60	21.32	24.02	19.25	2.13	2.40	1.92
G.Nut	421.25	373.92	53.6	473.60	5.50	6.16	4.88	0.55	0.61	0.49
Summer crops										
Bitter Gourd	495.7	392.7	53.6	507.6	4.64	5.86	4.54	0.46	0.59	0.45

Table 7: Water productivity based on net return of open well

Crops	Water productivity (Rs /m^3)		
	ET0	ET crop	I+ER
***Kharif* Rice**	2.46	2.46	-
Rabi crops			
Raddish	9.37	12.54	9.37
Potato	11.40	14.79	11.97
Tomato	10.78	12.30	9.66
Brinjal	16.01	20.40	15.05
Chilli	11.86	14.77	10.55
Onion	14.17	15.96	12.79
G.Nut	7.92	8.93	7.05
Bitter Gourd	6.63	8.37	6.47

Fig.3: Irrigation schedule and ET crop of Brinjal during 2009-10



Cropping pattern followed in bore well command:

During *kharif* season in this bore well command area, total six acres and eighteen farmers were selected for demonstration. They had taken high yielding long and medium duration rice varieties Moti (long duration),Naveen & Swarna (medium duration) during *kharif* season of 2009. They used bore well water for nursery and subsequent irrigation were also provided to nursery crop. Canal water was available during August 2009 to November 2009. During August 2009, the canal water discharge rate was only 0.15 cumec, which was not sufficient to take paddy transplanting. They were dependent on rainfall for transplanting of the rice seedling before inception of the project. Sufficient amount of canal water was also not available during long dry spell of 5.10.2009 to 4.11.2009. The rainfall was only 7.8 mm during above period. The crop ET demand during above crop growth period was 114.4 mm. On 12 th November again there was 48 mm rainfall, which helped the farmers to save their long duration paddy crop. During 1.7.2009 to 1.11.2009 the total rainfall was 1291.5 mm, which was dominated during first three months period (July, August September) but during milk and dough stages, the rainfall was meager and hence some farmers irrigated their field crop during October month and saved their crop from moisture stress.

During the dry spell period i.e. 5.10.2009 to 4.11.2009, only seven farmers irrigated their field crop, one to three times with total depth ranged from 8.3 cm to 18.5cm but rest of the farmers did not irrigate and hence their crop was suffered due to lack of irrigation water and rice grain yield reduced considerably.

With the result of supplemental irrigation to paddy crop (long duration variety ***Moti***), the farmers harvested maximum grain yield of 4624 kg/ ha with maximum net return of Rs22,848/ha. But the same variety grown without irrigation during dry spell period, the grain yield was 3727 kg/ha with less return. Similar situation was observed in remaining two varieties.

Table:8 Performance of paddy crop under irrigated and un irrigated situation

variety	**2009-2010**			
	Yield (kg/ha)	Expenditure (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)
Irrigated				
Moti	4624	23149	45997	22848
Naveen	4223	20038	43209	20871
Swarna	4311	19800	41375	21575
Rainfed				
Moti	3727	19570	37021	17451
Naveen	3638	17995	34556	16561
Swarna	3444	18406	33057	14651
CD(p=0.05)	124	1780	2368	2701
CV %	2.6	7.4	5.2	12.2

(b) Rabi season crops :

After harvest of paddy crop, farmers had taken tomato, potato , brinjal, bhendi crops. Irrigations were provided through tube well water as per irrigation schedules. These vegetable crops were taken in field where medium duration variety ***Naveen*** were grown. The crop yields of potato was 18350 kg /ha with net economic return of Rs 28280 per ha. In case of tomato (Hybrid) the crop yield was 15670 to 17750 kg/ha with net return of Rs 26560 to 34110/ per ha . Among all vegetable crops, brinjal crop gave more profit (Rs 75270 per ha) followed by bhendi (Rs 57780/ ha.) So with rice based cropping system having bore well water two hundred cropping intensity with high value cash crop can be taken up provided market facility exists. Because some of the perishable vegetable crop cannot remain for longer period (Table 9).

Table- 9: Rabi season cropping pattern and economic return

Sr no Farmers	Crop name	Crop yield (kg/ ha)	Total Expenditure (Rs per ha.).	Gross return (Rs per ha.).	Net return (Rs per ha.).
1)	Tomato	17750	36890	71000	34110
2)	Bhendi	8430	36950	94730	57780
	Brinjal	15650	34280	109550	75270
	Tomato	15670	36120	62680	26560
	Potato	18350	45120	73400	28280

Benefit cost ratio of open well and bore well irrigated command:

The total expenditure for developing ground water structure including capital cost in case of open well was Rs 33600.00. It included the cost of cement concrete ring and labour cost , 2 Hp electric pump and 2 % annual maintenance cost . In case of bore well, total expenditure including capital investment and maintenance cost was Rs 23918.00.

a) Open well command

In 1400 m^2 area, different rabi and summer crops were taken after harvest of rice crop, rice + brinjal was quite beneficial and benefit cost ratio was high (BC ratio 3.76) . When three crops were taken, after short duration rabi crops like potato and radish, the BC ratio was high (3.66) in rice+potato+ bitter gourd. However as compared to paddy + brinjal , the BC ratio was slightly less as brinjal crop was kept for longer duration and frequent irrigation even during summer months gave good crop yield. With the result, market price was comparatively higher and fetched goods market price.

Table 10:Benefit cost ratio under open well irrigation command

Open well	Crop name	Net return Rs / ha (2009-10)	BC ratio 2009-10
Total kharif paddy area and *rabi* area 1400 m^2	Paddy(*kharif*)	11186	0.47
	radish (*rabi*)	30025	1.26
	Potato (*rabi*)	43522	1.82
	Tomato(rabi)	48650	2.03
	Onion (rabi)	55455	2.32
	Bitter gourd (summer)	32860	1.37
	Brinjal (rabi)	78845	3.30
	Chilli(rabi)	51170	2.14
	Ground nut (rabi)	33375	1.40
Crop sequences And net return	Rice +radish	41211	1.72
	Rice +potato	54798	2.29
	Rice+tomato	59836	2.50
	Rice+onion	66641	2.79
	Rice+brinjal	90031	3.76
	Rice+radish+bittergourd	74071	3.10
	Rice+potato +bitter gourd	87568	3.66

b) Bore well command

In bore well command area, maximum benefit cost ratio was recorded in rice brinjal cropping system , because brinjal crop was continued by the farmers till onset of monsoon and during summer season the market rate of brinjal was very high . Hence this system could gave best return to the farmers(Table 11)

Table 11: Benefit cost ratio under bore well command during 2009-10

Bore well	Crop name	Net return Rs / ha (2009-10)	BC ratio 2009-10
Kharif and rabi crops	Paddy *kharif*) (Naveen)	16917	0.71
	Tomato (rabi)	34110	1.43
	Bhendi (*rabi*)	57780	2.42
	Brinjal (*rabi*)	75270	3.15
	Potato (rabi)	26560	1.11
Crop sequences	Paddy + tomato	51027	2.13
	paddy +bhendi	74397	3.11
	paddy +brinjal	92187	3.85
	Paddy + potato	43447	1.82

DISCUSSION

Water is the most important natural resource for all economic, social development and eradication of poverty and hunger. At global level irrigated agriculture withdraws 70% of total water but in Asia the irrigated agriculture withdraws 90% of total available water (Seckler et al. 1998). The Multiple uses of water i.e. for domestic, crop production, aquaculture can improve water productivity and reduce poverty. Hence there is a need for proper understanding and to greater in-depth knowledge about the linkages between water management activities and aquatic ecosystems ((Meinzen-Dick and van der Hoek, 2001 and Bakker and Matsuno, 2001).

Ground water uses in conjunction with surface water without depletion of ground water resources has becomes a big challenges to keep water balance at stable condition in future as in some of the states like Punjab, Haryana, have over exploited and used ground water intensively. The ground water development in March, 2004 in Punjab, Haryana and Rajsthan was 145 %, 125 % and 109 % , respectively as against national average of 58 % (CGWB, 2004). This is primarily due to high cropping intensity. To avoid such problem, considerable attention has been given on over exploitation of ground water and problems of salinity even at national and global level.(Cummings and Winkle 1974, Khepar and Chaturvedi, 1982 , Panda et al., 1985, Hallaji and Yazickigil, 1996). Similarly to make best use of both surface and ground water, number of simulation and optimization model has been developed to optimize reservoir water with single crop (Kumar and Pathak 1989, Vedula and Majumdar, 1992). Rao et a.,(1990) developed a model for weekly irrigation scheduling policy for two crops for both seasonal and intra seasonal water demand and optimize available water resources for crop production and improving water productivity

Multiple Use of water in Eastern Region of India:

Multiple uses of water are gaining lot of importance in villages and poor farmers. This particular work has been taken in eastern region under watershed area, canal water command area and in farm pond by harvesting rain water in field itself and stored in low lying area/ waterlogged area for its utilization during off season. During rabi or non rainy season where sufficient canal water or harvested rain water is not available then the farmers are pumping ground water and keeping the water level at suitable depth in pond at constant head and using for various enterprises. For example in Bihar multiple use of water was implemented by routing pumped irrigation water through secondary reservoir, where water was stored up to a desired capacity for aquaculture and then released in desired stream size for irrigation purpose(Khan 2010). Three multiple water use based farming systems namely secondary reservoir fed by canal seepage, fish trenches-cum-raised bed and rice-fish culture using nylon pen under seasonally waterlogged lands in Patna main canal were undertaken (Sikka et al.2010).

a) Benefit from Fish , rice , horticultural crop

At Patna(Bihar)secondary reservoir with horticulture on embankment s gave highest gross income as well as net income followed by fish in secondary reservoir alone. Net income from fish in the secondary reservoir with horticulture on dykes was Rs 132590 per ha per year. Fruit crops contributed 56% followed by fish (27%) and vegetables (17 %). Net income gained from fish alone in secondary reservoir was Rs 93550 /ha /year and the entire amount came from fish production. Net income from this system was Rs 80951/ha/year . Out of which 54% was contributed by fruit crops, vegetable 22% and fish 24 % . These systems were compared with traditional rice-wheat system where net income was Rs 27965 per ha per year. Increase in net income was highest (374.13 percent) in case of fish in dugout pond and horticulture on dykes. Increase in net income over rice wheat system was 6.18% in rice-wheat system with fish refuse at the center, 189.47 percent in fish in sunken trenches with horticulture on raised beds, and 234.53 percent in fish in dugout secondary reservoir. Water productivity (return in rupees/cubic meter of water used) of secondary reservoir with water exchange ranged between 3.74 to 15.2 where as in control pond without water exchange it ranged between 10.3 to 14.4. In the trenches water productivity values ranged between 1.5 to 6.51.

b) *Multiple use of water in West Bengal*:

In the Gangetic flood plain of Indian state of West Bengal, wetlands are used as multiple systems and have significant impacts on livelihoods of the local people(Mukherjee, 2008).The study showed that the people living in the surrounding area of wetland derive the major economic benefits from wetland cultivation, direct irrigation, jute retting, and fisheries. The most important benefit was the direct use of ground water during dry period and harvest maximum return from the system

c) *Multiple use of water and WP in Orissa*

The technology of multiple use of canal water was demonstrated at Water Technology Centre for Eastern Region at Bhubaneswar, (Srivastava et al.2004), where a 2510 m^3 service reservoir was constructed in such a way that water can be applied through gravity to a command of 1.9 ha under drip and 2.8 ha under sprinkler irrigation. In another set of run -off water harvesting structure multiple water use was demonstrated with the integration of fish in the ponds and raising horticultural crops on the embankments. It was reported that service reservoir could be used for multiple use and the annual cost of the pond could be recovered by growing papaya in the bund and fish in the pond. With the integration of ducks and intensive vegetable cultivation on outward slopes of the embankment, the total cost of the system inclusive of drip and sprinkler can be recovered from multiple uses of reservoir itself.

In our present study, the water productivity in open well and bore well command area with two crops was quite high as compared to one crop as most of the farmers follows due to inadequate water supply. In case of rice brinjal cropping system , the water productivity was high and the benefit cost ratio was 3.85 in case of bore well and 3.76 in case of open well command area. The water productivity with individual crop was also improved due to better irrigation water management practices followed during rabi and summer season as compared to the survey data collected from 12 villages of the selected distributory. In selected distributory , the WP in high yielding variety was Rs 1.41per m^3 crop ET and in vegetable crops it was Rs 5.63 per m^3 crop ET.

In our present study, the ground water was used during non rainy period without declining ground water table. In the command area even during summer season, it was within 6-7 meter depth and it was fully recharged during each rainy season and during canal operation period. During our experimentation, the farmers used ground water to the extent of 20% of crop water demand during dry spell period and improved crop yield significantly. During rabi and summer season, the ground water was used effectively in vegetable crops and improved crop yield as well as water use efficiency as effective irrigation practices were followed in both open well and tube well irrigation command. Similarly, the ground water table was not declined due to continuous use of open and bore well. So the experimental result can be used on large scale in coastal belt area where recharge is quite high.

Conclusion and recommendations :

In general the canal command area's irrigation water demand and supply does not match with respect to quantity, timeliness and space. It results in delayed field operation; crop also suffers due to moisture stress. The problem is more serious in the tail reach of the canal system.

The finding of present study could be used to utilize groundwater in conjunction with canal system to enhance the crop productivity, crop intensity and multiple use of irrigation water. The developed ground water structures like open well and bore well has helped the farmers to grow rabi and summer crops as well as provided irrigation water to rice crop during dry spell period.

Suggestion for further work:

In canal command area where the tail reach farmers are not receiving sufficient canal irrigation water in proper time, it should be regulated from the tail reach by closing all authorized/ unauthorized outlets. In this coastal belt of Orissa, ground water is available at shallow depth, and in ample amount, the number of wells may be increased to increase command area under irrigation. As far as possible the farmers should use low horse power pump , to avoid any sea water intrusion. As land holding of farmer is less, they should use all ground water structures on share basis. They also should develop further ground water structures on participatory mode to avoid further expenditure. Electrical networking in rural area is highly essential to use electrical pump for irrigation as kerosene or diesel operated pump is expensive. Under developed small reservoir, rice- fish – vegetable combination could be effectively to maximized water productivity of the system. The major findings of the project could be utilized by the concerned state agencies for its larger dissemination to the farmers. .

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