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FINAL REPORT

EFFICIENT USE OF WATER FOR INCREASINGCROPPING INTENSITY THROUGH CONJUNCTIVE USE PLANNING IN COASTAL TRACT OF ORISSA

BY

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DECTORATE OF WATER MANAGEMENT
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BHUBANESWAR (ORISSA)-751023

FINAL REPORT

Title of the scheme: **EFFICIENT USE OF WATER FOR INCREASING CROPPING INTENSITYT HROUGH CONJUNCTIVE USE PLANNING IN COASTAL TRACT OF ORISSA.**

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FINAL REPORT (2006-07 to 2009-2010)

A) Salient features of the scheme

1.	Name and Address of the Institute:	Directorate of Water Management, (formerly Water Technology Centre for Eastern Region) SE Rly Project P.O. Chandrasekhapur, Bhubaneswar - 751023 Orissa
2.	Name and address of PI and other Investigators:	**PI: Dr. R. B. SINGANDHUPE** **Associates:** 1) Mrs R.R.Sethi (Soil and Water Cons. Engg) 2) Dr. H. Chakraborty (Soil Physics) 3) Dr. R.K. Mohanty (Fishery) 4) Dr B.K. James (Soil and Water Cons. Engg) 5) Dr Ashwani Kumar (Soil and Water Cons. Engg)
3.	Title of the scheme:	EFFICIENT USE OF WATER FOR INCREASING CROPPING INTENSITYT HROUGH CONJUNCTIVE USE PLANNING IN COASTAL TRACT OF ORISSA.

4) Financial details:

i) Sanctioned cost:	Rs 18, 92. 000.00
ii) Amount released:	Rs 12, 89, 000.00
iii) Expenditure:	Rs. 15, 52, 369.00*
iv) Unspent balance	(-) Rs 2, 63,369

* It includes Rs. 3.00 lakh as institutional charges sanctioned with the project.

5) ORIGINAL OBJECTIVES AND METHODOLOGY AS IN THE SANCTIONED PROPOSAL:

OBJECTIVES:

1. To assess the existing available water resources for planning the best use of surface water during *kharif* season
2. To exploit groundwater during *rabi* and summer season for increasing cropping intensity through high value cash crop.
3. To monitor the changes in groundwater quality, drawdown due to three hundred percent cropping intensity.
4. To optimize the best use of water and to analyze water productivity through multiple use of water in the developed system.

METHODOLOGY

a) Site selection and cropping pattern followed

Canal command area in Mahanadi Delta I of Cuttack district, Patmundai canal , distributory no.5.

b) Irrigation source:

(i) Rainfall,

(ii)Canal operation period is mid July to October 15 every year during rainy season and mid - January to February end during rabi season for green gram and black gram.

iii) Cropping pattern: Rice followed by green gram, black gram on residual soil moisture at middle and tail reaches. In head reach the farmers receive canal water for both pulse crops.

c) Assessment of surface water:

(i) Monitor the canal operation period and amount of water released during different months.

(ii) Assessment of Crop water demand in the command area.

iii) Optimize the irrigation water in kharif rice crops

d) Selection of sites and construction of water reservoirs and groundwater structures

Use of groundwater for high values cash crops through ground water structure

Conjunctive use planning: Irrigation through canal water during canal operation and groundwater will be pumped during off-season. Small reservoir /pond will be prepared and rice –fish integration practice will be followed. Optimum water level for fish will be maintained through bore well water. After harvest of rice crop, vegetable crops will be taken to optimize irrigation schedule and increase water use efficiency in vegetable crops. Summer crop after harvest of rabi crops will be grown if sufficient time period is available

e) Monitoring the draw-down and groundwater quality during the cropping period.

f) Physico-chemical properties of soil before crops and after crops to assess any changes in nutrient status of soil.

6: ANY CHANGES IN THE OBJECTIVES DURING THE OPERATION OF THE SCHEME

The project work was carried out as per approved objectives only.

7. ALL DATA COLLECTED AND USED IN THE ANALYSIS WITH SOURCES OF DATA

During the course of study all required secondary and primary data has been collected and analysed for completing approved objectives of the project.

I) DETAILS OF THE PROJECT SITE:

Secondary data:

The information on design discharge rate , scheduling of canal operation was collected from irrigation department (Govt. of Orissa) . The project area is selected in distributory no. 5 a (CCA 272.353 ha), 5 b (CCA 388.903 ha) and minor of 5 b (CCA 92.673 ha) with total **command cultural command area (CCA)** of 753. 929 ha of Patmundai canal in Mahanga block of **Cuttack district** (Orissa). In this command area, rice is the major *kharif* crop followed by green gram and black gram. For irrigation, canal is operated during July to October/ November every year for major *kharif* rice crop and between January to February during *rabi* season for green gram and black gram. The Design discharge and location of the distributory is given Table 1 and Figure no. 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
Total CCA				753.929

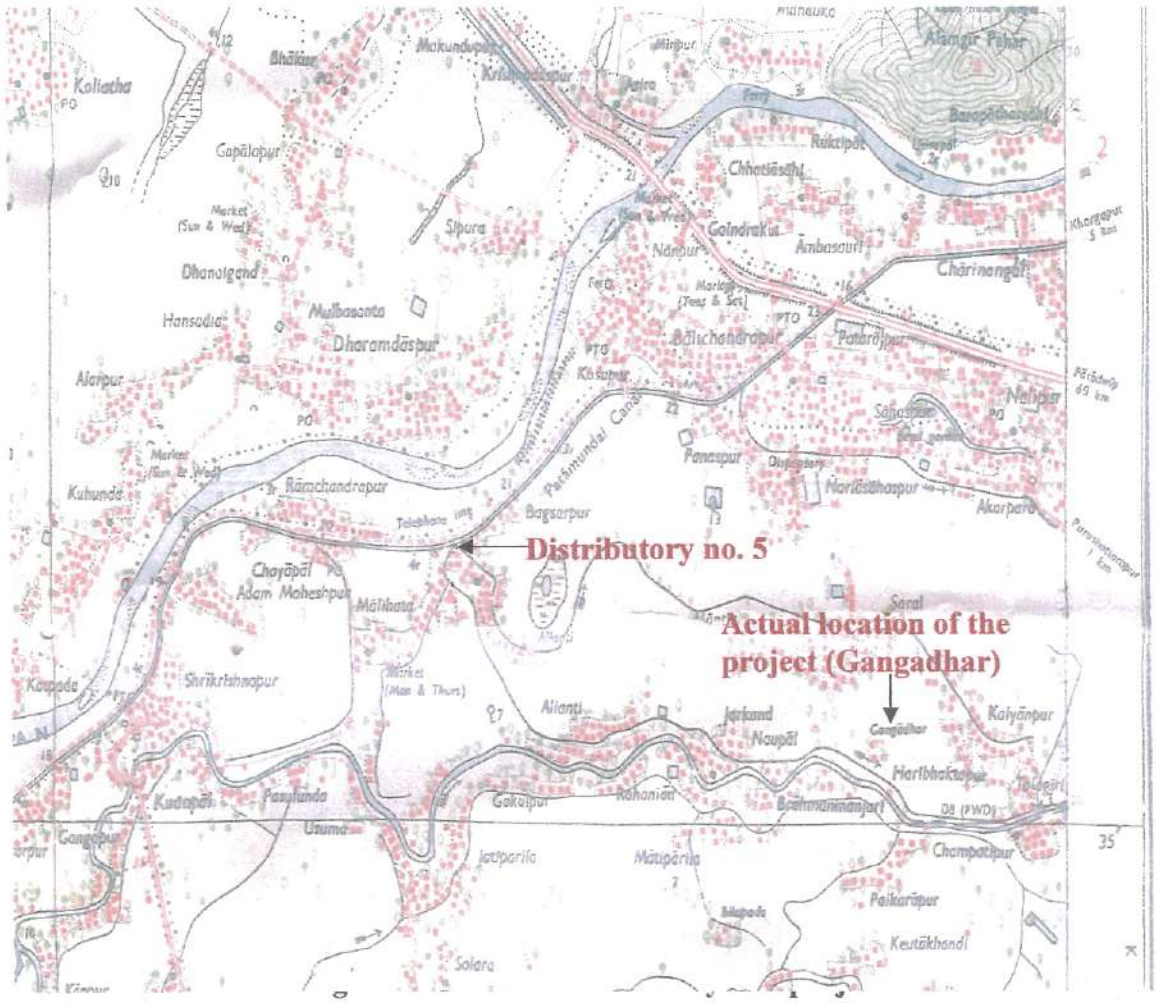


Fig. 1 Location of the distributory

. ***Ecosystem of command and un –command area***

In 12 villages irrigation through canal water is provided in 749.929 ha area out of total 1173ha cultivated area. Out of this 1173ha area about 165 ha area is high land, 535 ha area is medium land and 473ha area is lowland (Fig. 2 a, b). In head reach and tail reach medium land is occupied with maximum area, however low land area are maximum in middle reach because of depression in land topography. The area under high land category is maximum in tail reach as canal water does not reach and they uses drainage water from Gobari Nala for irrigation to *rabi* vegetable crop.

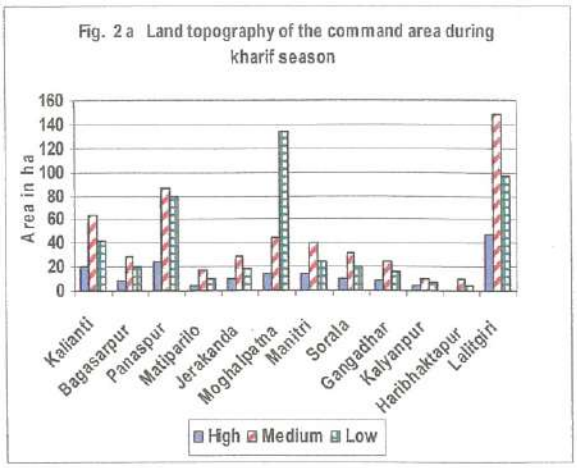


Fig. 2 aVillage wise topography of command area

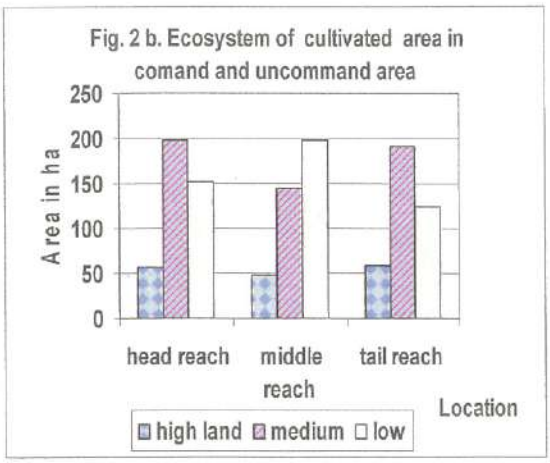


Fig.2 bTopography of the command area

Cropping pattern adopted prior to inception of the project:

For implementing the approved project, preliminary survey with respect to groundwater and surface water resources, fluctuations in groundwater table in the selected distributory no.5 of the Patamundai canal (block Mahanga, district Cuttack) was done and the survey report on cropping pattern which are being followed in this distributory is described briefly in the following text.

i)Kharif Season:

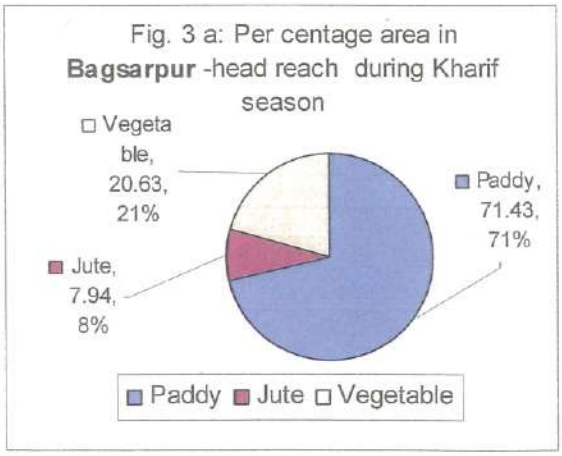
In the selected distributory No.5 of Patmundai canal (Mahanadi Delta I) about 12 villages are benefited with canal water. The CCA of the distributory is about 752.929 ha but the total cultivated area during *kharif* season is 983.1 ha. The rice is main crop of that area. In head reach villages (**Panaspur, Bagasarpur, Kalianti, and Matiparilo**), about 71% to 86.9% area is occupied with rice and rest area is occupied with jute, vegetable crops and spices (in Fig. 3, a,b,c one village of head reach, middle reach and tail reach is given for reference). In middle reach village (**Mogalpatna, Jerkanda, Manitri and Sorala**), the paddy is dominated having 74% to 88% area. But in tail reach villages (**Haribhaktapur, Gangadhar, Kalyanpur, and Lalitgiri)** the area occupied by *kharif* paddy is slightly less (54% to 74%) than middle and head reach villages as the farmers are not receiving canal water in proper time and most of the land area is upland / medium land. In upland and medium land the farmers are cultivating jute and vegetable crops and area occupied by these two crops are to the tune of 6-13% in jute and 13- 27% in vegetable crops.

ii)Rabi Season-

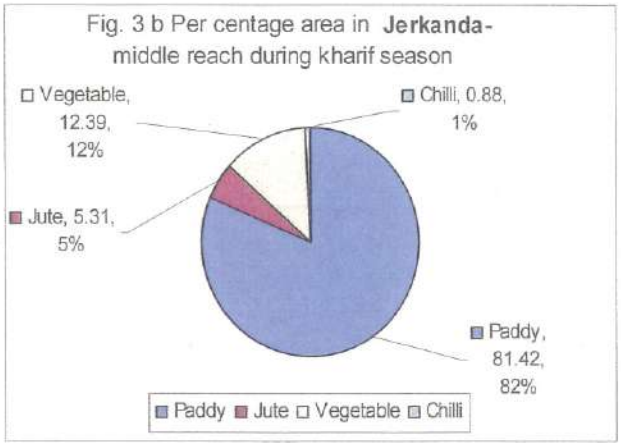
After harvesting *kharif* crops, farmers are growing vegetable, pulses, and oil seed crops in the command area where irrigation facilities exists through canal and shallow tube well, open well and drainage water from canal. In head reach (Panaspur, Bagasarpur, Kalianti and Matiparilo), the major crops were green gram and black gram. The area occupied with these crops ranged from 22 % to 33% and 11 % to 44% respectively except in Matiparillo, it was very low i. e. 8% and 4% respectively of the total cultivated area. (Fig. 3 d,e,f). The *rabi* ground nut was also dominated in this area and it was 0.4% to 8.0% in different villages. In middle reach villages green gram and black gram also occupied maximum area and it ranged from 6 % to 25% in green gram and 10% to 21% in black gram. Besides the pulse crop, ground

nut being oilseed crop also occupied more area than green gram and black gram particularly in village Manitri where 26% of the total area was cultivated. In remaining three villages the cultivated area ranged from 12 % to14%. This trends shows that the farmers are switching over toward oilseed crops as this crop gives more profit than green gram and black gram but this ground nut crops needs about 4 to 5 irrigations to harvest potential yield up to 2.9 t/ha as soil texture is quite favorable for cultivation of ground nut crop.

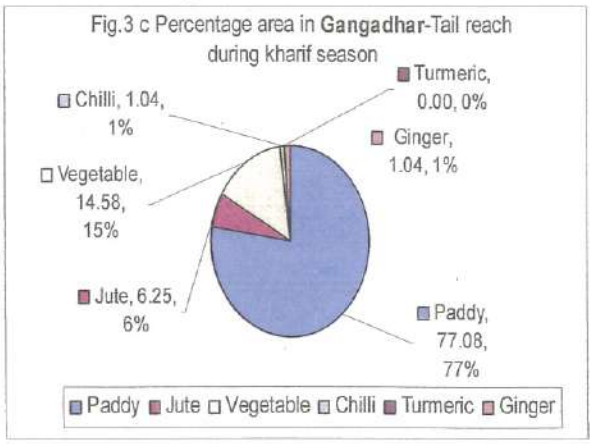
In tail reach villages (**Haribhaktapur, Gangadhar, Kalyanpur, and Lalitagiri**), green gram crop occupied 5 % to 49% of the cultivated area and black gram crop occupied 7 % to 24% area. These crops are grown on residual soil moisture because the canal water is not available with sufficient quantity. The vegetable crops (tomato, brinjal) are also dominated as shown in others category and the area ranged from 9% to 50% of cultivated area. The ground nut crop also occupied good amount of cultivated area in specific villages particularly in Gangadhar where 23% area were occupied.



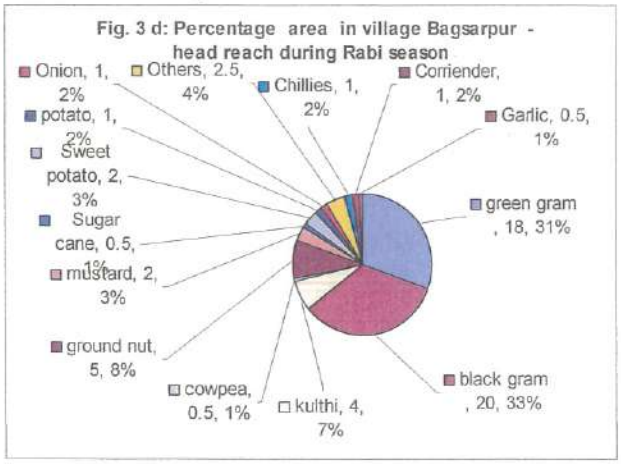
Kharif season – Head reach



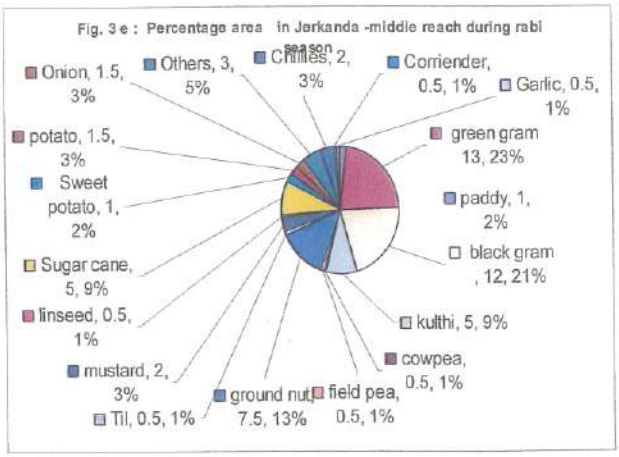
Kharif season – middle reach



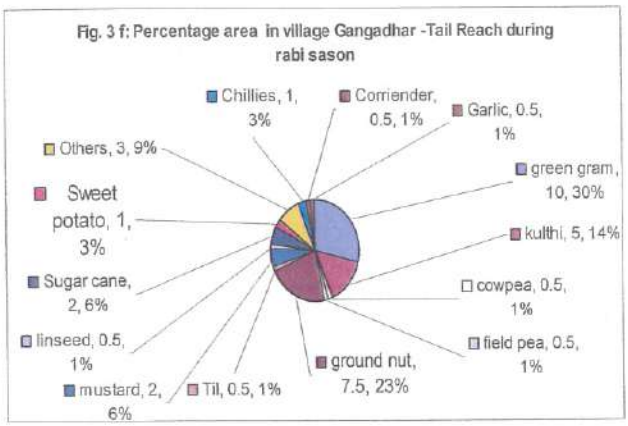
***Kharif* season – Tail reach**



***Rabi* – Head reach**



***Rabi* - Middle reach**



***Rabi* - Tail Reach**

Report on crop yield

In this command area, farmers grow paddy crop during *kharif* season and after that they grow mainly green gram and black either on residual soil moisture or with heavy pre sowing irrigation through canal which is released for short period during January –February month every year. In this cropping systems they get very low yield (Table 2) . If irrigation facility is created through shallow tube wells/ open wells they can easily grow two to three hundred per cent cropping intensity with high value commercial crops and harvest potential yield. Growing of two –three crops in a year is possible with creation of irrigation sources. Once the water resources are created through tube well and open well then multiple use of the groundwater is possible by making pond/ reservoir in field itself as the land holding of the farmer is small.

II) WATER PRODUCTIVITY OF COMMAND AREA BEFORE INITIATION OF THE PROJECT:

Importance of Water Productivity

At global level, there is absolute or economic shortage of water, therefore there is an urgent need to increase the water productivity (WP) of crops through crop improvement (breeding) or natural resources management. The options for increasing WP through breeding are: (i) to reduce non-transpiration uses of water; (ii)to reduce transpiration without reducing production; (iii) to increase production without increasing transpiration; and (iv) to enhance tolerance of water-related stresses –drought, salinity and water logging or submergence. The best option to improve water productivity through natural resources management are (i)pressurized irrigation system and fertigation in seasonal and horticultural crops (ii) multiple use of water like fish, livestock farming etc. Considering the importance of water in agriculture sector as the availability of water is decreasing in agriculture sector, Seckler et al. (1998) recommended four options to improve crop production under shortage of water. They were: (i) development of additional water resources and water-storage facilities; (ii) increased productivity of existing water supplies ;(iii) regional diversion of water; and(iv) increased importation of food.

Water productivity Term: The definition of water productivity differs various scale of water management.Dong et al.,(2001) has defined WP in three ways in rice crop

i) 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 inflow)

ii) In rainfed farming system , the WP is defined as

=(mass of crop production/rain water consumed by the plant i.e. actual evapotranspiration)

iii) Based on net monetary return WP is

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

iv) Water use efficiency(WUE) is defined in physiological term by Peng et al.,(1998) as

=(crop production/amount of water transpired)

v) Water use efficiency (WUE) as per irrigation agronomists is

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

The water productivity term was calculated based on both crop ET and net return before initiation of the project .

From each village's crop yield data of *kharif*, *rabi* and summer season was collected and the water productivity of important crops was computed by dividing crop yield with crop ET. The crop ET was computed by Penman Monteith equation (FAO 56 Irrigation and Drainage paper). The farmers are cultivating paddy (high yielding, and local varieties), vegetables (under upland), turmeric, chilli, and gingers during *kharif* season. In case of high yielding paddy varieties, the water productivity is 0.70 kg/m^3 ET crop, but in normal paddy it is only 0.5kg/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 other vegetables followed by ginger (Table 2)

Table 2: WATER PRODUCTIVITY OF *KHARIF* CROPS,

Crop	Yield, kg/ha	ET Crop, mm	ET Crop m^3/ha	Water Productivity based on yield and ET (kg/ $m^{3)}$	WP based on Net return	
					Net return (Rs /ha)	Rs/m^3 of ET
H Y Paddy	2801.00	399.20	3992.00	0.70	5668	1.41
Normal paddy	1557.50	309.61	3096.10	0.50	2966	0.95
Other 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 crops which are grown during *kharif* season, the farmers are taking *rabi* crops either providing irrigation water through canal as well as through irrigation structures like open well, shallow tube wells. But most of the farmers are 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. The WP during rabi season was highest in vegetables followed by garlic. (Table 3)

Table 3: 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
Till	275	196.40	1964.0	0.14	3441	0.75
Mustard	216.66	262.58	2625.8	0.08	1854	0.71
Linseed	250	214.11	2141.1	0.12	1300	0.61
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
Other Vegetable	9837.50	248.30	2483	3.96	18948	7.52
Chilli	780.00	232.11	2321	0.34	70000	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

III) *PRELIMINARY WORK DONE FOR START OF THE PROJECT*

Preliminary survey on water availability through selected distributory was done by collecting data from the irrigation department. Thereafter we collected details of the canal water release pattern, availability of canal water to the farmers at head reach, middle reach and tail reach. The canal water is available to the farmers during *kharif* season from July end; however it is not distributed equally to the farmers of whole command. After making detail survey, it has been observed that tail reach farmers are not receiving canal water in time. They are not making any efforts to use groundwater due to non availability of ground water structures. . Similarly during *rabi* season it is released for growing green gram. During this period, the canal water never reaches to tail reach farmers and they are growing green gram on residual soil moisture. So we contacted the farmers of four villages, falling in tail reach of the command. After visit to four villages and personal discussion with farmers of the villages for creating water resources structures like bore well, open well for irrigating field crops and pond for rearing fish, we selected village **Gangadhar** and provided pond, bore well and open well for irrigation and rearing of fish by using groundwater.

The bore well, opens wells and pond was constructed in farmer's field on participatory mode with an agreement that, the owner of ground water structure will provide irrigation water to the adjoining farmers. Fifty percent expenditure was borne by the farmer for bore well and opens well. For construction of pond, they made 50 % area of pond and, we made 50 % area.. Regarding construction open well, about 6.65 m depth with 3 meter diameter well was constructed. In case of bore well 15 meter depth with pipe diameter of 10 cm was created near the pond to irrigate during January to May for rearing the fish in pond as well as growing vegetable / high value cash crop during *rabi* and summer season, as well as during *kharif* season when long dry spell is occurs

Primary data:

To fulfill four objectives of the approved projects, primary data on various aspects were collected. The details are described in the following text.

General Climate of the Area and 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. The annual rainfall of this area (Cuttack) is 1501.3 mm and annual crop ETo demand is 1656.0 mm. Thus there is deficit of water by 154.7 mm for crop production throughout the year . But the rainfall distribution pattern is quite erratic and it is not matching with crop water demand. During rainy season (June to October), total rainfall is 1265 mm and crop ETo demand is 624.4 mm only. Thus there is 640.6 mm excess rain water available during wet season. In rabi season (November to March), however, the rainfall amount very low (114.1 mm) as against crop ETo (621.1 mm) . Similarly during April to May, the crop ETo is very high (410.7 mm and rainfall is only 12.7 mm. Hence it is highly essential to make alternative arrangement to grow minimum two crops in a year and improve crop productivity as well

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i) 2007-2008

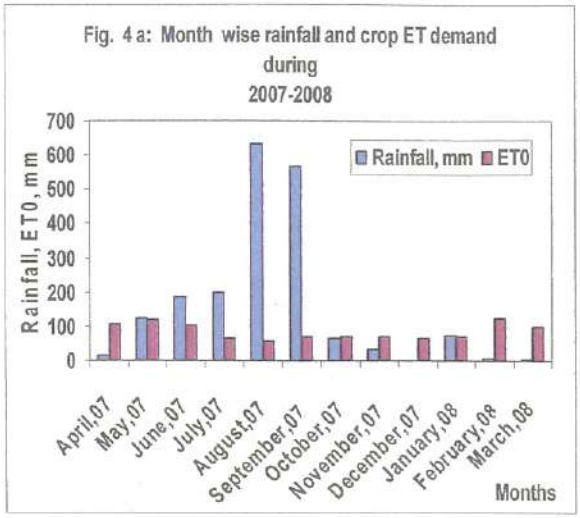
During first year of experimentation general climatic situation was quite comfortable for growth of different crops. Total rainfall was 1905.8 mm and crop ETo was 1022.46 mm. So there was surplus rainwater available for growing field crops throughout. Average maximum and minimum temperature was 31.3 ^{0} C and 22.3 ^{0} C, respectively. Wind speed was 5.30 km/h, bright sunshine was 6.04 hours per day, water evaporated from open water body was 4.07 mm /day, relative humidity during morning and evening was 91.01 % and 60.13 %, respectively. This weather parameters with varying magnitude influenced crop growth without any adverse effect on crop yield (fig. 4 a, b).

ii) 2008-09

During April 2008 to March 2009, rainfall received was 2206.2 mm as against annual ETo of 1610.79 mm. During the report period, the water deficit was observed against the rainfall received in the month of April 2008, May and October 2008 to March 2009; however the magnitude of amount of water deficit in these months varied considerably based on the amount of rainfall received. The remaining weather parameters (relative humidity %, temperature ^{0}C, sunshine hour, wind speed km/hr, and evaporation mm per day) are also quite favorable for growth of most of the vegetable crops besides rice during *kharif* season. The average monthly maximum and minimum temperature was 31.33^{0}C and 21.75 ^{0}C, respectively. The average relative humidity in the morning and evening was 92.36 % and 58.86 % respectively, the wind speed was 3.24 km /hr and bright sunshine was 5.54 hour per day and evaporation rate was 4.18 mm per day. In this area bright sunshine plays very important role during *kharif* season as cloudy days affect overall photosynthesis rate and total biomass production is reduced considerably (fig. 4 c, d)..

iii) 2009-2010

During the report period, the water deficit was observed against the rainfall received in the month of April 2009 and October 2009 to June 2010; however the magnitude of amount of water deficit in these months varied considerably based on the amount of rainfall received. During deficit period (October to June), the farmers are growing vegetable crops. Hence they needs frequent irrigation, which is possible through groundwater use as canal water is available to the farmers for limited period and most of the tail reach farmers does get sufficient canal water during canal running period. 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 and bright sunshine was 5.96 hour per day and evaporation rate was 4.55 mm per day (fig. 4 e,f).



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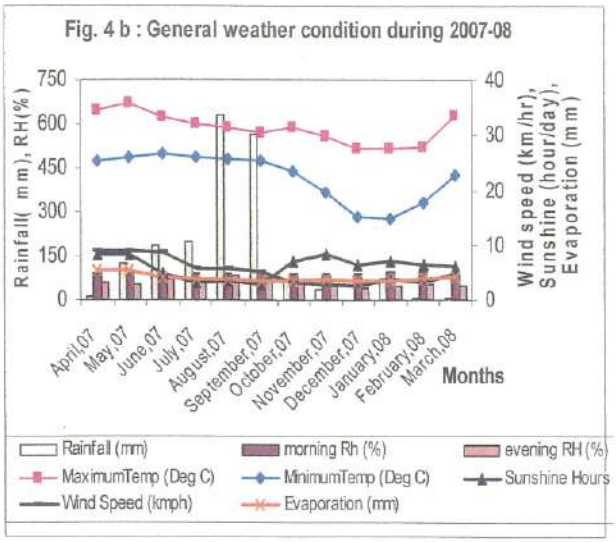
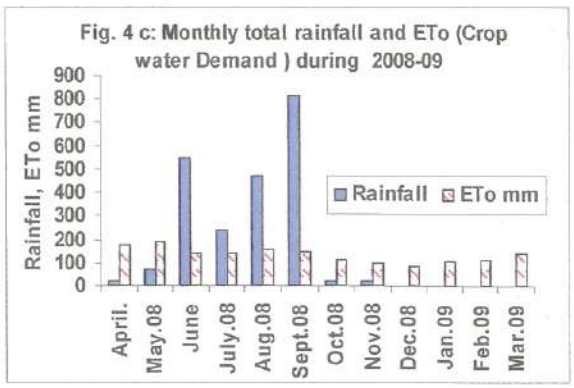
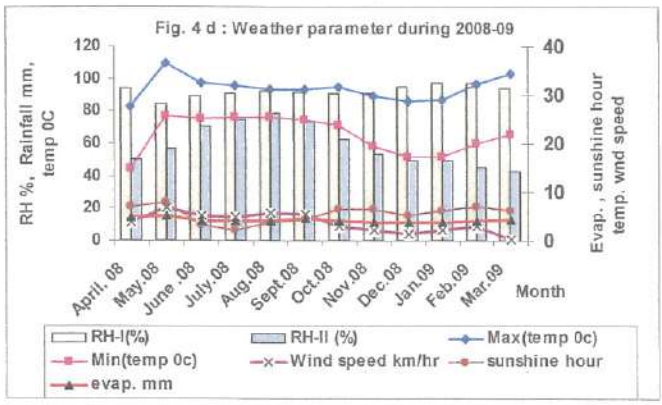


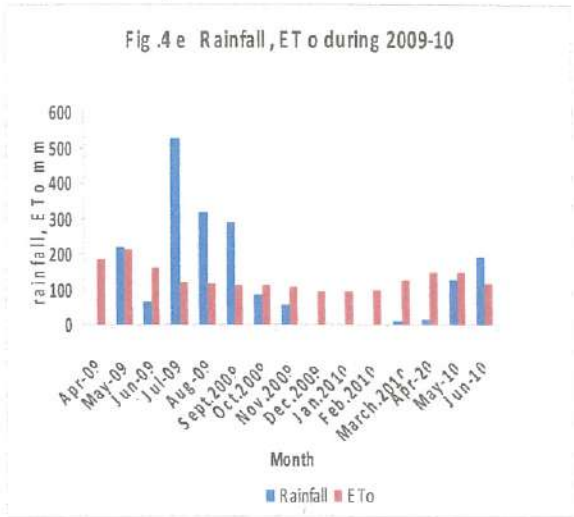
WEATHER PARAMETERS. 2007-08



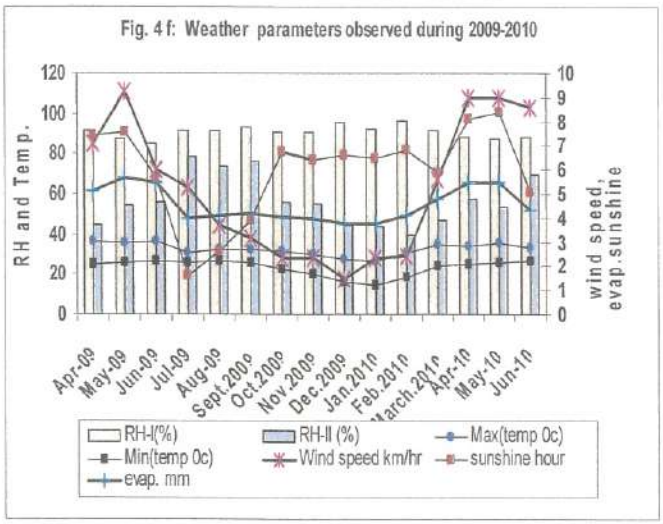
RAINFALL, ETo 2008-09.



WEATHER PARAMETERS. 2008-09



RAINFALL, ETo 2009-10.



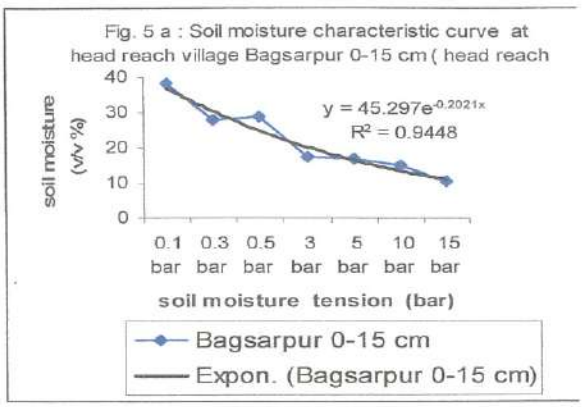
WEATHER PARAMETERS. 2009-10

PHYSICO- CHEMICAL PROPERTIES OF THE SOIL OF PROJECT AREA :

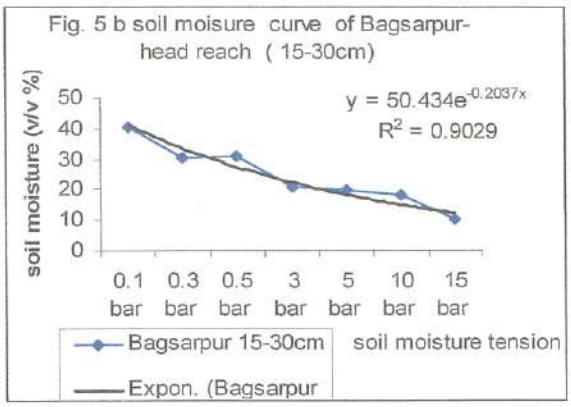
The soil samples from different village were collected from four soil depth (0-15, 15-30, 30-45 and 45-60 cm depth) and analyzed for it textural class and soil moisture characteristic curve (Table 4). In middle reach and tail reach of the command area the clay content is comparatively more than at head reach in 30- 45 and 45-60 cm soil depth The soil is not well drained as it happen in head reach. The soil moisture characteristic curve help us to know the available moisture in different soil layer for adopting irrigation scheduling in different crops and to assess percent depletion of available soil moisture in root zone. Similarly in command area, it is essential to know the actual soil moisture available in soil profile to follow the amount of water to be released so that it may not get waterlogged due to poor drainage. The detail soil moisture characteristics curve are given in figure 5 a,b,c,d,e,f.

Table 4: Textural analysis of project site

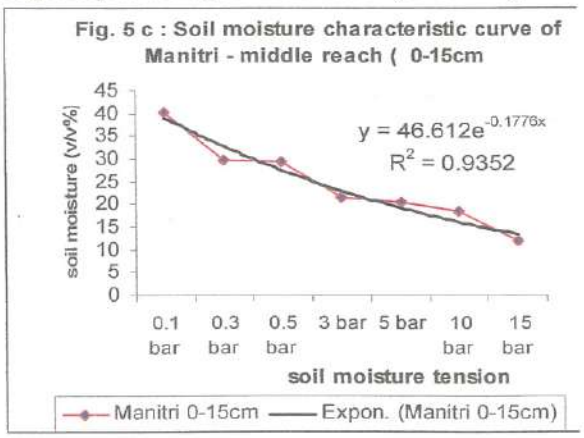
Location	Soil properties	0-15 cm	15-30 cm	30-45 cm	45-60 cm
Head reach	Sand (%)	85.84	81.84	79.84	80.84
	Silt (%)	5.70	7.7	8.7	7.7
	Clay (%)	11.46	10.46	11.46	11.46
	Class	Loamy sand	Sandy loam	Sandy loam	Sandy loam
Middle reach	Sand (%)	77.84	77.84	79.84	77.84
	Silt (%)	10.7	13.4	7.7	6.7
	Clay (%)	11.56	8.7	12.46	15.46
	Class	Sandy loam	Sandy loam	loam	Loam
Tail	Sand (%)	75.84	79.84	79.84	80.84
	Silt (%)	11.7	7.7	7.7	6.7
	Clay (%)	12.46	12.46	12.46	12.46
	Class	loam	Loam	Loam	Sandy loam



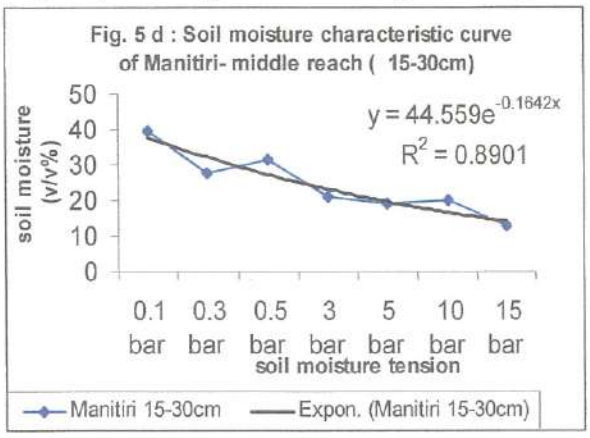
Bagasarpur village: head reach (0-15 cm)



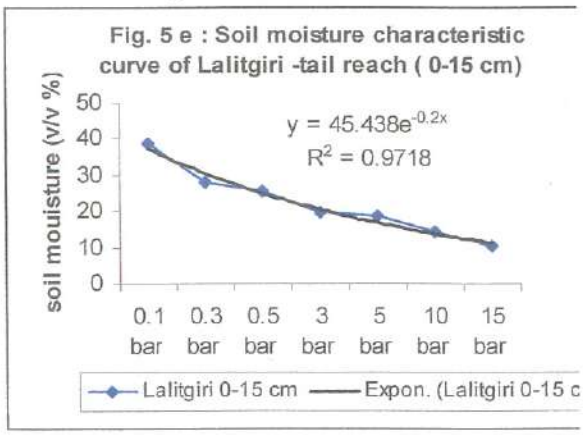
Bagasarpur village: head reach (15-30 cm)



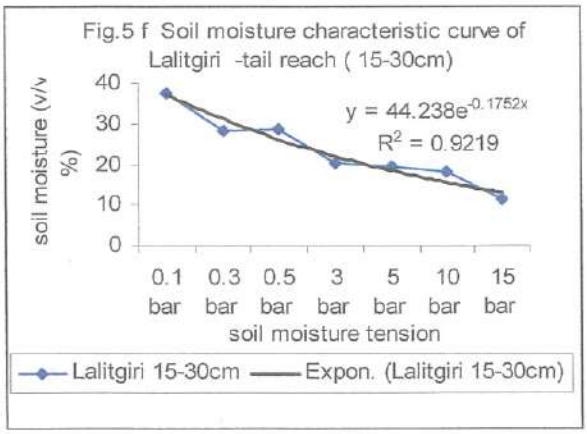
Manitri village –middle reach 0-15 cm



Manitri village –middle reach 15-30 cm



Lalitgiri village tail reach 0-15 cm



Lalitgiri village tail reach: 15-30cm

INSTALLATION OF METEOROLOGICAL EQUIPMENT FOR MOINITORING RAINFALL, EVAPORATION, TEMPERATURE AT PROJECT SITE

For monitoring important weather parameters, like temperature, evaporation, rainfall the apparatus was installed in project site.

Photo no. 1: Photo of meteorological equipments

OBJECTIVE .NO. 1.

TO ASSES THE EXISTING AVAILABLE WATER RESOURCES FOR PLANNING THE BEST USE OF SURFACE WATER DURING *KHARIF* SEASON.

Introduction

On an average of 50 years rainfall data (1901-1950) Orissa receives 1492.8 mm rainfall in 73 rainy days annually. Out of this, 1295.7 mm (86.8%) is received during June- October, 98.6 mm (6.6%) during November to March and rest 98.5 mm (6.6%) during April and May. With respect to crop water demand, annual evaporative demand is 1657.8 mm. This total annual crop evaporative demand (ETo) is higher by only 11% over the water available through rain alone. But the water supply through rain is highly erratic during different seasons and it affects the overall production in both coastal and non-coastal districts of Orissa. The evaporative demand during June to October (*kharif* season) is only 627. 3 mm and rainfall is 1295.7 mm, showing surplus of 106.5 % over demand. During *rabi* season, the evaporative demand is 604.3 mm resulting a deficit of 83.7 % and during summer month (April –May) the evaporative demand is 426. 3 mm, resulting a deficit of 76.9%. When season wise and district wise crop evaporative demand and availability of rainwater is concerned, in most of the coastal districts of Orissa, availability of water through rain during *kharif* (June to October) is quite high (1042.6 mm to 1278 mm) than the crop evaporative demand (614.4 mm to 657.1 mm). Similarly in non coastal districts of Orissa the water available through rain alone during *kharif* season is 1230.1 mm to 1489.1 mm against evaporative demand of 580.5 mm to 634.0 mm. The excess rain water over crop demand during *kharif* season causes severe problem of unfavorable edaphic environment (water logging) in agricultural crop production particularly in coastal tract as the seasonal fluctuation of the groundwater table is at shallow depth i.e. 1.5 to 3 m. However in eastern ghat region, northern plateau, and central table land of Orissa, the problem of water logging is not much severe as the topography is undulating and groundwater table remains below the critical depth in most of the growing period (except in valley) the excess rain water stagnates for short period without any adverse effect.

In coastal districts of Orissa, rice is the main important crop of the *kharif* season however; the yield potential is very low due to inadequate edaphic environment. The excess water occurring during rainy season can be recharged in to the groundwater by various techniques wherever the groundwater recharge technique is feasible. Subsequently this recharged water can be reutilized for crop growth during dry season i.e. *rabi* and summer and the cropping intensity and irrigated area can be increased as there is substantial deficit of water exists during *rabi* and summer season. Similarly the water available from groundwater is also in ample quantity (ground water yield moderate 15-40 lps to > 40 lps) but exploitation is very low .In some of the coastal districts of Orissa, groundwater is available at shallow depth however the exploitation is very low as irrigation through canal particularly in Mahanadi delta I and II, has good irrigation net work. Due to this reason the shallow dug wells are in limited numbers i.e 11414 and 2797 in Cuttack and Puri districts, respectively. Similarly in Western Orissa, canal irrigation source is available from Hirakud project and hence the shallow dug wells are in limited numbers in Sambalpur (9267 nos.) and in Bargarh (5269 nos). Maximum numbers of shallow dug wells are found in Ganjam district (31078 nos), followed by Angul (25974 nos.). Similarly maximum numbers of medium deep tube wells (1161 nos.) are dominated in Balasore district and hence the groundwater development in this district is quite high as compared to rest of the districts of Orissa.

In Orissa, the groundwater development is hardly 18.71 % (CGWB, Report, 2004) with maximum development in Balasore district (47.46) due to more number of tube wells and growing of summer rice and vegetable crops. The districts Bargarh, Sambalpur, Sonpur where major cropped area falls in Hirakud Irrigation Command, the groundwater development is 14.32, 10.39 and 11.23 %, respectively. To increase irrigation intensity and cropping intensity in this area, groundwater exploitation is not possible as discharge rate is low (less than 10 lps) even if the exploratory drilling is done up to 300 m. In coastal districts viz. Cuttack and Puri under Mahanadi delta I and delta II, groundwater utilization is also low i.e. 18.64% and 10.51 %, respectively. The groundwater level is also shallow (Fig. 6 Hydrogeology of Orissa).

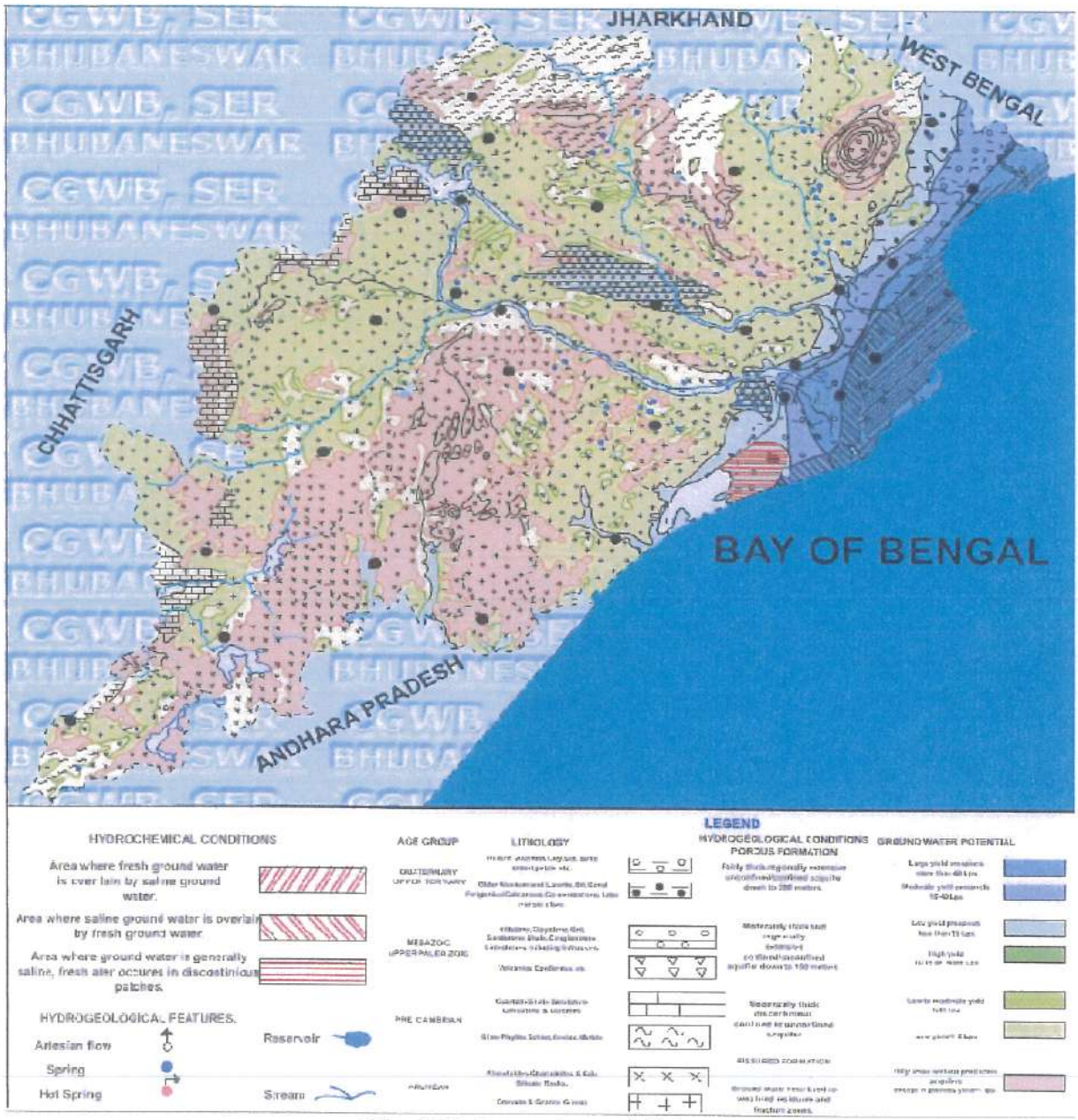


Fig. 6 Hydrogeology of Orissa

This shallow depth of groundwater can be easily pumped with minimum investment. Hence, it is highly imperative to increase cropping intensity by raising crops during *rabi* and summer season and increase overall income of the farmers as they are habituated with mono crop though sufficient groundwater is available with them. Considering these problems in

mind, the project proposal was made for efficient utilization of groundwater and surface water in crop production and increase cropping intensity by 200 % over the existing cropping intensity of 158% (Orissa Agricultural Statistic 2006-07).

In Orissa state, irrigation through canal network is limited due to limited number of major, medium and minor irrigation projects. Further development of new irrigation projects also needs lot of investments and more time to complete the project and bring in to operational status. In areas where irrigation development has taken place, the distribution of irrigation water is not uniform and the tail end farmers of the canal / distributory suffers largely due to non-availability of canal water in time. Under such condition, it was essential to make study on proper utilization of groundwater and canal water. Hence the project was undertaken in canal command area where groundwater and surface water was used for growing the *rabi* and summer crop by creating water resources structures.

ASSESSMENT OF AVAILABLE WATER IN CANAL COMMAND AREA DURING 2006-07 to 2009-2010

a)Computation of Crop water Demand (Evapotranspiration)

The reference crop ET demand gives us an idea for planning available water resources to be used effectively for crop production in selected location. For assessing crop ET demand of this command area the daily crop evaporative demand (reference evapotranspiration) for the period from April 2008- March 2009 and up to summer crop growing period was computed by Penman Monteith methods (FAO56), which is widely adopted by irrigation engineers, agronomist and other researchers, engaged in planning and executing the programme for estimating crop water demand by considering all weather parameters namely temperature (maximum, minimum) relative humidity, wind speed, sunshine hours as per the following equation.

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} U_2 (e_s - e_a)}{\Delta + \gamma (1 + 0.34U_2)}$$

ET_0 = reference evapotranspiration, mm/day

Δ = slope of vapour pressure curve (kPa /^{0} C)

R_n = net radiation (MJ/m^2/day)

G = soil heat flux density (MJ/m^2/day)

γ = psychrometric constant (0.0671 kPa /^{0} C)

T = mean daily temperature at 2 m height

U_2 = wind speed at 2 m height (m/s)

e_s = saturation vapour pressure (kPa)

e_a = actual vapour pressure (kPa)

e_s-e_a = saturation vapour pressure deficit (kPa).

The weather parameters were collected from the nearest meteorological station i.e Central Rice Research Institute Cuttack (ICAR), Orissa which is identical place for this study.

b) *Water availability during kharif and rabi season 2007-2008*

The canal was operated in *kharif* season for 129 days period during 12.07.2007 to 21.11.2007 and six observations on discharge rate was monitored in distributory at various distance intervals. Based on average discharge rate of 0.816, 0.703 and 0.209 cumec from all three distributory no. 5a, 5b and minor of 5 b, respectively, the water availability through canal was computed for the above period. In total command area of 753.929 ha, canal water available was 1970.9ha-m and water available from rainfall was 1399.0 ha-m with total amount of 3369.9ha-m. However the crop ETo demand of the command area was only 514.09 ha-m, which was derived by computation of ETo, with meteorological data by Penman Monteith equation. So there was excess water of 2855.81 ha-m, which caused problem of water logging and increase of groundwater level to shallow depth (Table 5). After harvest of *kharif* rice again canal water was released for 19 days period during 12.01.2008 to 31.01.2008 because of heavy rains in between and about 290.9ha-m water was released besides 26.17 ha-m from rainfall . Total amount of water available through canal+ rainfall was 317.07 ha-m as against 36.30 ha- m crop water demand. Since *rabi* crop is generally continued up to March-April, there is substantial deficit of water (Table 5). This deficit of water can be only fulfilled with groundwater once groundwater structure is developed.

Table 5: Total water available in canal (distributory No.5) in *kharif*- 2007 (duration of flow of water in distributory 129 days)

	Command area (ha)	Water available (canal head) ha-m	Water available (rainfall) ha-m	Total water available ha-m	Demand ETo ha-m	Average discharge at head reach, (six observation.) cumec
5a	272.353	909.1	508.8	1417.9	76.88	0.816
5b	388.903	828.5	717.1	1545.6	108.37	0.743
minor	92.673	233.3	173.1	406.4	26.16	0.209
total	753.929	1970.9	1399.0	3369.9	211.74	
Total water available in canal (distributory No.5) in *rabi*- 2007 (duration 19 days						
5a	272.353	130.0	9.53	139.53	13.20	0.792
5b	388.903	124.4	13.40	137.80	18.61	0.758
Minor	92.673	36.5	3.24	39.74	4.49	0.220
total	753.929	290.9	26.17	317.07	36.30	

c)*Water availability during kharif and rabi season 2008-2009*

The canal water was released on 27.7 2008 and continued up to 24.11.2008. During *kharif* season the canal water was continued for 124 days. On an average of five observations on discharge rate of water in different segment of distributory, the average discharge rate was 0.716 cumec in distributory 5 a, 0.703 cumec in 5b and 0.219 cumec in minor of 5 b. As the distance from head reach increased the flow rate is reduced due to more number of unauthorized outlets available in the distributory for release of water in to field channel. The table 6 clearly shows that the reduction in flow rate at tail reach in distributory 5 a is very high

and it ranges from 9.6 % at 0.2 km away from main outlet to 86.0% at 5 km away from main outlet. In distributory no. 5 b and minor of 5 b, the reduction in flow rate of water ranged from 32.6% at 1.5 km to 64.9% at 4.5 km away from main outlet. In minor of 5 b, the reduction in discharge rate was was 68.8%.

During *rabi* season the water was released on 12.1.2009 and closed on 24.2.2009.The total duration of water flow was 43 days. The flow rate on an average of three observations were 0.622 cumec at head reach and no water flow had seen at tail reach at 5.0 km away from head reach in distributory no.5a and 0.658 cumec at head reach and 0.238 cumec at 4.5 km away from head reach in distributory no. 5 b. In minor of 5 b, it was only 0.187 cumec. Thus there was substantial reduction of discharge rate in both the distributory as compared to head reach and the extent of reduction was 2.2% at 0.2 km away from source of outlet to 100 % reduction at 5.0 km away from source in distributory no. 5a and 33.5 % at 1.5 km to 63.8 % at 4.5 km away from source in distributory no.5b. In minor of 5 b, the reduction in flow rate of water was 71.5 %.

Table 6: Flow rate in different location in selected distributory during *kharif* season

a) **(Flow rate cumec)**

Distance from head reach	Distributory no. 5 a		Distance from head reach	Distributory no. 5 b	
	Avg. flow (cumec)	Volume of flow, (ha-m)		Avg. flow,cumec	Volume of flow, ha m
0km	0.716	766.9	0.1km	0.703	753.6
0.2km	0.647	693.4	1.5 km	0.4738	507.6
0.5km	0.521	558.2	2.5km	0.3978	426.2
0.55km	0.469	502.5	3.5km	0.3028	324.4
0.61km	0.351	376.3	4.5km	0.2488	266.6
1.0km	0.255	273.2	**minor of 5 b at 0.3km**	0.2192	234.8
2.0km	0.172	184.5			
3.0km	0.141	151.1			
4.0km	0.121	129.6			
5.0 km	0.100	107.1			

Table 7: Flow rate in distributor 5a, during *rabi* season (total duration of flow 43 days)

Distance	Distributory no.5 a		Distributory no.5 b		
	Avg. flow, cumec	Volume of flow, ha m	Distance from head reach	Avg. flow, cumec	Volume of flow, ha m
0km	0.622	231.1	0.1km	0.658	244.6
0.20km	0.608	226.0	1.5 km	0.438	162.7
0.50km	0.348	129.2	2.5km	0.325	120.9
0.55km	0.326	121.2	3.5km	0.277	102.8
0.61km	0.230	85.6	4.5km	0.238	88.4
1.00km	0.174	64.5	minor of 5 b at 0.3km	0.187	69.6
2.00km	0.094	34.8			
3.00km	0.060	22.2			
4.00km	0.030	11.3			
5.00 km	0.000	0.0			

OVERALL SCENARIO OF WATER SUPPLY AND DEMAND IN CANAL COMMAND AREA:

Generally the farmers are taking paddy crops during June to November in different locations of the distributory. So considering the growing period of rice from June to November as planting of rice is done in different phases, the crop water demand is only 553.4 ha-m (Table 8), neglecting water loss in conveyance, special application, percolation etc. The water available through rainfall during above period was 1594.9 ha-m and through canal water 1755.31 ha-m during canal operation period.

During winter and summer season (December – May), the crop water demand was 615.3 ha – m and water available through rainfall water was 68.4ha-m. The water available through canal operation period of 43 days was 172.0 ha –m in distributory no.5 a and 244.6 ha-m in distributory no.5 b at head reach point. However it was very low at tail reach point. So it is thus inferred that, the best possibility to take up *rabi* and summer in this command area is to develop groundwater structure on participatory basis as land holding of the farmer is very small and they can not afford to develop shallow bore well or open well for their own purpose

The annual (April 2008 to March 2009) crop ET demand was 1214.4 ha-m and the water available through rain itself was 1663.3 ha-m. However, the distribution of available rain water was not proper.

Table 8: Total crop water demand and supply through rainfall in command area of 753.929 ha

Month	Rainfall mm	ETo mm	Water available through rain (ha-m)	ET demand of command area (ha-m)
April. 08	18.2	179.04	13.7	135.0
May.08	72.5	192.28	54.7	145.0
June.08	546.8	143.84	412.2	108.4
July.08	236.3	139.34	178.2	105.1
Aug.08	473	152.69	356.6	115.1
Sept.08	812.2	145.08	612.3	109.4
Oct.08	23.6	115.51	17.8	87.1
Nov.08	23.6	98.26	17.8	74.1
Dec.08	0	82.21	0.0	62.0
Jan.09	0	104.95	0.0	79.1
Feb.09	0	114.66	0.0	86.4
Mar.09	0	142.93	0.0	107.8
Total	2206.2	1610.79	1663.3	1214.4

d) *Water availability during kharif and rabi season 2009-2010*

The canal water was released on 17.7 2009 and was continued up to 15.11.2009. On an average of five observations on discharge rate of water in distributory, 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 of water ranged from 32.6% at 1.5 km away from main outlet to 64.9% at 4.5 km away from main outlet. In minor of 5 b, the reduction was 67.7%.

During *rabi* season the water was released on 12.1.2010 and closed on 27.2.2010.The total duration of water flow 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 %. (Table 10)

Table 9: Flow rate in distributor 5a, during *kharif* season

Distance	Distributory no. 5 a		Distributory no. 5 b		
	Avg. flow (cumec)	Volume of flow (ha m)	Distance (km)	Avg. flow (cumec)	Volume of flow (ha m)
0km	0.775	810.0	0.1km	0.699	669.1
0.2km	0.706	738.3	1.5 km	0.470	430.7
0.5km	0.580	606.4	2.5 km	0.394	355.4
0.55km	0.528	552.0	3.5 km	0.299	334.5
0.61km	0.410	428.8	4.5 km	0.245	223.7
1.0km	0.314	328.3	Minor of b 0.300 km	0.225	219.5
2.0km	0.231	241.7			
3.0km	0.200	209.1			
4.0km	0.180	188.2			
5.0 km	0.159	166.2			

Table 10: Flow rate in distributor 5a, during *rabi* season (total duration of flow 46 days)

Distance	Distributory no.5 a		Distance	Distributory no.5 b	
	Avg. flow, (cumec)	Total volume of flow (ha-m)	Avg. flow (cumec)	Total volume of flow (ha-m)	
0km	0.715	284.2	0.1 km	0.74	120.7
0.2km	0.701	278.7	1.5 km	0.52	84.5
0.5km	0.441	175.1	2.5 km	0.40	66.0
0.55km	0.419	166.7	3.5 km	0.35	58.1
0.61km	0.323	128.5	4.5 km	0.32	51.7
1.00km	0.267	106.0	Minor of 5 b at 0.3km	0.22	35.8
2.00km	0.187	74.2			
3.00km	0.153	60.7			
4.00km	0.123	49.0			
5.00 km	0.090	35.8			

OVERALL SCENARIO OF WATER SUPPLY AND DEMAND IN CANAL COMMAND AREA:

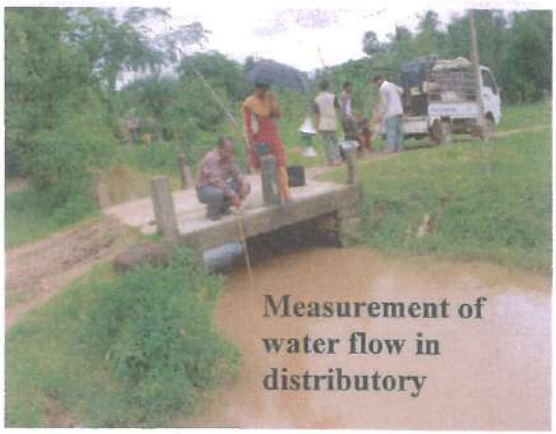
During June to November the crop water demand is only 553.4 ha-m (Table 11). The water available through rainfall during above period is 1326.0 ha-m and through canal water at head reach is 810 ha-m in distributory no. 5 a, and 669.1 ha –m in distributory no.5 b during canal operation period.. However in tail reach, the availability of water is 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 is 535.6 ha – m and water available through rainfall water is 114.1 ha-m. However the water available through canal operation period of 46 days is 284.2 ha –m in distributory no.5 a and 120.7 ha-m in distributory no.5 b at head reach point. However it is very low at tail reach point.

Table 11: Total crop water demand and supply through rainfall in command area of 753.929 ha during 2009-2010

Month	Rainfall (mm)	water available through rainfall (ha-m)	monthly crop water demand, mm	monthly crop water demand (ha-m)
April 2009	0	0.0	186.37	140.5
May 2009	217.9	164.3	215.56	162.5
June 2009	63.1	47.6	164.96	124.4
July2009	526.2	396.7	121.21	91.4
August 2009	314.4	237.0	118.15	89.1
Sept.2009	287.3	216.6	109.91	82.9
Oct.2009	81.4	61.4	113.06	85.2
Nov.2009	53.6	40.4	106.73	80.5
Dec.2009	0	0.0	94.81	71.5
Jan.2010	1.4	1.1	92.75	69.9
Feb.2010	0	0.0	96.96	73.1
March.2010	10.2	7.7	125.98	95.0
Total	**1555.5**	**1172.7**	**1546.4**	**1165.9**
April 2010	14.6	11.0	149.2	112.5
May 2010	125.1	94.3	150.68	113.6
June 2010	188.6	142.2	117.17	88.3

PHOTO NO.2 : DISTRIBUTORY NO. 5 PATMUNDAI CANAL



Measurement of water flow in distributory

GROUNDWATER FLUCTUATION OF COMMAND AREA :

i) *Year 2007-2008*

The groundwater fluctuations were monitored during canal on and off period in 12 villages to assess influence of groundwater level and recharge of groundwater in selected distributory. The canal water was released on 12. 07. 2007 and continued up to 21. 11. 2007 for *kharif* season crop and 12. 01. 2008 to 31. 01. 2008 for *rabi* season crops.

The groundwater table which was monitored in 61 observations wells in whole command area revealed that one week before releasing canal water, the water table in head reach area ranged from 2.43 m to 4.40 m. The corresponding value in middle reach was 3.18m to 4.26m. But in tail reach villages the groundwater table was at shallow depth and ranged between 2.3m to 3.32m. In tail reach villages most of the observation wells was influenced due to influx of water from drainage nala (Gobari nala) which was draining excess subsurface flow from Kendrapara canal.

After harvest of *kharif* season rice crop, canal water was released on 12.1.2008 and continued only up to 31. 01.2008 for *rabi* crops. During this *rabi* season, canal water was available only for 19days due to receipt of good amount of rainfall.

During canal off period, groundwater table depth went to deeper depth rapidly till on-set of monsoon i.e.from13. 01. 2008 to 04. 04. 2008 as good amount of rainfall influenced rise in groundwater table depth in most of the observation wells, either located in head reach and middle reach of the command area.

The groundwater fluctuation data was further categorized into pre-monsoon (March-May), monsoon (June-October) & post monsoon (November to February). It has been observed that the groundwater table during pre-monsoon & post monsoon period was at shallow depth. In pre-monsoon (March-May) period, canal water was available in January end which has helped to rise groundwater level & hence it was 1.89 m. In post monsoon period it was also 1.98m. But in monsoon period it was 3.18m. This high value was found in June & July months where rain water recharge was found to be less. But in August onward groundwater level was rising at faster rate. The coefficient of variation is maximum of 48.40% during pre monsoon period (March – May) followed by post monsoon (June to October), in which the coefficient of variation was 34.59%. In these periods, the farmers have utilized groundwater for irrigating *rabi*/summer crops wherever the bore wells & open wells were available during post monsoon period. The coefficient of variation was very low i.e. 26.71%. This could be due to recharge of groundwater by rainfall and anal water supply

ii) Year 2008-2009

The groundwater fluctuation data of whole command area (61wells) comprising 12 villages was analyzed and categorized as monsoon (June 2008- to October 2008), post monsoon (November 2008-February 2009) pre-monsoon and (March 2009 - May2009),) The data on groundwater fluctuations showed that the groundwater table during the month of May was at deeper depth because of dry month and no canal water supply was existing. 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 2009 and continued up to February 2009. In tail reach villages the groundwater table was at shallow depth. The detail statistical

analysis of the groundwater table fluctuations is given in Table 5, which clearly indicates abundant source of groundwater at shallow depth even in tail reach of. irrigation command

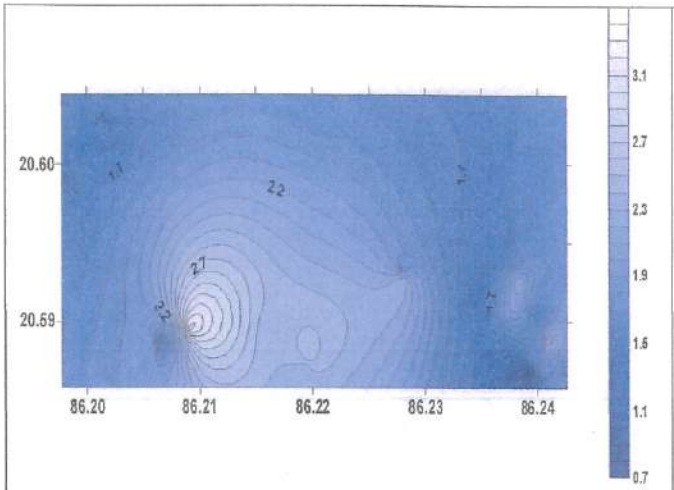
iii)*Year 2009-2010*

The groundwater fluctuation data of whole command area 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.

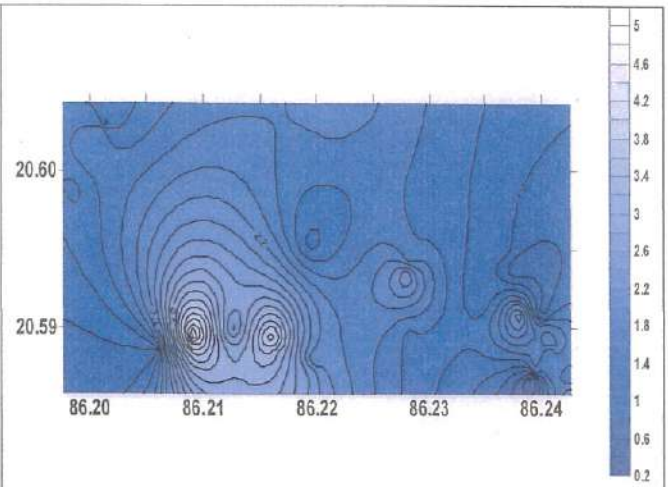
Table: 12. Statistical analysis of water table depth (in meter)

Parameters	2007-08			2008-09			2009-2010		
	Mar-May (Pre-monsoon) m	June-Oct (Monsoon), m	Nov-Feb (Post monsoon),m	Mar-May (Pre-monsoon),m	June-Oct (Monsoon)	Nov-Feb (Post monsoon)	Mar-May (Pre-monsoon)	June-Oct (Monsoon)	Nov-Feb (Post monsoon)
Mean	3.18	1.89	1.98	2.04	1.91	3..23	2.73	2.10	2.08
Maximum	5.98	5.01	3.4	5.53	4.60	5.93	5.02	3.58	5.26
Minimum	0.73	0.25	0.66	0.69	0.28	0.76	0.61	0.69	0.26
SD (m)	1.10	0.92	0.53	0.55	0.86	1.12	0.95	0.61	1.02
CV %	34.59	9.2	26.71	27.0	45.02	34.7	34.8	29.1	49.0

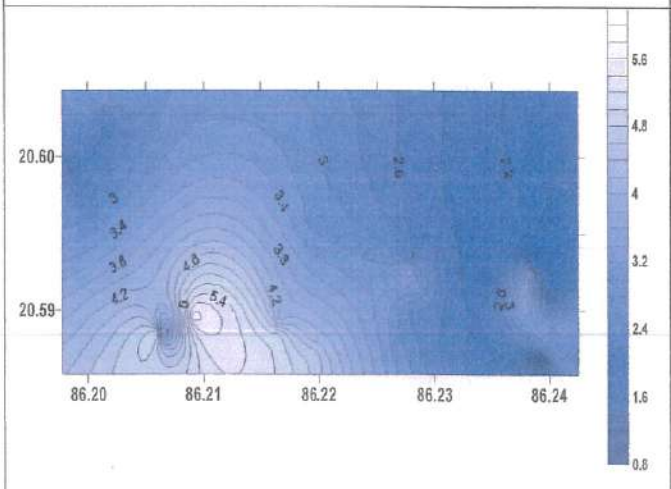
Figure 7 : Counter map of ground water fluctuation table in command area during different period and year



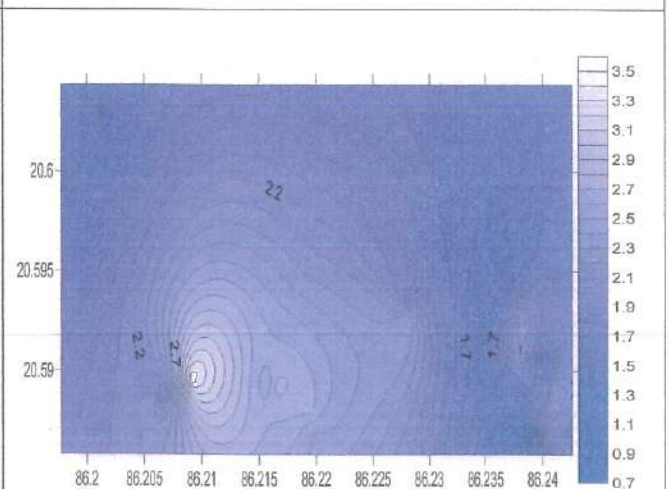
Contour map of groundwater table depth during monsoon periods (June 2007 -October 2007)



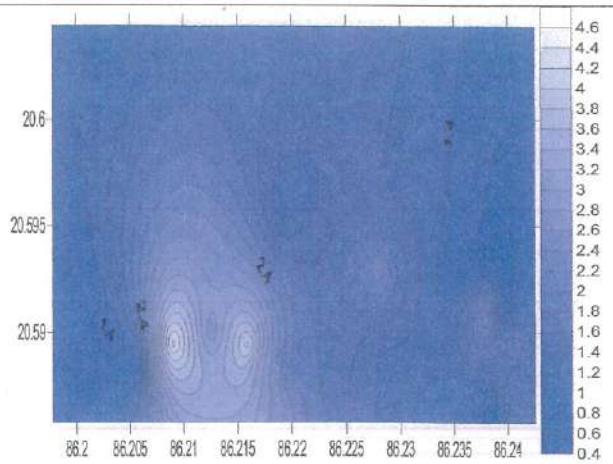
Contour map of groundwater table depth during post monsoon periods (November 2007 -Feb 2008)



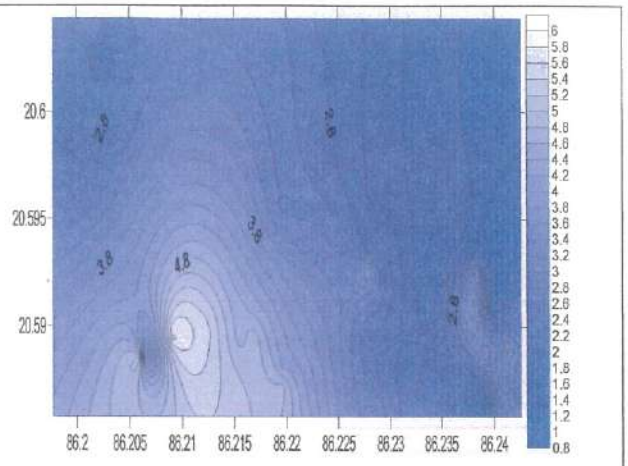
Contour map of March 2008 -May2008



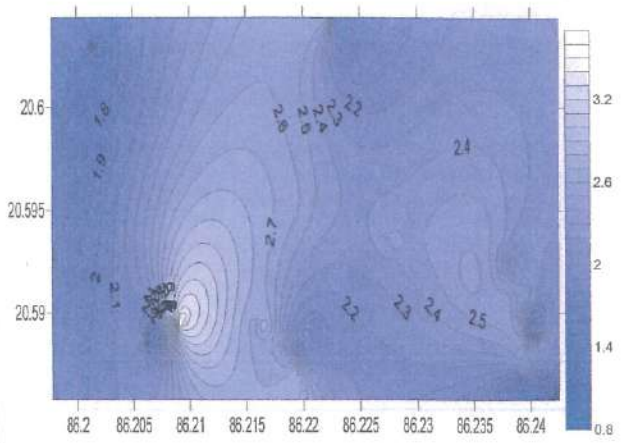
Contour map of June 2008- Oct. 2008



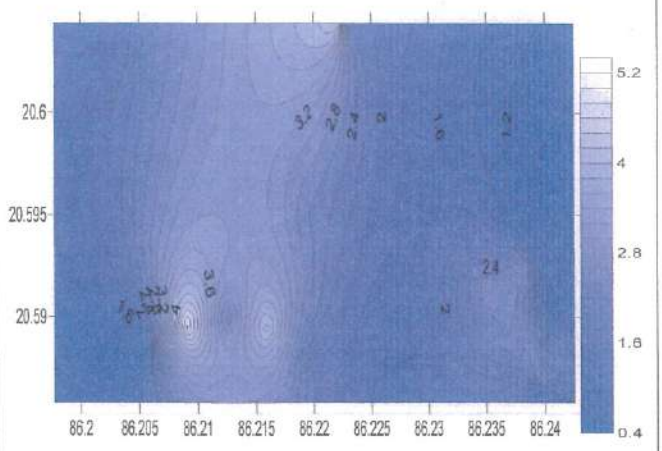
Contour map for **November 2008 –February 2009**



Contour map of March 2009–May2009



Water table fluctuation during **June 2009-October 2009**



Water table fluctuation during November 2009-February 2010

OBJECTIVES 2:

TO EXPLOIT GROUNDWATER DURING *RABI* AND SUMMER SEASON FOR INCREASING CROPPING INTENSITY THROUGH HIGH VALUE CASH CROP

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 . In this case total expenditure for purchase of cement concrete ring was Rs 9900 and excavation charges and refilling of soil surrounding the cement concrete ring was Rs 8500. Thus total expenditure incurred was Rs 18400.00 (Rs Eighteen thousand four hundred only). The maintenance charges was incurred by one of the farmers who was providing irrigation water to the adjoining farmers and he was collecting money from them . In this open well , the farmer was using 2 Hp electric pump and the cost of pump with accessories was Rs 11500.00

In case of bore well , the total depth was only 47 ft(14.33 m) and diameter was 4 inch(10.16 cm). The total expenditure was Rs 9480.00. With regards to maintenance of bore well and sharing of bore well water for irrigation to the adjoining farmers , similar practice like open well was adopted by them.

After development of groundwater structures at project site, irrigations through open well, bore wells were given during *kharif*, *rabi* and summer season. The data pertaining to irrigation requirement, water use efficiency, water productivity, and overall economic return obtained by the farmers is described year-wise in the following text to fulfill above mentioned objective.

a*) Report for the 2007-08 from open well command (Open well no.1) :*

The open well with diameter of 3 m and depth 6.65 m was used for growing three crops i.e. jute, rice and onion during 2007-08.

Irrigation requirement and water use efficiency has been computed based on crop yield and ET crops. The ET based crop has more water use efficiency than irrigation based crops. In case of Jute crop it was reverse as irrigation was not applied once rainfall received (Table 13).

The data presented on economic return of jute – rice and onion grown in open well command area reveals that jute crop which was taken during March end to July end produced about 3029 kg fibre yield per ha with net return of Rs 13546 per ha. After harvest of this crop Khandagiri a short duration rice variety was planted and continued up to October end and produced 3125kg/ ha grain yield with net return of Rs 9020/ ha. After *Kharif* paddy again local onion variety was taken and produced bulb yield of 6667kg/ ha with net return of Rs 45006 per ha. Thus with three crops in a year under irrigated condition about Rs 67572 /ha was obtained (Table 14). There was no severe depletion of well water depth even during hot summer month as the farmers used 2 hp kerosene operated pump when electric power supply was not regular. It is thus inferred that if groundwater is available in sufficient quantity then three crops in a year can be easily taken up provided the varieties selected are of short duration.

Table 13: Irrigation scheduling and water requirement of crops

Crop	Duration	ET crop mm	Irrigation water mm	Rainfall, mm	WUE ETcrop base Kg/ha-mm	WUE irrig. Base Kg/ha-mm
Jute	25.3.2007 to 30.7.2007	373.31	310	877	8.11	9.77
Onion	27.10.2007 to 10.3.2008	329.8	380	58	20.2	17.5
In rice crop no irrigation was applied and it was grown under rain-fed condition.						

Table- 14: *Kharif, rabi* season and summer season cropping pattern and economic return in pen well command area

Farmers	Crop name	Crop yield (kg/ ha)	Total Expenditure Rs/ ha	Gross return Rs/ ha	Net return Rs/ ha
Open well Area 2080 m^2	Jute	3029	28860	42406	13546
	Paddy	3125	12855	21875	9020
	Onion	6667	24990	69996	45006
	Jute+paddy+onion		66705	134277	67572

During the year 2008-09 experimentation jute crop was taken on 27, April 2008 after pre - sowing irrigation and subsequent one extra irrigation was given in the month of May 2008. After harvest of jute crop on 17 th August, 2008, rice seedings were grown in separate field and planted in main field on August 28, 2008 and harvested on 5th December 2008. After that onion and garlic seedling was planted on 17 th December, 2008 and harvested on April 8, 2009. From these three crops, the best combination was Jute-rice - garlic in which the total net return was Rs1, 10,839/ha (Table 15). When five irrigations was applied to onion and garlic during *rabi* and two irrigations to jute crop during summer season the groundwater remained even at shallow depth.

Table- 15 *Kharif, rabi* season and summer season cropping pattern and economic return

Open well no.1	Crop name	Crop yield (kg/ ha)	Total Expenditure (Rs/ ha)	Gross return (Rs / ha)	Net return (Rs / ha)
Total *rabi* area 2360 m^2	Jute (*Kharif*)	3000	32470	39600	17930
	Paddy *kharif*) (Naveen)	3560	19311	30260	10949
	Onion (*rabi*)	9583	29850	100621	70771
	Garlic (*rabi*)	7540	30540	112500	81960
	Green gram (*rabi*)	625	7200	25000	17800
	Jute+paddy+onion		81631	170481	99650
	Jute+paddy+garlic		82321	182360	110839
	Jute+paddy+green gram		58981	94860	46679

During 2009-10 , the farmers adopted same cropping system as they adopted like previous year in this open well command. The yield of rice variety was not satisfactory due to

delayed planting. After that onion seedling was planted on 17 th December2009 and harvested on April 8, 2010. As the planting of onion was late, the crop yield was also quite low but overall production and economic return was high as compared to single crop system. In this case the total net return of three cropping system was Rs. 103340 /ha. If garlic crop is grown under three cropping system the net return came Rs. 108405/ha (Table 16).

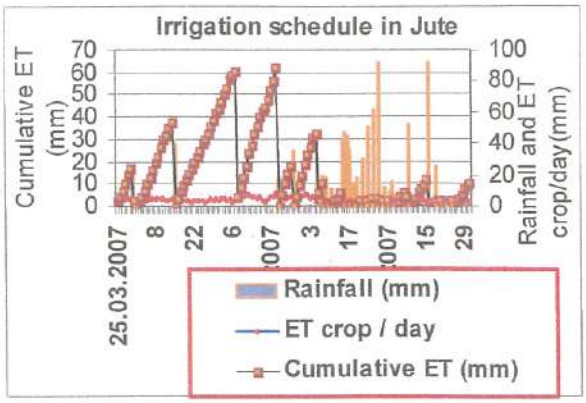
This can be further improved if Jute crop is sown early and harvested in end of July on after week of August every year. In onion crop five irrigations were provided during complete crop growth period.

Table- 16: *Kharif, rabi* season and summer season cropping pattern and economic return (open well command) 2009-10

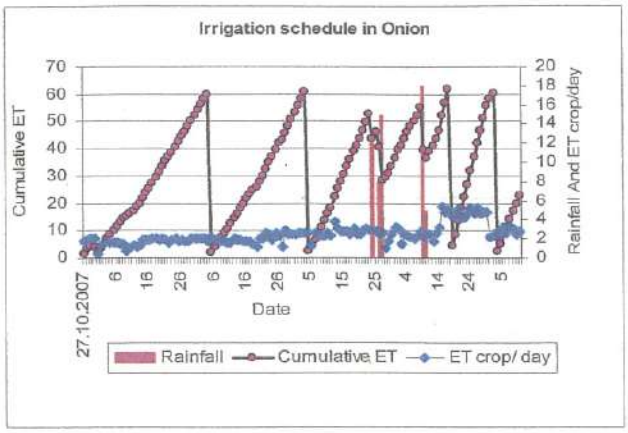
Open well no.1	Crop name	Crop yield (kg/ ha)	Total Expenditure Rs/ ha	Gross return Rs / ha	Net return Rs / ha
Total *rabi* area 2360 m^2	Jute (*Kharif*)	2840	32035	56800	24765
	Paddy *kharif* (Naveen)	3025	17750	29040	11290
	Onion (*rabi*)	9120	33035	100320	67285
	Garlic (*rabi*)	7140	34750	107100	72350
	Three cropping system (jute+paddy+ onion)		82820	186160	103340
	Three cropping system (Jute+paddy+ garlic)		84535	192940	108405

***Note**: During three years of experimentation, irrigation scheduling and water requirement of the crop has been computed. The date wise irrigation schedule is presented here for reference.*

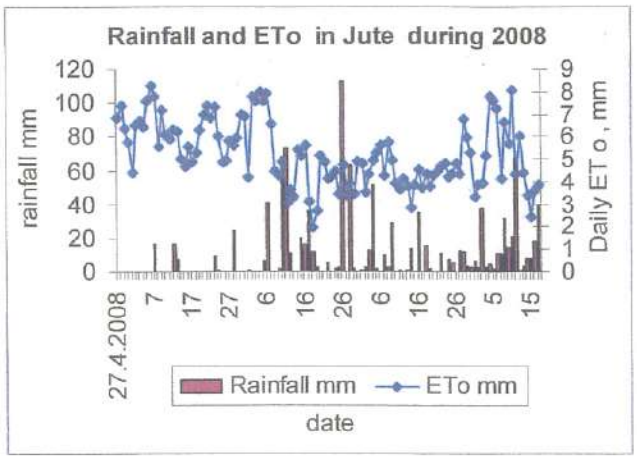
Fig.8 Includes irrigation schedule and water requirement of crops in open well no.1



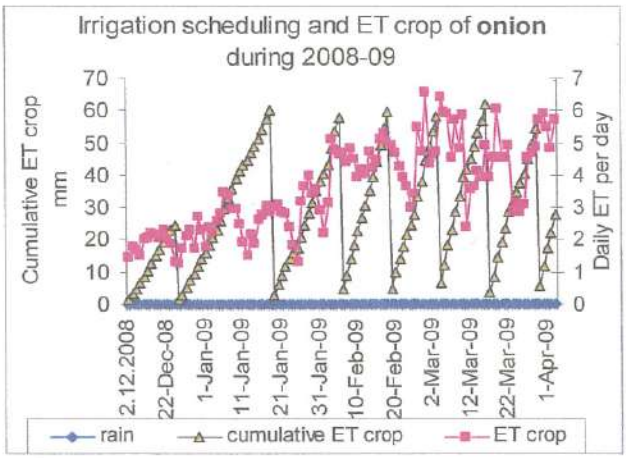
IRRIGATION IN JUTE 2007



IRRIGATION IN ONION 2007-08



IRRIGATION IN JUTE 2008



IRRIGATION IN ONION 2008-09

PHOTO NO.3 : DETAILS OF CROPS GROWN IN OPEN WELL COMMAND AREAS

CROP PHOTO:

Jute crop

Measuring water table depth in open well

Paddy crop

Onion crop

After seeing the benefit from the previous years on effective utilization of open well water for growing rabi crops, they got convinced and made another bore well on participatory basis and used open well water for rabi and summer crops during 2008-09.

b) Crop performance and economic returns of different crops in open well no.2 :

The short duration rice crop varieties *Khandagiri* was grown in open well command area during June 20, 2008 to October 9, 2008. The data on crop yield and economic return on paddy crop revealed that the grain yield of rice was 3032 kg/ha (Table 17), The net return from the paddy crop during *kharif* season was Rs.7774/ha.

After harvest of *kharif* paddy crop, different vegetable crops were grown in 1400 m^2 area with open well water. The result showed that out of all six vegetable crop, tomato gave maximum return of Rs. 41200/ha followed by potato (Rs 31180/ha). After harvest of these small duration vegetable crop, the farmers kept the land fallow due to social constraints instead of taking third crop during summer season. In this open well command area, three crops can be taken up without further reduction of groundwater table. Under two hundred percent cropping system, paddy +onion system recorded maximum net profit of Rs 49079 /ha followed by paddy + tomato (Rs. 48974 /ha).. After harvest of *rabi* vegetable, growing of summer crop is quite feasible since the field of potato and radish was almost ready for summer crop. The most profitable summer crop is bitter gourd and water melon which are very much common to this area.

Table 17: Crop performance under open well command area (open well no.2) during 2008-09

Open well no.2	Crop name	Yield (kg/ha)	Crop yield (kg/ ha)	Gross return (Rs / ha)	Total Expenditure Rs/ ha	Net return Rs / ha
Kharif season crop	rice	3032	3032	21224	13450	7774
Rabi season crops Total area 1400 m2	Radish	18750	18750	37500	17120	20380
	Cucumber	5000	5000	15000	7320	7680
	Potato	12500	12500	62500	31320	31180
	French bean	5312	5312	56250	34340	21910
	Tomato	18330	18330	73320	32120	41200
	Onion	8375	8375	58625	17320	41305
Green gram Rainfed average of 10 farmers	Green gram	371.4	371.4	14856	6477	8379

Regarding irrigation requirement of crops, water use efficiency and water productivity, underground tuber (radish, potato) crops as well as tomato had more water use efficiency, water productivity during *rabi* season (Table 18) than remaining crops. The WP in terms of net return obtained against amount of water used was highest in case of onion (Table 18 A)

Considering the net return and water use efficiency and water productivity of different crops, rice –onion, rice -tomato is highly feasible, besides radish; however the radish vegetable crop is not being cultivated extensively.

Table 18: Irrigation scheduling and water requirement of different crops under open well no. 2 command area 2008-09

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	450	450	1253.5		6.73	6.73		0.67	0.67	
***Rabi* crop**										
Radish	305	227	0	280	61.5	82.54	66.96	6.14	8.26	6.70
Cucumber	300	224	0	290	16.7	22.32	17.24	1.67	2.23	1.72
French bean	387.9	306.7	0	330	13.7	17.3	16.1	1.37	1.73	1.61
Potato	409.1	309.6	0	320	30.5	40.4	39.1	3.05	4.04	3.91
Tomato	484.5	429	0	450	37.7	42.7	40.7	3.78	4.27	4.07
Onion	462.7	362.3	0	410	18.2	23.0	20.4	2.31	1.81	2.04
Un-irrigated moong	282.3	176.6	4.9	4.9 mm rainfall only	1.3	2.1	Not computed, due no rainfed crop	0.13	0.21	Not computed, due no rain fed crop

Table 18 (A): Water productivity based on net return of different crops under open well no. 2 command area in 20908-09

Crops	Water productivity (Rs //m^3)		
	Based on ET0	Based on ET crop	Based on I+ER
Kharif Rice	1.72	1.72	-
***Rabi* crop**			
Radish	6.68	8.98	7.27
Cucumber	2.56	3.43	2.65
French bean	5.65	7.14	9.74
Potato	7.62	10.67	6.64
Tomato	8.50	9.60	9.16
Onion	9.68	11.40	10-.07
Un-irrigated moong	2.97	4.74	-

Command area of open well no.2 :

During 2009-10 in total command area of 3400 m2 different vegetables as well as one oilseed crop were grown after *kharif* rice crop. So in this open well three crops in a year is possible, provided small duration rice varieties are cultivated.

Crop performance and economic returns of different crops:

The short duration rice crop varieties *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 i.e. before introduction of the project work. During above period in case of paddy, the ET crop was 464.03 mm and reference ET0 was 454.59 mm. Since the soil profile was saturated with heavy rains most of the received rain water was non 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 19). 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 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(Fig. 20A).

The irrigation schedules followed in different vegetable crops is given in Fig. 18. The irrigation cycle is reflected in peak value shown in different graphs based on cumulative crop ET and rainfall received during the crop growth period.

Table 19: Crop performance under open well command area (open well no.2)

Open well no.2	Crop name	Crop yield (kg/ ha)	Gross return Rs / ha	Total Expenditure Rs/ ha	Net return Rs / ha
Kharif crop	rice	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 20: Irrigation scheduling and water requirement of different crops under open well no. 2 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 20 (A): Water productivity based on net return of open well no. 2 command area

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

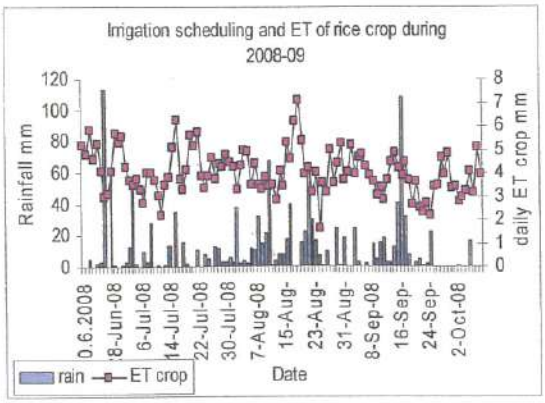
Best combination of crop with three crops:

Since different crops were grown in this open well water command, and crops has different yield potential, the rice equivalent yield was computed and economic return was analyzed statistically and presented in Table 21. Under three hundred percent cropping system (paddy + radish + bitter gourd and paddy- potato –bitter gourd the net return was Rs. 73871 to Rs. 87648/ha, respectively . If brinjal crop is grown with 200% cropping intensity then net return comes to Rs. 90,031/ha. The crop yield of bitter gourd during summer season was comparatively low hence the net return with three crops was comparatively lower than brinjal crop.

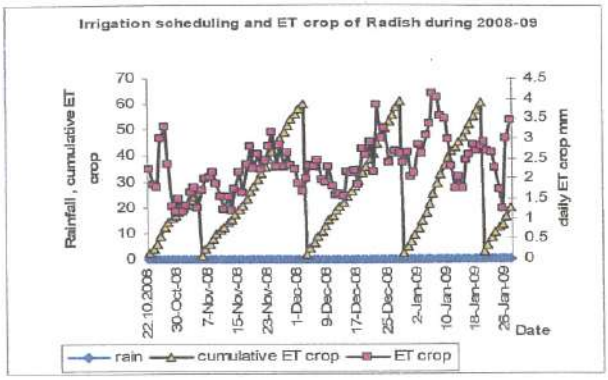
Table 21: **Suitable cropping pattern in open well command during 2008-09 and 2009-10**

Cropping pattern	Rice equivalent yield (kg/ha)		Gross return (Rs/ha)		Total expenditure (Rs/ha)		Net return (Rs/ha	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
Rice-radish	8389	8103	58724	77791	30570	36580	28154	41211
Rice -cucumber	5175		36224		20770		15454	
Rice -potato	11660	11148	83724	107016	44770	52308	38954	54708
Rice-french bean	11068		77474		47790		29684	
Rice-tomato	13506	12439	94544	119416	45570	59580	48974	59836
Rice –onion	11407	12522	79849	120211	30770	53570	49079	66641
Rice-green gram	5154		36080		19927		16153	
Rice -brinjal		14980		143811		53780		90031
Rice -chilli		12179		116916		54560		52356
Rice-ground nut		9712		93236		48680		44556
Rice-radish-bitter gourd		14353		137791		63920		73871
Rice-potato-bittergourd		17398		167016		79648		87368
CD(5%)	852	385	2506	5073	929.6	410	1106	379
CV (%)	5.0	1.78	2.11	2.43	1.52	0.42	1.92	0.34

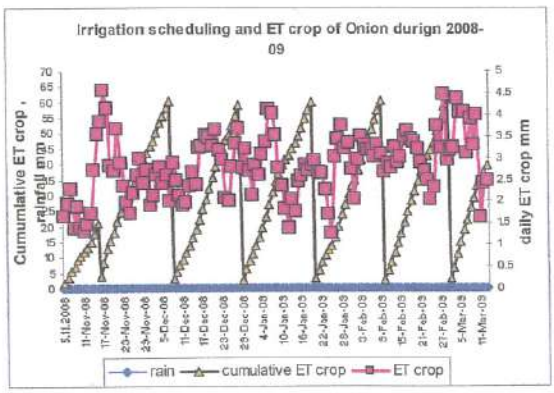
Fig. 9. Irrigation scheduling and Crop ET of different crops grown under open well command area (open well no.2) during 2008-09 and 2009-10



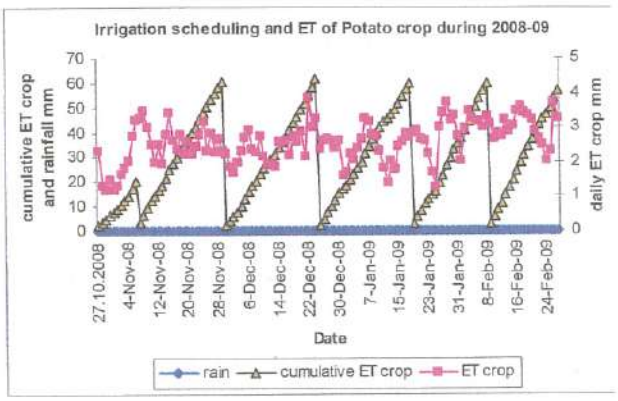
Paddy 2008



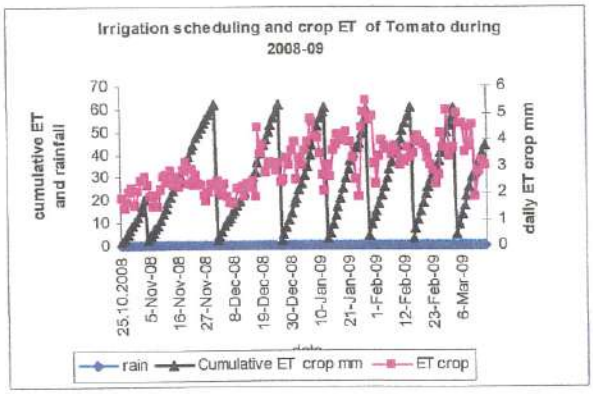
Radish, 2008-09



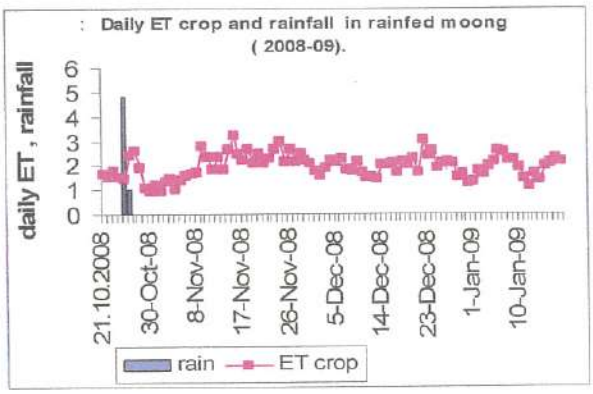
Onion 2008-09



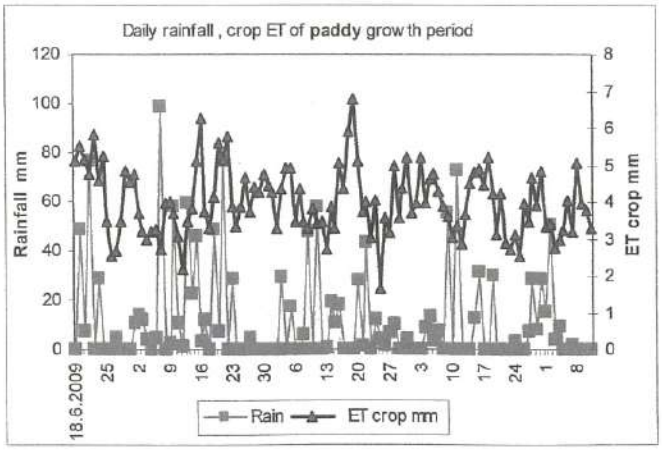
Potato 2008-09



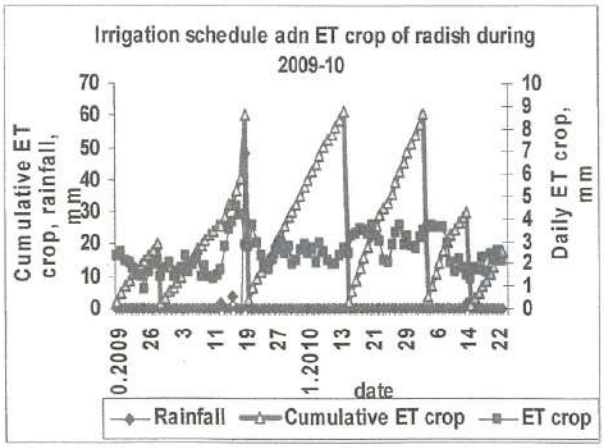
Tomato 2008-09



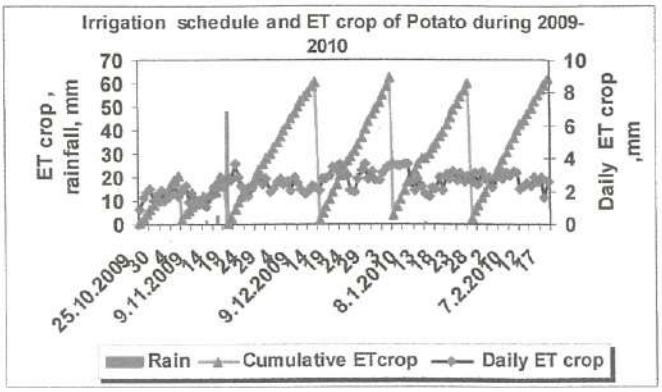
Rainfed green gram



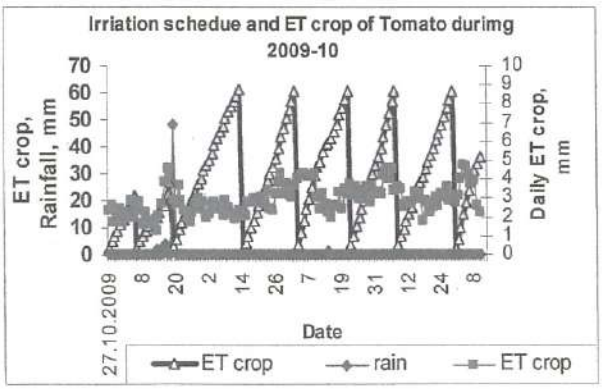
Paddy 2009-2010



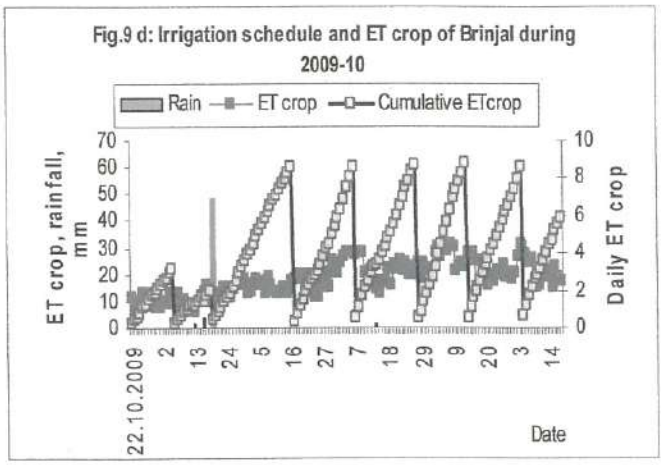
Radish 2009-2010



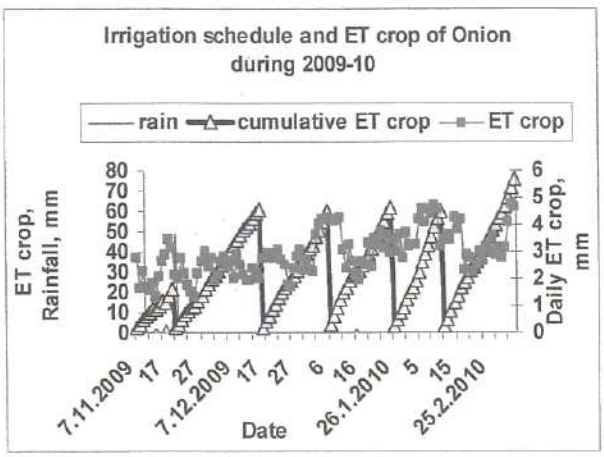
Potato 2009-2010



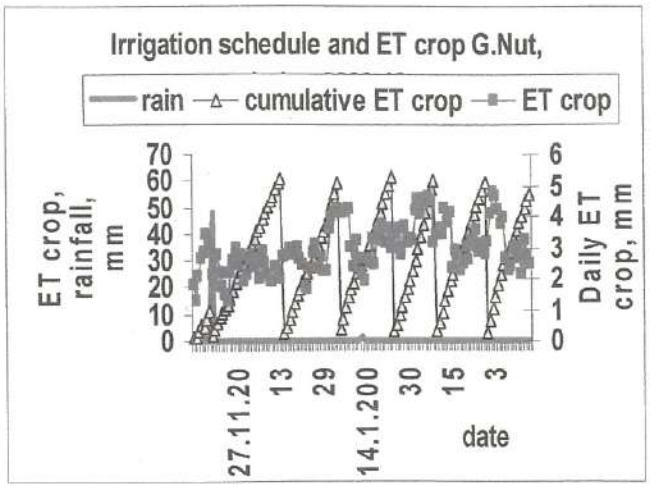
Tomato 2009-2010



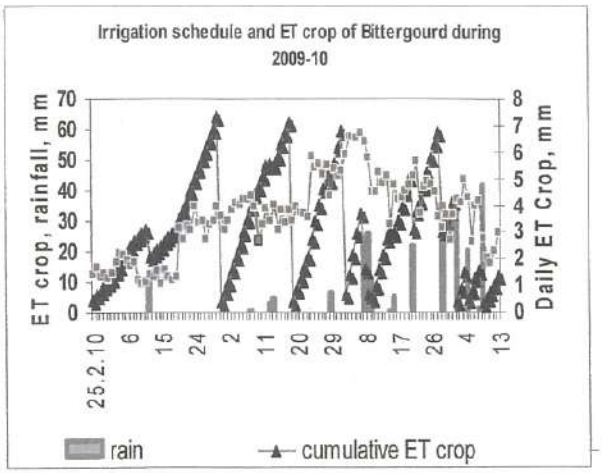
Brinjal 2009-10



Onion 2009-10



Ground nut 2009-2010



Bitter gourd 2009-2010 (summer crop)

PHOTO NO. 4 : PHOTOGRAPH OF OPEN WELL NO. 2 WITH CROPS IN COMMAND AREA

CONSTRUCTION OF OPEN WELL 2008-09

FARMER WITH FULLY CONSTRUCTED WELL

HYBRID TOMATO 2008-09

POTATO 2008-09

ONION 2008-09

HYBRID TOMATO 2009-10

POTATO 2009-10

CHILLI 2009-10

GROUND NUT 2009-10

BRINJAL 2009-10

II) *CROPPING PATTERN FOLLOWED IN BORE WELL COMMAND AREA DURING 2007-08 to 2009-10*

Report of Kharif season 2007-08

In six acres of paddy area, 18 farmers were involved. They had taken rice crop variety Moti (long duration),Naveen & Swarna (medium duration) & Satabdi (short duration) during *kharif* season 2007. At the time of nursery, they had irrigated the crops through tube well water for preparation of nursery bed & subsequently grown with rainwater. Most of the farmers had started transplanting rice seedlings in second week of July 2007 and continued up to first week of August 2007. Harvesting of paddy crops were started in October and continued even up to first week of December, 2007

The results revealed that the long duration rice variety **Moti** performed well and gave highest crop yield of 4875 kg/ha but due to high cost of cultivation, the net return was less than some of the medium duration rice varieties. The net return obtained by cultivating medium duration variety Naveen ranged from Rs 8218/ha to as high as Rs 15070 per ha. In case of variety **Swarna** the net return was Rs 9960 per ha. While the farmers who had taken short duration rice variety **Satabdi,** had obtained net return of as low as Rs 6182 to as high as Rs11189 /ha

Regarding magnitude of variations on yield and other parameters within farmers and rice varieties cultivated, there is not much variation as expressed by coefficient of vitiation with respect to crop yield as the soil variation and inputs particularly fertilizer was applied by the farmers were not differenced with higher magnitude.

Table 22: *Kharif* season Cropping pattern and economic return (Tube- well)

Farmers Sr no	Crop name and variety	Crop yield (kg/ ha)	Total Expenditure (Rs /ha)	Gross return (Rs /ha)	Net return (Rs /ha)
1	Paddy (Naveen))	4200	16750	29400	12650
2	Paddy (Naveen)	4062	15968	28434	12466
3	Paddy (Naveen)	4300	15030	30100	15070
4	Paddy (Naveen)	4375	17392	30625	13233
5	Paddy (Naveen)	4375	22407	30625	8218
6	Paddy (Naveen)	4375	21344	30625	9281
7	Paddy (Naveen)	4062	19905	28434	8529
8	Paddy (Naveen)	4375	21625	30625	9000
	Mean	**4266**	**18803**	**29859**	**11056**
	Maximum	**4375**	**22407**	**30625**	**15070**
	minimum	**4062**	**15030**	**28434**	**8218**
	Standard deviation	**140**	**2856**	**977**	**2597**
	CV(%)	**3.27**	**15.2**	**3.27**	**23.49**
9	Paddy (Satabdi)	3840	17218	26880	9662
10	Paddy (Satabdi)	3700	19718	25900	6182
11	Paddy (Satabdi)	3900	17061	27300	10239
12	Paddy (Satabdi)	3500	13311	24500	11189
13	Paddy (Satabdi)	3500	19576	24500	9924
14	Paddy (Satabdi)	3450	14686	24150	9464
15	Paddy (Satabdi)	3540	15230	24780	9550
16	Paddy (Satabdi)	3937	19311	27559	8248
	Mean	**3647**	**16985**	**25527**	**9257**
	Maximum	**3937**	**19718**	**27559**	**11189**
	minimum	**3450**	**13311**	**24150**	**6182**
	Standard deviation	**202**	**2628**	**1413**	**1620**
	CV(%)	**5.52**	**15.5**	**5.53**	**17.5**
17	Paddy (Moti)	4875	23218	34125	10907
18	Paddy(Swarna)	4250	19800	29750	9950

Report of kharif season 2008-09:

In this bore well command area, six acres of paddy area was taken for demonstration. All the farmers used bore well water for growing paddy nursery initially. Later on, rainfall was quite enough to grow rice seedlings. Canal water was available during August 2008 to November 2008. During August 2008, the canal water discharge rate was very low which was not sufficient to take transplanting operations. Hence they started transplanting with rain water.

Total amount of rainfall during July 2008 to November 2008 was 1308.40 mm as against 567.8 mm ETo of crop. During July, August and September, 2008, there was good amount of rainfall. However in the month of October 2008 and November 2008, the amount of rainfall was only 23.60 mm and nil, respectively. So to save their paddy crop about thirteen farmers with different varieties taken by them were irrigated with bore well water during October 2008 and November 2008. The depths of water applied were in the range of 14.30 to 20.1 cm with 2-3 numbers of irrigations..

The results presented in Table 23 revealed that the long duration rice variety **Moti** performed well and gave highest crop yield of 4635 kg/ha with maximum net return of Rs16799/ha. But the same variety grown without irrigation during dry spell period, gave low crop yield (3940 kg/ha) with less return. Similar was the case with remaining two varieties where the farmers had irrigated their crop, harvested very good grain yield and net return. It clearly indicates that use of groundwater during drought period has boon to the farmers.

Table 23: *Kharif* season Cropping pattern and economic return (Tube- well command)

Farmers sr no	Farmer name	Crop name and variety	Crop yield (kg/ha)	Total Expenditure (Rs /ha)	Gross return (Rs /ha)	Net return (Rs /ha)
1	Sisir kanta Kar	Paddy (Naveen)	4350 Irrg.18.4 cm	17350	30450	13100
2	Kuncha	Paddy (Naveen)	4120 irrig 17.5 cm	16350	28840	12490
3	Kuna	Paddy (Naveen)	3540	15400	24780	9380
4	Bipin	Paddy (Naveen)	3450	15750	24150	8400
5	Prafula	Paddy (Naveen)	3910 Irrig. 17.50 cm	16750	27350	10620
6	Sarat Satpathy	Paaddy Naveen	4035 Irrig 16.80 cm	16580	28245	11665
7	Hari Das	Paddy (Naveen)	3780 Irrig 16.50 cm	15680	26460	10780
8	Dushanan Jena	Paddy (naveen)	3940 Irrig 19.50 cm	18750	27580	8850
9	Bhikari Jena	Paddy (Naveen)	4175 Irrig. 14.50 cm	17100	29225	12125
10	Surendra Sathpathy	Paddy (Naveen)	3940 Irrig 17.50 cm	16800	27580	10780
11	Khageswar Sathpathy	Paddy (Naveen)	4140 Irrig 18.7cm	18750	28980	10230
		mean	**3944**	**16842**	**27604**	**10765**
		maximum	**4350**	**18750**	**30450**	**13100**
		minimum	**3450**	**15400**	**24150**	**8400**
		SD	**270**	**1120**	**1893**	**1502**
		CV %	**6.9**	**6.7**	**6.9**	**14.0**
12	Ramesh	Paddy (Moti)	4310 Irrig. 18.10 cm	17400	31894	14494

13	*Rabi* Jena	Paddy (Moti)	4635 Irrig 14.50cm	17500	34299	16799
14	Dina	Paddy (Moti)	3650	19225	29200	9975
15	Markand	Paddy (Moti)	4350 irrig. 19.50 cm	19750	32190	9975
		mean	**4236**	**18469**	**31896**	**12811**
		maximum	**4635**	**19750**	**34299**	**16799**
		minimum	**3650**	**17400**	**29200**	**9975**
		SD	**417**	**1196**	**2092**	**3407**
		CV %	**10**	**6.5**	**6.6**	**26.6**
16	Hari Das	Paddy (swarna)	3735 Irrig. 16.50 cm	16850	26145	9295
17	Duryodhan Jena	Paddy (Swarna)	3750 irrig 17.50 cm	15950	26250	10300
18	Niranjan Jena	Paddy (Swarna)	3540	15500	24780	9280
		mean	**3675**	**16100**	**25725**	**9626**
		maximum	**3750**	**16850**	**26250**	**10300**
		minimum				
		SD	**117**	**687**	**820**	**585**
		CV %	**3.2**	**4.3**	**3.2**	**6.2**

Report of kharif season 2009 -2010:

During *kharif* season in this bore well command area, total six acres and the same 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 was 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 transplanting They were dependent on rainfall for transplanting of the rice seedling though bore well water was available with them. 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 particularly variety Moti. 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 ranges 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.

The results presented in Table 24 revealed that the long duration rice variety ***Moti*** performed well and gave highest crop yield of 4860 kg/ ha with maximum net return of Rs22562/ha. But the same variety grown without irrigation during dry spell period, gave low crop yield (3700 to 3900 kg/ha) with less return. Similar situation was observed in remaining two varieties..

Table 24: *Kharif* season Cropping pattern and economic return (Tube- well command)

Farmers sl no	Farmer name	Crop name and variety	Crop yield (kg/ ha)	Total Expenditure (Rs /ha)	Gross return (Rs /ha)	Net return (Rs /ha)
1	Sisir kanta Kar	Paddy Naveen	4150 Irrg.17.3 cm	18650	39936	21286
2	Kuncha	Paddy Naveen	3840	18250	36864	18614
3	Kuna	Paddy Naveen	3425	16340	32880	16540
4	Bipin	Paddy Naveen	3562	17890	34195	16305
5	*Rabi* Jena	Paddy Naveen	4230 Irrig 15.40cm	18980	40608	21628
6	Prafula	Paddy Naveen	3790	18392	36384	17992
7	Bhikari Jena	Paddy Naveen	4275 Irrig. 8.3 cm	20900	41040	20140
8	Surendra Sathpathy	Paddy Naveen	3670	20125	35332	15207
9	*Rabi*	Paddy Naveen	3540	17230	33984	16754
10	Khageswar Sathpathy	Paddy Naveen	4380 Irrig 16.70cm	21625	42048	20423
		mean	388	18838	37327	18489
		maximum	4380	21625	42048	21628
		minimum	3425	16340	32880	15207
		SD	346	1633	3325	2279
		CV %	8.9	8.7	8.9	12.3
11	Hari Das	Paddy (Moti	4624 Irrig. 17.40 cm	21718	44852	23134
12	Ramesh	Paddy (Moti)	3900	19450	37830	18380
13	Dina	Paddy Moti	3700	21576	35890	14314
14	Markand	Paddy Moti	3850	17686	37345	19659
15	Hari Das	Paddy Moti	4860 Irrig 17.80 cm	24580	47142	22562
		mean	4187	21002	40612	19610
		maximum	4860	24580	47142	23134
		minimum	3700	17686	35890	14314
		SD	319	2600	5033	3560
		CV %	12.4	12.4	12.4	18.4
16	Dushanan Jena	Paddy Swarna	4310 Irrig 18.50 cm	19800	41376	21576
17	Duryodhan Jena	Paddy Swarna	3450	21500	33120	11620
18	Niranjan Jena	Paddy Swarna	3437	19311	32995	13684
		mean	3444	20406	33058	12652
		maximum	4310	21500	41376	21576
		minimum	3437	19311	32995	11620
		SD	500	1149	4803	5255
		CV %	14.5	5.6	14.5	41.5

COMPARATIVE PERFORMANCE OF IRRIGATED AND RAINFED RICE VARIETIES DURING 2008-09 AND 2009-2010 :

Generally most of the farmers grow paddy crops under rainfed condition. However under dry spell period, they are dependent on canal water. At tail reach area, canal water is not available in time and the crop suffers due to lack of irrigation water. During two years of experimentation, it has been observed that during crop milk and dough period (October-November), inadequate amount of rainfall adversely affected the crop yield particularly those farmers who have not applied irrigation water. The reduction in crop yield is substantial as it is shown in Table 25. Due to availability of bore well water for irrigation the farmers used that water and saved their crops from moisture stress. The variety Moti being a long duration crop performed well and recoded more crop yield as compared to remaining two varieties.

Table 25: Effect of irrigation of tube well water on crop performance and economic return

variety	2008-09				2009-2010			
	Yield (kg/ha)	Expenditure (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	Yield (kg/ha)	Expenditure (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)
Irrigated								
Moti	4432	18217	32794	14577	4624	23149	45997	22848
Naveen	4043	17123	28301	11198	4223	20038	43209	20871
Swarna	3676	17517	30837	13320	4311	19800	41375	21575
Rainfed								
Moti	3650	17225	29220	11995	3727	19570	37021	17451
Naveen	3495	15575	24465	8890	3638	17995	34556	16561
Swarna	3540	15550	24780	9230	3444	18406	33057	14651
CD(p=0.05)	271.4	2412	3208	1969	124	1780	2368	2701
CV %	7.1	14.1	11.9	18.9	2.6	7.4	5.2	12.2

Report of rabi season crops 2007-2008

After harvest of rice crop, two farmers had taken different vegetable crops viz. onion, tomato, potato during *rabi* season 2007-2008. The vegetable crops were taken in field where short duration rice variety *Satabdi* and medium duration variety *Naveen* were grown. Irrigations were provided through tube well water as per irrigation schedules. In onion the crop yields was recorded to the extent of 5000 kg/ha ha with net economic return of Rs18600/ha ha. In case of *Tomato* (variety BT 10), the crop yield was 15625 kg / ha and net return was Rs 42188/ha. In case of potato the crop yield was 19687 kg/ha and net return was Rs 34375/ha. So with rice based cropping system having bore well water two hundred percent cropping intensity with high value cash crop could be taken up provided market facility exists in nearby places particularly for tomato crop as it is highly perishable vegetable crop(Table 26).

Table- 26: *Rabi* season cropping pattern and economic return

Sl no Farmers	Crop name	Crop yield (kg/ ha)	Total Expenditure (Rs per ha.).	Gross return (Rs / ha.).	Net return (Rs per ha.).
1	Onion	5000	21400	40000	18600
	Tomato	15625	35937	78125	42188
	Potato	19687	44375	78750	34375
2	Bhendi	7500	34375	75000	40625
	Brinjal	17703	32812	194733	161921
	Chilli	2187	16354	35000	18646
Remaining 16 farmers took green gram on residual moisture					
Sr no. 3 to 18	Moong	281- 450 kg	Rs 3618 to Rs 4162	Rs 5911 to Rs 9960	Rs 2526 to Rs 5798

IRRIGATION WATER REQUIREMENT AND WATER USE EFFICIENCY RABI CROPS

Out of six vegetable crops, potato crop had highest irrigation water use efficiency, as it is modified stem and developed underground. This crop is bulky/ tuberous which has very high utilization efficiency as compared to other vegetable crops. Among all vegetable crops, green chilli had very low water use efficiency.

The water productivity (kg fruit yield/ m^3 of water used) is highest in potato followed by brinjal. The water productivity of potato in distributary's no 5 over the average of 12 villages was 4.23 kg yield/ m^3 of crop ET, but from the present study, the water productivity was enhanced to 8.413 kg fruit/m^3 of crop ET and 6.613 kg fruit/ m^3 of irrigation water applied. In other vegetable crops the water productivity of the study area was comparatively more than that of average value of 12 villages

PHOTO NO. 5: PHOTO OF TUBE WELL IRRIGATION COMMAND

KHARIF 2007

KHARIF 2007

KHARIF 2007

BHENDI 2007-08

POTATO 2007-08

BRINJAL 2007-08

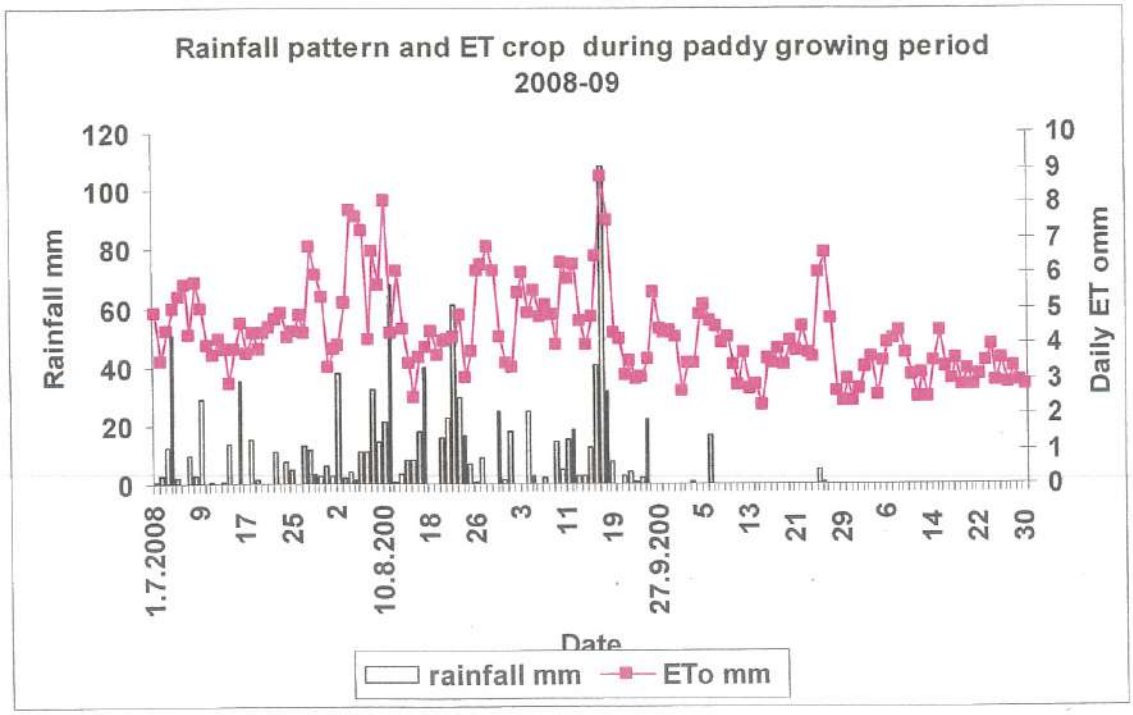
Table 27: Irrigation water use efficiency in vegetable crops

Crop name	ET crop (mm)	Irrigation water (mm)	Crop yield (kg/ha)	Irrigation water use efficiency kg fruit/ha of irrigation water (mm)		Water productivity (kg yield/ m^3 water used)	
				ET crop	Irrigation water	Through ET	Through irrigation water
Brinjal	435.40	400	17703	46.7	44.26	4.06	4.42
chili	345.37	395	2187	6.33	5.54	0.63	0.55
Bhendi	419.50	455	7500	17.88	16.48	1.78	1.64
Tomato	352.31	470	15625	44.35	33.24	4.43	3.32
potato	234.05	295	19687	84.11	66.73	8.41	6.67
Onion	329.76	380	5000	15.16	13.16	1.51	1.31

Table 28: WP based on net return under different vegetable crops.

Crop name	Water productivity (Rs / m^3 water used)	
	Through ET	Through irrigation water
Brinjal	37.19	40.48
chili	5.40	4.72
Bhendi	9.68	8.93
Tomato	11.97	8.98
potato	14.69	11.65
Onion	5.64	4.89

Fig. 10: Rainfall pattern and Crop ET of Paddy



RICE CROP *KHARIF* 2008

Report of rabi season crops (year 2008-09)

After harvest of medium duration rice variety, farmers had taken onion, tomato, potato, bhendi chilli, brinjal crops. Pre planting irrigations were given for ploughing the field. The seedlings of vegetable crops viz. tomato, onion, chilli were planted in November, 2008. The potato tuber was also planted in the same month. But the sowing of bhendi and planting of brinjal seedling was done in the month of January, 2009. Irrigations were provided through tube well water as per irrigation schedules i.e at 60 mm cumulative crop ET. But at initial period, frequent irrigation was provided i.e at 20-25 mm cumulative crop ET for proper establishment of seedlings.

The result presented in Table 29 on crop yield and economic return of various vegetable crops grown through bore well water during *rabi* and summer season, reveals that among all vegetable crops, brinjal crop gave more profit i.e. Rs 76530/ha followed by bhendi (Rs 57390/ ha.). Tomato crop is also performed well and produced good return. So with rice based cropping system having bore well water two hundred per cent cropping intensity with high value cash crop could be taken up.

Table- 29 *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.).
Sarat Satpathy	Tomato	19350	33240	77400	44160
Sisir Kant Kar	Bhendi	8340	34350	91740	57390
	Brinjal	18480	34350	110880	76530
	Onion	7530	16400	52710	36310
	Potato	14120	32350	70600	38250
	Chili	1820	33250	72800	39550

IRRIGATION REQUIREMENT AND WATER USE EFFICIENCY OF DIFFERENT VEGETABLE CROPS DURING 2008-09

Initially reference crop ET was computed and with the help of crop coefficient value, actual crop ET was calculated and irrigation scheduling was followed based on cumulative crop ET. Since brinjal and bhendi crops were grown during January 2009 onwards, where high water demand occurred and being a long duration crops, the irrigation requirement as well as reference crop ET was more than remaining vegetable crops, grown during November 2008-March/ April 2009 (Table 30 and 31). In case of Bhendi the irrigation requirement was 520 mm, and in Brinjal, it was 690 mm, besides good amount of rainfall of 24.8mm and 342.4mm respectively. The water use efficiency and water productivity in tomato, potato and brinjal was higher than remaining vegetable crops as these three crops are more perishable and retain more water.

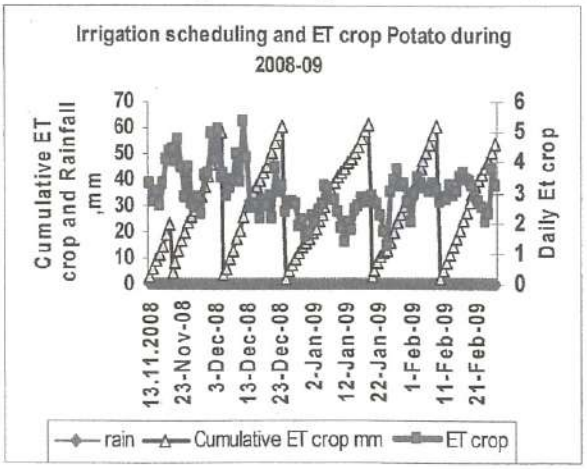
Table 30: Irrigation requirement, water use efficiency in different crops grown under bore well command during 2008-09.

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
***Rabi* crop**										
Potato	353.6	319.0	0	380	39.9	44.3	37.2	4.0	4.4	3.2
Onion	466.3	366.8	3.6	483.6	16.1	20.5	15.6	1.61	2.1	1.57
Tomato	435.3	342.7	3.6	463.6	44.4	56.5	41.7	4.4	5.6	4.2
Bhendi	527.7	452.7	24.8	544.8	15.8	18.9	15.3	1.58	1.8	1.5
Chilli (dry)	468.3	440.6	3.6	523.6	3.9	4.1	3.5	0.4	0.41	0.35
Brinjal	918.9	765.3	342.4	1032.4	20.1	24.1	17.9	2.01	2.41	1.79

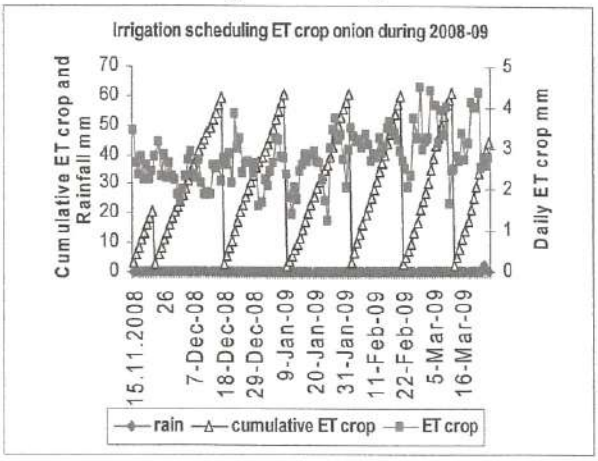
Table 31:Water productivity based on net return in different crops grown under bore well command during 2008-09.

Crops	Water productivity (Rs /m^3)		
	ET0	ET crop	I+ER
Potato	10.82	11.99	10.06
Onion	7.79	9.90	7.51
Tomato	10.14	12.88	9.52
Bhendi	10.87	12.68	10.53
Chilli (dry)	8.44	8.98	7.55
Brinjal	8.33	10.00	7.41

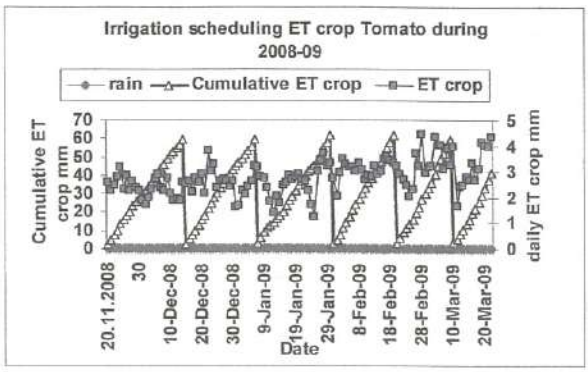
Fig 11: Irrigation schedule, crop ET of different vegetable crops.



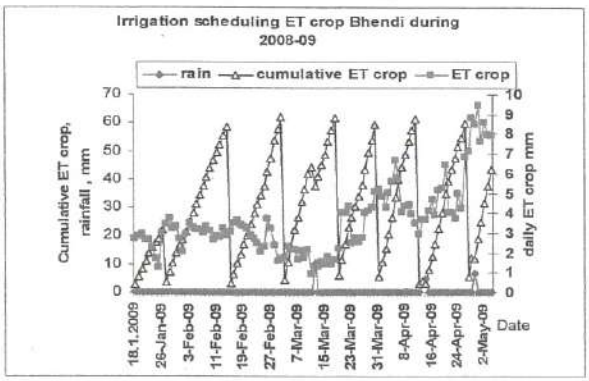
POTATO 2008-09



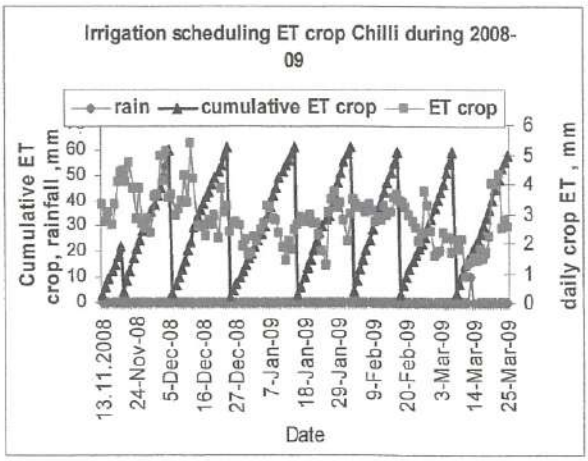
ONION 2008-09



TOMATO 2008-09



BHENDI 2009



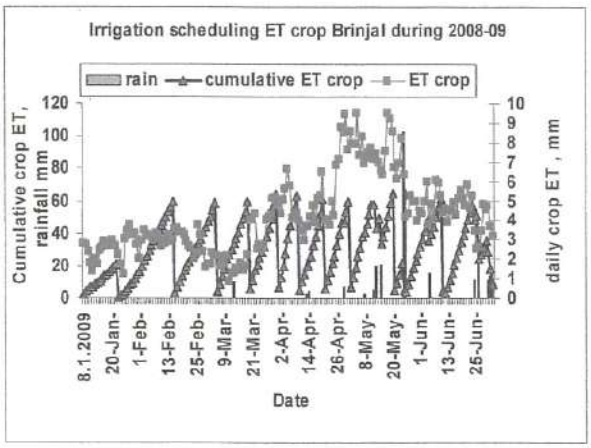


PHOTO NO. 6 : PHOTO OF RABI CROPS IN TUBE WELL IRRIGATION COMMAND AREA:

POTATO 2008-09

TOMATO (Hybrid) 2008-09

BRINJAL 2009

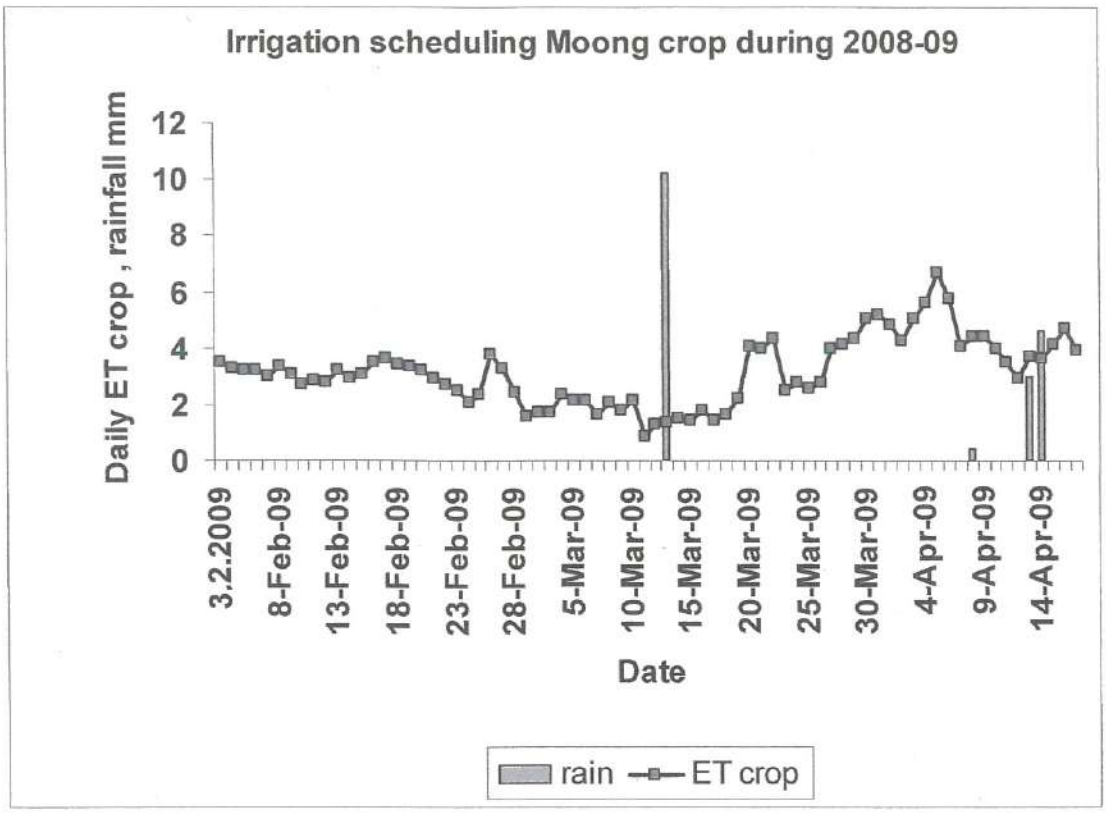
BHENDI 2009

Report of summer green gram(2008-09):

Due to development of bore well in this area, the farmers irrigated their field during second to third week of January 2009. All farmers completed their sowing in first week of February 2009. The total depth of irrigation water given as pre sowing irrigation ranged from 12.5 cm to 20.5 cm. Very heavy depth of water was given by the farmers, because the field was totally dry as paddy crop was harvested in November end to first week of December 2008.

The result revealed that the yield of irrigated moong crop grown in 3.52 ha area ranged from 550 kg/ha to 856kg/ha with net return of Rs 12120 to Rs 22900/ha. However, under un-irrigated condition the crop yield was very low and it ranged from 310 kg/ha to 480 kg/ha. The net economic return ranged from 6826 /ha to 13420 /ha. For harvesting potential crop yield of this crop, one pre-sowing irrigation and another during 35-40 days after sowing is essential. Total crop ET during growing period of 74 days (3 Feb. to 17 th April 2009) was 263.5 mm with a rainfall of 18.3 mm..

Fig. 12 : Rainfall and crop ET of green gram



CROPPING PATTERN FOLLOWED IN BORE WELL COMMAND AREA AND ECONOMIC RETURN OF CROPPING SYSTEM DURING 2009-2010

(b) *Rabi* season crops 2009-2010

After harvest of rice crop, two farmers had taken tomato, potato, brinjal, bhendi crops. Irrigations were provided through tube well water as per irrigation schedules. The crop yields of potato was 18350 kg /ha with net economic return of Rs 28280/ha(Table 31).In case of tomato (Hybrid) the crop yield was 15670 to 17750 kg/ha with net return of Rs 26560 to 34110/ ha. Among all vegetable crops, brinjal crop gave more profit (Rs 75270/ha) followed by bhendi (Rs 57780 per ha.)

Table- 31 *Rabi* season cropping pattern and economic return

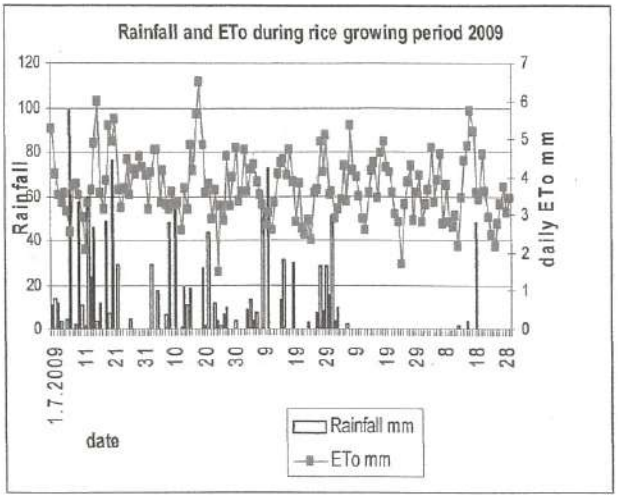
Sr no Farmers	Crop name	Crop yield (kg/ ha)	Total Expenditure (Rs per ha.).	Gross return (Rs per ha.).	Net return (Rs per ha.).
1) Sarat Satpathy	Tomato	17750	36890	71000	34110
2) Sisir Kant Kar	Bhendi	8430	36950	94730	57780
	Brinjal	15650	34280	109550	75270
	Tomato	15670	36120	62680	26560
	Potato	18350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

RABI GREEN GRAM :

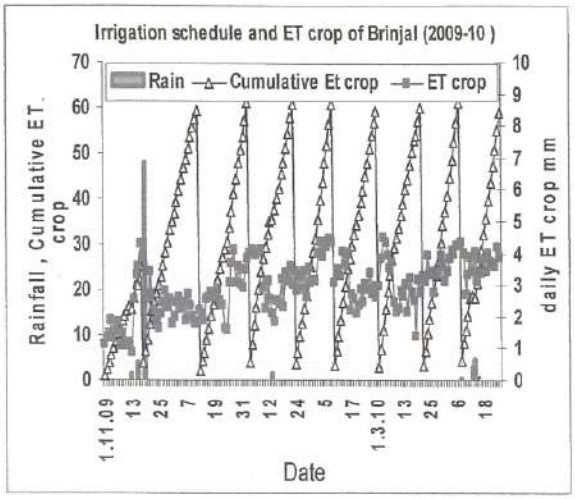
After harvest of *kharif* rice crop, the farmers irrigated their field for growing green gram (moong) during summer season. During January month every year, canal water is released and the command area is irrigated with canal water for growing green gram But in this tail reach area canal water does not reach and the farmers grow this crop on residual moisture and harvest very low crop yield. Due to development of bore well in this area, the farmers irrigated their field during second to third week of January 2010 and prepared their field for sowing green gram. The total depth of irrigation water given as pre-sowing irrigation was 9.45 cm to 22. 5 cm Very heavy depth of water was given by the farmers, because the field was totally dry as paddy crop was harvested in November end to first week of December 2009.

The data given in annual report 2009-2010 revealed that the yield of irrigated green gram, grown in 3.52 ha area ranged from 478 kg/ha to 832 kg/ha with net return of Rs 11640 to 26200 /ha. However, under un irrigated condition the crop yield was very low and it ranged from 271 kg/ha to 450 kg/ha with net return of Rs 5510 to Rs 13275/ha.. So for harvesting potential crop yield of this crop, one pre sowing irrigation and another during 35-40 days after sowing is essential. Total crop ET during growing period of 75 days (Jan. 25 th to 10 th April 2010) was 213.36 mm.

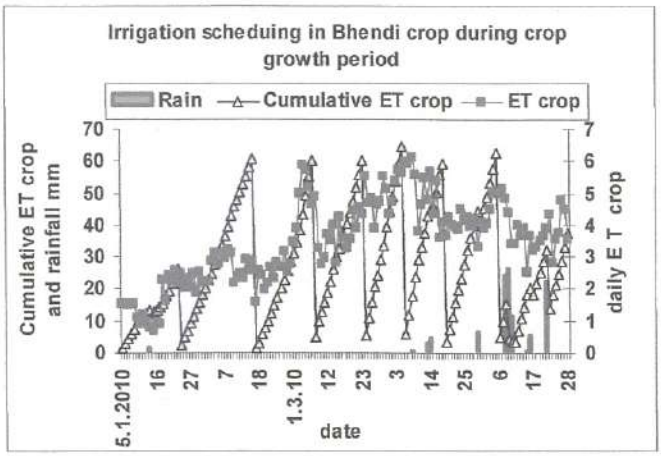
Fig. 13. Rainfall anf ETcrop of rice and different vegetable crops



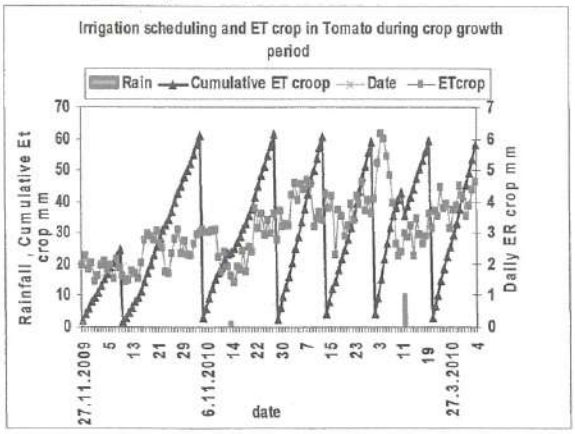
***Kharif* rice ETo, rainfall 2009**



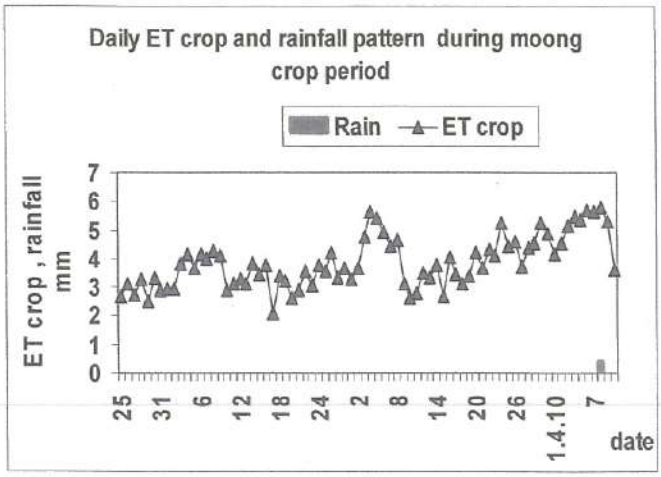
Brinjal ET, rainfall 2009-10



ET crop, rainfall in Bhendi 2009-10



ET crop, rainfall Tomato 2009-10



Green gram 2010

PHOTO NO.7: PHOTO OF RICE AND VEGETABLE CROPS (2009-2010)

Rice variety: Moti

Rice variety: Naveen

Hybrid Tomato 2009-10

BRINJAL (Var. GREEN STAR) 2009-10

BHENDI 2009-10

POTATO 2009-2010

EFFECT OF FERTILISER APPLICATION ON CROP YIELD AND FERTILISER PRODUCTION EFFICIENCY

i)Kharif season 2007-08

The results presented in Table 32 reveals that about 47.1 to 47.5kg N /ha was applied in Satabdi, 61.0kgN/ha in Naveen and Swarna and 70.5kg N /ha in Moti. The sources of nitrogenous fertilizer was gromer (grade 28:28:0 N, P_2O_5 K_2O) and FYM (0.5 %,0.2 % and 0.5% N,P_2O_5 K_2O respectively). But the source of phosphorus was solely gromer & also FYM. For potassium the fertilizer used was muriate of potash and FYM and application rate was 45.3kg K_2O/ha to 45.8kg/ha in Satabdi, 56.8kg/ha in Naveeen / Swarna and 64.6kg/ha in Moti.

Nitrogen response in Naveen & Satabdi was quite high followed by Moti. Similar was the case with respect to phosphorus and potassium except in one of the farmer's field, it was lower than rice variety Moti.

As a general practices, it has been observed that most of the farmers are applying good amount of nitrogen & potassium but very low amount of phosphorus. Since the soil is acidic in reaction (pH <6.0), the availability of applied phosphorus is further reduced due to fixation of phosphorus with Fe & Mn, which are available in sufficient quantity in acidic soil. So the results on fertilizer response can be properly assessed and recommended for efficient use of fertilizer in rice field.

The results from the Table 32 reveals that about 57.8 to 69.5kg N per ha in Moti, 46.1 to 60.9 kgN/ ha in Naveen and 48.1 to 49.5 kg/ha in Swarna was applied. The response to applied Nitrogen was comparatively higher in irrigated through bore well to rice variety Moti as compared to the same variety which was not irrigated during dry spell. Similar was the case with respect to phosphorus and potassium. The sources of nitrogenous fertilizer was gromer (grade 28:28:0 N, P_2O_5 K_2O) and FYM (0.5,0.2 and 0.5% N,P_2O_5 K_2O). But the sources of phosphorus were solely through gromer & also through FYM. For potassium the fertilizer used was muriate of potash and FYM. The application rate of phosphorus was 17.2 to 24.6 kg/ha in Moti, 16.8 to 18.4 kg/ha in Naveen and 18.5 to 20.8 kg/ha in Swarna varieties. In case of potassium application, it was applied at the rate of 55.4 to 55.8 kg/ha in Moti, 48.6 to 56.6 kg/ha in Naveen and 46.8 to 49.5 kg/ha in Swarna. The response of the applied nitrogen to grain yield in Moti variety was 59.8 to 70.6 kg grain per kg of applied nitrogen. in rice variety Naveen and Swarna it was 59.3 to 86.7 kg grain per kg of applied nitrogen and 69.7 to 76.8 kg grain per kg of applied nitrogen, respectively. In case of Phosphorus, it was 182.2 to 255.5 kg grain per kg of applied P in Moti, 122.3 to 232.7 232 kg grain per kg of applied P in Naveen and 185.8 to 211.3 kg grain per kg of applied K in Swarna variety. The grain yield with application of potassium was also seen with good response. Application of irrigation water during dry spell period had good impact on N response..

ii)Kharif season 2008-09

At the time of transplanting and at 35-40 days and 55-60 days after planting the farmers applies fertilizer to different varieties as the long duration rice variety i.e. Moti, requires more dose of fertilizer, most of the farmers have applied fertilizer as per recommended dose of fertilizer, but the dose of phosphorus given to paddy crop is very low (Table 33). Application of nitrogen dose given by different farmers was 47.3 to 58.2 kg/ ha in Naveen, 47.3 to 57.3 kg/ha in Swarna and 61.3 to 67.9 kg/ha in Moti. The phosphorus application in corresponding varieties were 16.6 to 20.3 kg/ha in Naveen, 17.4 to 19.4 kg/ha in Swarna and 19.4 to 22.8 kg/ha in Moti. The application of potassium was 45.3 to 57.6 kg/ha, in Naveen, 45.3 to 50.6 kg/ha in Swarna and 47.3 to 54.8 kg/ha in Moti. Application of potassium dose in rice varieties was adequate, but the amount of nitrogen and phosphorus was low.

The results presented in Table 33 on fertilizer response reveals that the response to applied nitrogen was comparatively higher in irrigated through bore well to rice variety Moti as compared to the same variety which was not irrigated during dry spell. Similar was the case with respect to phosphorus and potassium. This clearly indicate that availability and utilization efficiency is high under adequate moisture environment. So for better crop growth and yield, supplemental irrigation through bore well water is desirable which can improve fertilizer use efficiency in rice field.

iii)Kharif season 2009-2010

As a general practices, it has been observed that most of the farmers are applying good amount of nitrogen & potassium but very low amount of phosphorus. Since the soil is acidic in reaction (pH <6.0), the availability of applied phosphorus is further reduced due to fixation of phosphorus with Fe & Mn, which are available in sufficient quantity in acidic soil. So the results on fertilizer response can be properly assessed and recommended for efficient use of fertilizer in rice field.

The results from the Table 34 reveals that about 57.8 to 69.5kg /ha in Moti, 46.1 to 60.9 kgN/ ha in Naveen and 48.1 to 49.5 kg/ha in Swarna was applied. The application rate of phosphorus was 17.2 to 24.6 kg/ha in Moti, 16.8 to 18.4 kg/ha in Naveen and 18.5 to 20.8 kg/ha in Swarna varieties. In case of potassium application, it was applied at the rate of 55.4 to 55.8 kg/ha in Moti, 48.6 to 56.6 kg/ha in Naveen and 46.8 to 49.5 kg/ha in Swarna. The response to applied Nitrogen was comparatively higher in irrigated through bore well to rice variety Moti as compared to the same variety which was not irrigated during dry spell. Similar was the case with respect to phosphorus and potassium. The response of the applied nitrogen to grain yield in Moti variety was 59.8 to 70.6 kg grain per kg of applied nitrogen. In rice variety Naveen and Swarna it was 59.3 to 86.7 kg grain per kg of applied nitrogen and 69.7 to 76.8 kg grain per kg of applied nitrogen, respectively. In case of Phosphorus, it was 182.2 to 255.5 kg grain per kg of applied P in Moti, 122.3 to 232.7, 232 kg grain per kg of applied P in Naveen and 185.8 to 211.3 kg grain per kg of applied K in Swarna variety. The grain yield with application of potassium was also seen with good response.

Table 32: Response of Fertilizer on paddy crops during *kharif* season 2007-08

Farmers Name	Variety	Paddy yield kg/ha	Nutrients applied kg/ha			Nutrient response (kg of grain yield /kg of nutrient applied		
			N	P_2O_5	K_2O	N	P_2O_5	K_2O
Sisir kanta Kar	Naveen	4200	60.9	18.4	56.6	69.0	227.9	74.2
Bipin	Naveen	4062	61.0	18.8	56.8	66.6	216.6	71.6
Abhi	Naveen	4300	61.0	18.8	56.8	70.5	229.3	75.8
Prafula	Naveen	4375	60.9	18.4	56.6	71.9	237.4	77.3
Rabi	Naveen	3540	61.0	18.8	56.8	58.0	188.8	62.4
Bhikari ena	Naveen	4375	47.3	18.4	56.6	71.9	237.4	77.1
Duryodhan Jena	Naveen	4375	47.5	18.8	56.8	71.7	233.3	77.1
Surendra Sathpathy	Naveen	4063	47.5	18.43	56.6	66.7	220.4	71.8
Khageswar Sathpathy	Naveen	4375	61.0	18.75	56.8	71.7	233.3	77.1
	Mean	4185	56.5	18.6	56.7	68.7	224.9	73.8
	minimum	3540	47.3	18.4	56.6	58.0	188.8	62.4
	Maximum	4375	61.0	18.8	56.8	71.9	237.4	77.3
	SD	274.7	6.8	0.2	0.1	4.5	15.3	4.8
	CV (%)	6.6	12.6	1.1	0.2	6.6	6.8	6.6
Kuncha	Satabdi	3840	47.3	13.5	45.5	81.3	284.4	84.4
Hari Das	Satabdi	3700	47.5	14.1	45.8	77.9	262.0	80.9
Ramesh	Satabdi	3900	47.5	13.2	45.4	82.1	295.9	86.0
Kuna	Satabdi	3500	47.1	13.8	45.6	74.3	253.4	76.7
Dina	Satabdi	3500	47.4	13.8	45.6	73.9	253.4	76.7
Markand	Satabdi	3450	47.0	12.9	45.3	73.4	268.1	76.2
Niranjan Jena	Satabdi	3938	47.1	13.5	45.5	83.3	291.7	86.5
	Mean	3690	47.3	13.5	45.5	78.0	272.7	81.1
	minimum	2450	47.0	12.9	45.3	73.4	253.4	76.2
	Maximum	3938	47.3	14.1	45.8	83.4	295.9	86.5
	SD	207.4	0.2	0.4	0.2	4.2	17.9	4.6
	CV (%)	5.6	0.4	3.0	0.4	5.4	6.6	5.7
Hari Das	Moti	4875	70.5	22.6	64.6	69.1	216.1	75.4
Dushanan Jena	Swarna	4250	60.9	18.4	56.6	69.82	230.6	75.1

Table 33: Response of Fertilizer on paddy crops during *kharif* season (2008-09)

Name of farmer	Crop/ variety	Fertiliser applied (kg/ha)				Nutrient response (kg of grain yield /kg of nutrient applied		
		Grain yield kg/ha	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Sisir kanta Kar	Naveen	4350 Irrg	61.3	20.4	57.6	70.9	213.2	75.2
Kuncha	Naveen	4120 irrig.	59.3	19.6	45.3	69.5	210.2	90.5
Kuna	Naveen	3540	47.5	17.3	49.5	74.5	204.6	71.5
Bipin	Naveen	3450	60.2	17.8	54.9	57.3	193.8	62.8
Prafula	Naveen	3910 irrig.	53.4	17.9	53.4	73.2	218.4	73.2
Bhikari Jena	Naveen	4175Irrig.	48.4	18.3	48.6	86.3	228.1	85.9
Surendra Sathpathy	Naveen	3940 irrig	54.3	16.5	54.3	72.6	238.8	72.6
Khageswar Sathpathy	Naveen	4140Irrig	57.4	18.3	54.2	72.1	226.3	76.4
Sarat Satpathy	Naveen	4035Irrig	58.2	20.3	53.4	69.3	198.8	75.6
	mean	3962	55.6	18.5	52.4	71.7	214.7	76.0
	maximum	4350	61.3	20.4	57.6	86.3	238.8	90.5
	min	3450	47.5	16.5	45.3	57.3	193.8	62.8
	SD	296.1	5.0	1.3	3.9	7.4	14.7	8.1
	CV%	7.5	9	7.3	7.3	10.4	6.8	10.6
Niranjan Jena	Swarna	3540	47.3	17.4	45.2	74.8	203.4	78.2
Hari Das	Swarna	3735Irrig.	54.3	16.4	48.2	68.8	227.7	77.5
Duryodhan Jena	Swarna	3750	51.3	18.4	47.3	73.1	203.8	79.3
Dushanan Jena	Swarna	3750Irrig	57.3	19.4	50.6	65.4	193.4	74.1
	mean	3694	52.6	17.9	47.8	70.5	207.1	77.3
	maximum	3750	57.3	19.4	50.6	73.1	227.7	77.5
	min	3540	47.3	16.4	45.2	65.4	193.4	74.1
	SD	102.7	4.3	1.3	2.2	4.2	14.6	75.3
	CV%	2.8	8.1	7.2	4.7	6	7	2.9
Rabi Jena	Moti	4635 Irrig	63.8	21.6	47.3	72.6	214.6	98.0
Ramesh	Moti	4310 irrig.	67.9	22.8	54.8	63.5	189.0	78.5
Dina	Moti	3650	65.9	19.4	48.2	55.4	188.1	75.7
Markand	Moti	4350 irrig	64.3	21.4	54.3	67.6	203.3	80.1
Rabi	Moti	4635 irrig	67.8	21.4	55.3	68.4	216.6	83.8
Hari Das	Moti	3780	61.3	20.4	51.4	61.7	185.3	73.5
	mean	4145	65.4	21.1	52.8	63.3	196.5	78.3
	maximum	4635	67.9	22.8	55.3	68.4	216.6	83.8
	minimum	3650	61.3	19.4	48.3	55.4	185.3	73.5
	SD	414.6	2.8	1.3	3	5.2	13.3	4
	CV%	10	4.2	6	5.7	8.3	6.7	5.1

Table 34: Response of Fertilizer on paddy crops during *kharif* season (2009-10)

Farmers Name	Variety	Paddy yield kg/ha	Nutrients applied kg/ha			Nutrient response (kg of grain yield /kg of nutrient applied		
			N	P_2O_5	K_2O	N	P_2O_5	K_2O
Sisir kanta Kar	Naveen	4150 Irrg	62.9	19.4	57.6	65.98	213.9	72.04
Kuncha	Naveen	3840	49.3	16.5	44.5	77.9	232.7	86.3
Kuna	Naveen	3425	46.1	16.8	48.6	74.3	203.9	70.5
Bipin	Naveen	3562	56.0	18.0	55.8	63.6	197.9	63.8
Abhi	Naveen	4230 Irrig	60.0	19.8	46.8	70.5	213.6	90.4
Prafula	Naveen	3790	56.9	18.9	55.6	66.6	200.5	68.2
Rabi	Naveen	3540	60.0	17.8	52.8	59.3	200.0	67.0
Bhikari Jena	Naveen	4275 Irrig.	49.3	19.4	52.6	86.7	220.4	81.3
Surendra Sathpathy	Naveen	3670	49.5	17.4	55.6	74.1	210.6	66.0
Khageswar Sathpathy	Naveen	4380 Irrig	62.0	19.7	55.8	70.6	122.3	78.5
	mean	3886	55.2	18.4	52.6	71	201.6	74.4
	maximum	4380	62.9	19.8	57.6	86.7	232.7	90.4
	minimum	3425	46.1	16.5	44.5	59.3	122.3	63.8
	SD	346.2	6.1	1.2	4.5	7.8	29.8	9.2
	CV(%)	8.9	11.1	6.7	8.5	11	14.8	12.3
Hari Das	(Moti	4624 Irrig.	65.5	18.1	55.8	70.6	255.5	82.9
Ramesh	Moti	3900	57.8	17.2	55.4	67.5	226.7	70.4
Dina	Moti	3700	61.9	18.8	46.6	59.8	196.8	79.4
Markand	Moti	3850	62.0	20.9	52.3	62.1	182.2	73.6
Hari Das	Moti	4860 Irrig	69.5	24.6	65.6	69.9	197.6	74.1
	mean	4187	63.3	19.9	55.1	66.0	211.8	76.1
	maximum	4860	69.5	24.6	65.6	86.7	255.5	90.4
	minimum	3700	57.8	17.2	46.6	59.8	182.2	70.4
	SD	518.9	4.4	3	6.9	4.8	29.3	5
	CV(%)	12.4	6.9	14.8	12.6	7.3	13.8	6.6
Dushanan Jena	Swarna	4310 Irrig	56.1	20.4	51.6	76.8	211.3	83.5
Duryodhan Jena	Swarna	3450	49.5	20.8	46.8	69.7	165.9	73.7
Niranjan Jena	Swarna	3437	48.1	18.5	49.5	71.5	185.8	69.4
	mean	3732	51.2	19.9	49.3	72.7	187.7	75.5
	maximum	4310	56.1	20.8	51.6	76.8	211.3	83.5
	minimum	3437	48.1	18.5	46.8	69.7	165.9	69.4
	SD	500.3	4.3	1.2	2.4	3.7	22.8	7.2
	CV(%)	13.4	8.3	6.2	4.9	5.1	12.1	9.6

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 open well no. 1 command area where three crops were taken in a year with good amount of open well water with efficient management of irrigation water , the benefit incurred was quite high in case of jute during May to August, paddy during post rainy season and garlic during rabi season . So within a year itself, the investment made for construction of open well was recovered. In this project area in shallow depth open well, very less expenditure was incurred and good amount of ground water was recharged at faster rate due to canal water flow(Table 35). Similarly in open well no. 2, where 1400 m2 area was taken up and 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 35: Benefit cost ratio under open well irrigation command (open well no.1)

Open well no.1	Crop name	Net return Rs / ha (2008-09)	Net return Rs / ha (2009-10)	Average of two years	BC ratio 2008-09	BC ratio 2009-10	Average
Total *rabi* area 2360 m^2	Jute (*Kharif*)	17930	24765	21348	0.53	0.74	0.63
	Paddy *kharif*) (Naveen)	10949	11290	11120	0.32	0.34	0.33
	Onion (*rabi*)	49320	67285	69028	2.10	2.00	2.05
	Garlic (*rabi*)	81960	72350	77155	2.44	2.15	2.29
	Green gram (*rabi*)	17800	-	17800	0.53	-	0.53
Crop sequences	Jute+paddy +onion	99650	103340	101495	2.96	3.07	3.02
	Jute +paddy +garlic	110839	108405	109622	3.29	3.22	3.26
	Jute+paddy+green gram	46679	-	46679	1.39	-	1.39

Table 36 Benefit cost ratio under open well irrigation command (open well no.2)

Open well no.2	Crop name	Net return Rs / ha (2008-09)	Net return Rs / ha (2009-10)	Average of two years	BC ratio 2008-09	BC ratio 2009-10	Average
Total kharif paddy area and *rabi* area 1400 m^2	Paddy(*kharif*)	7774	11186	9480	0.33	0.47	0.48
	radish (*rabi*)	20380	30025	25203	0.85	1.26	1.05
	Cucumber (*rabi*)	7680	-	7680	0.32	-	0.32
	Potato (*rabi*)	31180	43522	37351	1.30	1.82	1.56
	French bean(rabi)	21910	-	21910	0.92	-	0.92
	Tomato(rabi)	41200	48650	44925	1.72	2.03	1.88
	Onion (rabi)	41350	55455	48380	1.73	2.32	2.02
	Green gram (rabi)	8379	-	8379	0.35	-	0.35
	Bitter gourd (summer)	-	32860	32860	-	1.37	1.37
	Brinjal (rabi)	-	78845	78845	-	3.30	3.30
	Chilli(rabi)	-	51170	51170	-	2.14	2.14
	Ground nut (rabi)	-	33375	33375	-	1.40	1.40
Crop sequences And net return	Rice +radish	28154	41211	34683	1.18	1.72	1.45
	Rice +cucumber	15454	-	15454	0.65	-	0.65
	Rice +potato	38954	54798	46831	1.63	2.29	1.96
	Rice+French bean	29684	-	29684	1.24	-	1.24
	Rice+tomato	48974	59836	54405	2.05	2.50	2.27
	Rice+onion	49079	66641	57860	2.05	2.79	2.42
	Rice+green gram	16153	-	16153	0.68	-	0.68
	Rice+brinjal	-	90031	90031	-	3.76	3.76
	Rice+radish+bittergourd	-	74071	74071	-	3.10	3.10
	Rice+potato +bitter gourd	-	87568	87568	-	3.66	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 37)

Table 37: Benefit cost ratio under bore well command during 2008-09 and 2009-10

Bore well	Crop name	Net return Rs / ha (2008-09)	Net return Rs / ha (2009-10)	Average of two years	BC ratio 2008-09	BC ratio 2009-10	Average
Kharif and rabi crops	Paddy *kharif*) (Naveen)	11067	16917	13992	0.46	0.71	0.58
	Tomato (rabi)	44160	34110	39135	1.85	1.43	1.64
	Bhendi (*rabi*)	57390	57780	57585	2.40	2.42	2.41
	Brinjal (*rabi*)	76530	75270	75900	3.20	3.15	3.17
	Onion(*rabi*)	36310	-	36310	1.52	-	1.52
	Potato (rabi)	38250	26560	32405	1.60	1.11	1.35
	Chilli (rabi)	39550	-	39550	1.65	-	1.65
Crop sequences	Paddy + tomato	55227	51027	53127	2.31	2.13	2.22
	paddy +bhendi	68457	74397	71427	2.86	3.11	2.99
	paddy +brinjal	87597	92187	89892	3.66	3.85	3.76
	paddy+onion	47377	-	47377	1.98	-	1.98
	Paddy + potato	49317	43447	46382	2.06	1.82	1.94
	Paddy+chilli	50617	-	50617	2.12	-	2.12

OBJECTIVE: 3

TO OPTIMIZE THE BEST USE OF WATER AND TO ANALYSES WATER PRODUCTIVITY THROUGH MULTIPLE USE OF WATER THROUGH DEVELOPED SYSTEM.

During the experimentation, the irrigation water, water use efficiency and water productivity of different vegetable crops, paddy crops grown under open well command and bore well command has been analyzed based on crop yield data and irrigation water used by the crops and crop ET for the growing season and presented in objective no. 2. However the water productivity of the developed structure and farmers practices is depicted in Table 38 . The results revealed that the water productivity comprising rice , vegetable and fish has resulted very high water productivity than two or only one component taken in the system. The results clearly show that with available ground water potential, the farmers can effectively utilize this water for other components and improve their income with a unit amount of water consumed.

Table 38: Comparative performance of water productivity under multiple use

Component s	WP (on biomass basis) , (kg/ m^3 water)	WP (on gross return basis) (Rs/ m^3 water)	WP (on net return basis) (Rs/ m^3 water)
A) Multiple use of water			
Component –I Rice	0.78	7.50	4.00
Component- II Brinjal	3.0	18.5	12.5
Component -III Tomato	3.98	17.9	8.7
Component IV Fish	0.18	8.10	4.90
Total	7.94	52.0	30.1
B) Cropping system suggested under conjunctive use of water			
Rice	0.64	6.11	2.41
Brinjal	4.28	29.9	20.4
Total	4.92	36.01	22.81
C) farmers practices			
Rice	0.50	3.52	1.29
Green gram	0.21	8.40	4.74
Total	0.71	11.92	6.03

Aquaculture Performance:

Low input-based scientific fish culture operation was carried out for two crops using surface and groundwater for two consecutive years (2008-10) in two earthen ponds of 282m^2 each. Pre-stocking pond preparation such as application of lime ($CaCO_3$) @ 750kg ha^{-1}, raw cattle dung (RCD) @ 7000kg ha^{-1} as basal dose and fertilizer (Urea: Single Super Phosphate:: 1:1) @ 3ppm was carried out prior to stocking. Seven days after pond preparation (1st week of September), fish seed of IMCs (*Catla catla, Labeo rohita* and *C. mrigala*) were stocked after proper acclimatization @ 5,000 fingerlings/ha (MBW 3.2 $\pm$ 0.7g). Stocking composition was 30:30:40:: SF:CF:BF Supplemental feeding was provided with a ratio of 55:35:10 (rice bran: mustard oil cake: fish meal) @ 5%, 4%, 3% and 2.5% of MBW, twice a day, during 1st, 2nd, 3rd and 4th month to harvesting, respectively. Rearing continued for 240 days in each crop. Periodic manuring with RCD @ 500kg ha^{-1} and liming @ 50kg ha^{-1} were carried out at every 15 days interval to maintain plankton population in the eco-system.

Periodic observation on water quality, soil quality, fish growth parameters, yields and yield components were carried out at regular intervals at the experimental site. Major physico-chemical parameters of pond water, e.g., dissolve oxygen (DO), temperature, pH, turbidity; total alkalinity, total suspended solids, and CO_2 were monitored bimonthly using standard method. Weekly growth study was carried out by sampling prior to feeding, so that complete evacuation of gut was ensured. Weekly mean body weight (MBW), per day increment (PDI), survival rate (SR%), biomass (kg), Performance index, production-size index, feed requirement, % feed used, apparent feed conversion ratio (AFCR) was estimated.

The recorded mean minimum and maximum values of various water quality parameters prevailed in the ponds during the ongoing evaluation period were: water temperature 27.1 - 33.7 ^{0}C; water pH 6.9 – 8.1; dissolved oxygen 4.3 - 6.9 ppm; total alkalinity 87 - 133 ppm; dissolved organic matter 2.9 - 6.6 ppm; transparency 34$\pm$4; and total suspended solid 177 - 372 ppm. TSS and DO concentration showed a decreasing trend with the advancement of rearing period while, gradual increase in nitrite, nitrate, ammonia were attributed by increased level of metabolites and organic matter. At any given point of time, other water quality parameters did not register any specific trend. Increased phytoplankton and chlorophyll-*a* concentration did not help in maintaining higher dissolved oxygen levels compared. This was probably due to the decomposition of organic matter (feed and excreta), resulting in higher oxygen consumption. As the oxygen budget is strongly influenced by the balance/ dominance of autotrophic/ heterotrophic process, lower dissolved oxygen concentration might be attributed to the decreased autotrophic / increased heterotrophic activity

After 240 days of rearing, 1st crop harvesting was carried out in the month of May, 2009. The average MBW was 710.5g, 480g, and 467.3g for *Catla, Rohu,* and *Mrigal* respectively and the productivity was 1506 kg/ha/240days. The apparent feed conversion ratio was 1.34. Biomass contribution was maximum by *C. catla* followed by *C. mrigala*. Higher and lower Production-size index was recorded incase of *C. catla* (626.2) and *L. rohita* (280.0) respectively. Specific growth rate however, ranged between 1.13-1.36 %d^{-1}.

Similarly, after 240 days of rearing, 2nd crop harvesting was carried out in the month of May, 2010. In the 2nd crop, the average MBW was 647.9g, 432.3g, and 448.5g for *Catla, Rohu,* and *Mrigal* respectively. Productivity was 2.11 t/ha/240days. The apparent feed conversion

ratio was 1.48. Higher and lower PSI was recorded incase of *C. catla* (610) and *L. rohita* (266.2) respectively, while growth pattern was almost similar in case of each species in both the crops as evident from the SGR (% d^{-1}). Specific growth rate however, ranged between 1.12-1.35 % d^{-1}.

Higher PSI in case of surface feeder was probable due to the stocking composition and minimal interspecific competition with column feeders, while moderate growth performance of both column and bottom feeders were due to stronger competition for food and space among each other.

Table 39: Water quality parameters

Parameters	Mean Minimum	Mean Maximum
Temperature, ^0C	27.1	33.7
pH	6.9	8.1
Dissolved Oxygen, ppm	4.3	6.9
Total Alkalinity, ppm	87	133
Transparency, cm	38	30
Total suspended Solids, ppm	177	372
Dissolved Organic Matter, ppm	1.12	6.1
NH_3, ppm	0.01	0.18
H_2S, ppm	0.001	0.01
Nitrite, ppm	0.006	0.82
Nitrate, ppm	0.05	0.58

Table 40: Growth performance of cultured species.

Species reared	2008-09			2009-10		
	MBW (g)	SGR % d^{-1}	PSI	MBW (g)	SGR % d^{-1}	PSI
Catla	710.5	1.13	626.2	647.9	1.12	610.0
Rohu	480.0	1.36	280.0	432.3	1.35	266.2
Mrigal	467.3	1.3	385.1	448.5	1.29	376.1

PHOTO No. 8 : INITIAL SURVEY FOR CONSTRUCTION OF FISH POND

Dropping of Fingerling in pond

Collecting fish from pond

Frequent sampling and recording growth rate of fish

Frequent sampling and recording growth rate of fish

Harvesting

OBJECTIVE 4:

TO MONITOR THE CHANGES IN GROUNDWATER QUALITY, DRAW- DOWN DUE TO THREE HUNDRED PERCENT CROPPING INTENSITY.

The soil pH in all locations is acidic in reaction in 0-15 to 45-60 cm soil depth. Under this condition most of the major plant nutrients are not effectively used by the plant. In acidic reaction, phosphorus availability is low due to very high soluble ions of Al, Fe and Mn. Salt concentration in soil is also very low as most of the basic salts are being washed away due to heavy rains and hence electrical conductivity is low. The soil pH was not materially changed with cropping years. The pH was high in middle reach as compared to head and tail reach(Table 41, 42, 43).

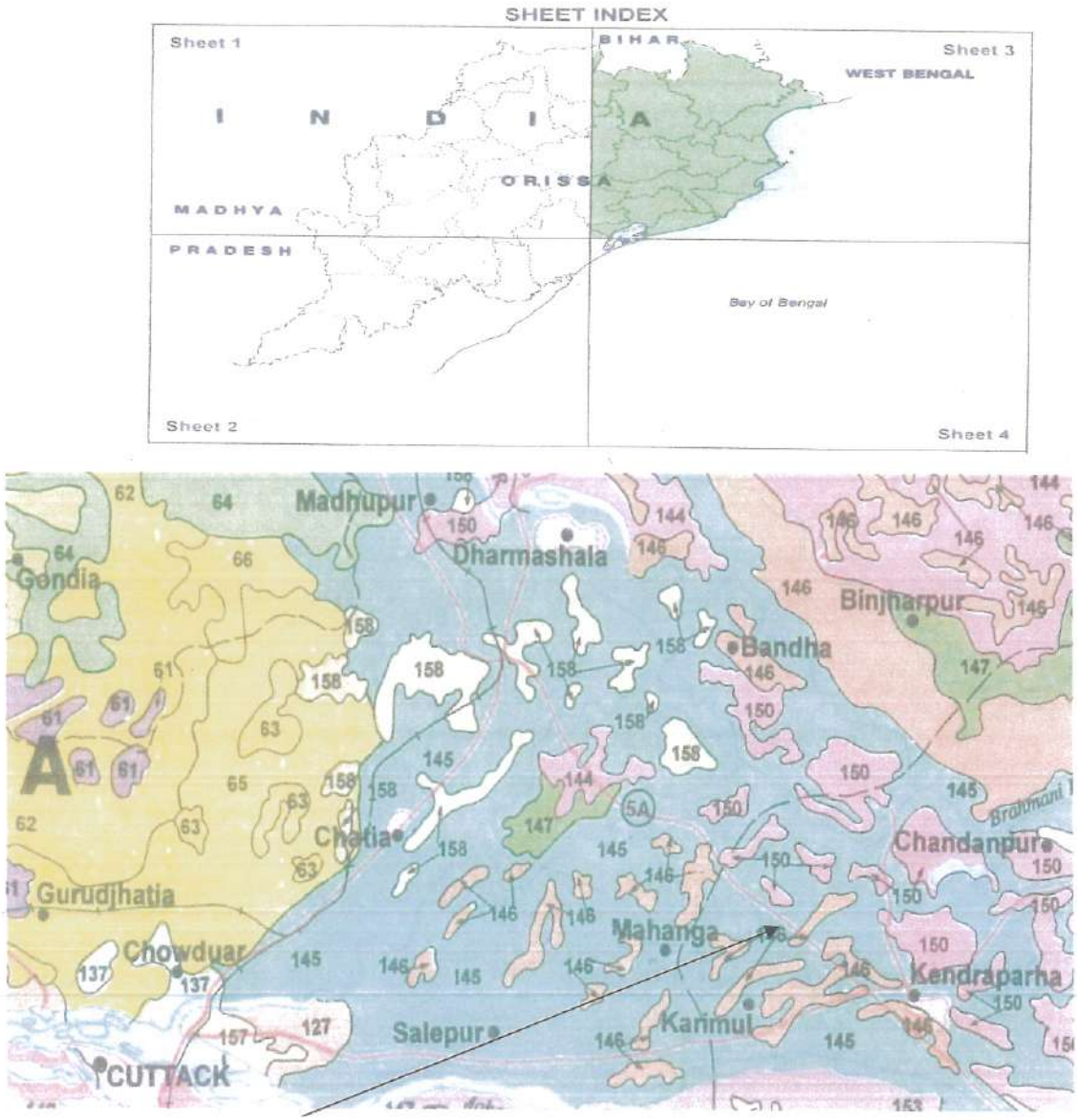


Figure 13: location of project site (Major Soil types of Project area)

Table 41: Physico- chemical properties of soil in different locations (2007-08 after harvest)

Location	0-15 cm	15-30 cm	30-45 cm	45-60 cm
	Soil pH			
Head	4.9	5.4	5.5	5.7
Middle	5.1	5.9	6.1	6.4
Tail	5.2	5.6	5.7	5.9
	Soil EC dS/m			
Head	0.02	0.03	0.03	0.02
Middle	0.04	0.06	0.08	0.07
Tail	0.03	0.03	0.04	0.05

Table 42: Physico- chemical properties of soil in different locations (2008-09 after harvest)

Location	0-15 cm	15-30 cm	30-45 cm	45-60 cm
	Soil pH			
Head	4.9	5.8	5.5	5.7
Middle	5.8	5.9	6.1	6.3
Tail	5.5	5.6	5.8	5.9
	Soil EC dS/m			
Head	0.033	0.039	0.038	0.032
Middle	0.054	0.069	0.079	0.075
Tail	0.038	0.043	0.048	0.059

Table 43: Physico- chemical properties of soil in different locations (2009-2010 after harvest)

Location	0-15 cm	15-30 cm	30-45 cm	45-60 cm
	Soil pH			
Head	4.7	5.6	5.4	5.8
Middle	5. 6	5.8	6.0	6.4
Tail	5.4	5.5	5.6	5.7
	Soil EC dS/m			
Head	0.023	0.033	0.032	0.022
Middle	0.047	0.067	0.081	0.071
Tail	0.034	0.039	0.043	0.053

Water Quality of different observation wells

During 2007-08 and 2009-2010 the water quality parameters like pH and Electrical conductivity was estimated from each village by collecting water samples from five open well/ bore wells at specific month interval. The data presented in Table 44, 45 of the year 2007-08 and 2009-2010, respectively reveals that water pH was not materially changed with time but electrical conductivity was changed in both the year showing higher value towards dry month period. During rainy season as canal operation period it was diluted and showed decreasing trend.

Table 44: Water Quality parameters in different well

Location / Village	August 2007		November 2007		March 2008		June 2008	
Head reach	pH	EC dS/m	pH	EC dS/m	pH	EC dS/m	pH	EC dS/m
Kalianti	5.8	0.30	5.7	0.50	6.2	0.67	6.6	0.89
Bagsarpur	5.9	0.25	5.8	0.35	6.0	0.56	6.2	0.71
Panaspur	6.0	0.26	5.9	0.32	6.1	0.46	6.3	0.67
Matiparilo	5.7	0.30	5.7	0.34	6.0	0.34	6.0	0.44
Middle reach								
Mugalpatna	6.0	0.20	5.9	0.20	6.0	0.25	6.1	0.29
Jerkanda	5.8	0.26	5.8	0.30	6.3	0.32	6.4	0.34
Manitri	5.8	0.35	6.0	0.46	6.1	0.56	6.5	0.66
Sorala	6.1	0.60	5.9	0.76	6.1	0.80	6.1	0.90
Tail reach								
Gangadhar	5.7	0.40	5.8	0.56	6.3	0.68	6..5	0.84
Haribhaktapur	5.8	0.36	5.7	0.58	6.0	0.80	6.3	0.86
Kalyanpur	5.9	0.35	5.9	0.50	6.2	0.70	6.6	0.84
Lalitgiri	6	0.30	5.8	0.35	6.6	0.68	6.8	0.77

Table 45: Water Quality parameters in different well

Location / Village	August 2009		November 2009		February 2010	
Head reach	pH	EC dS/m	pH	EC dS/m	pH	EC dS/m
Kalianti	5.7	0.32	5.6	0.53	6.1	0.69
Bagsarpur	5.6	0.27	5.7	0.36	6.2	0.57
Panaspur	6.2	0.27	5.8	0.34	6.0	0.47
Matiparilo	5.9	0.32	5.8	0.36	6.3	0.36
Middle reach						
Mugalpatna	6.1	0.20	5.9	0.20	6.2	0.25
Jerkanda	6.0	0.26	5.9	0.30	6.5	0.32
Manitri	5.9	0.35	6.2	0.46	6.3	0.56
Sorala	6.0	0.60	6.1	0.76	6.2	0.80
Tail reach						
Gangadhar	5.9	0.45	6.0	0.59	6.5	0.69
Haribhaktapur	5.9	0.39	5.8	0.60	6.2	0.85
Kalyanpur	6.0	0.39	5.7	0.54	6.4	0.75
Lalitgiri	6.1	0.38	5.9	0.39	6.2	0.69

RECUPERATION STUDY OF BORE WELL / OPEN WELL

Bore well with 1.5 Hp pump was monitored for conducting recuperation study in the project site. It was observed that during pre monsoon season the recuperation/ recharge rate in the bore well was 2.6 cm/hr and the same study was conducted in the post monsoon (November) period and the recuperation recharge rate was found out as 3.53 cm/hr. This shows that the groundwater potential is quite high and aquifer is having good yield potential to irrigate the *rabi* crops in the study sites.

This showed that more water resources can be developed in terms of dug wells / ponds to irrigate crops through out year. The density of these structures could be increased further with the condition of area of influence of each structure. However to determine the density of each structures further studies could be done.

PHOTO NO. 9: PHOTO FOR MEASURING DISCHARGE RATE OF BORE WELL AND DRAW DOWN THROUGH PIEZOMETER

Measuring Discharge rate

Measuring discharge rate

DISCUSSION

Water is the most important natural resource for all economic, social development and eradication of poverty and hunger. However due to increasing the demand of water in industrial and domestic sector and ever-increasing population, water pollution, and climate change, the water availability per capita is shrinking day by day. 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). Hence, efforts are essentially required to put and utilize the available limited water resources efficiently and effectively and avoid water scarcity and provide food and nutritional security, while ensuring multiple other factors. The Multiple uses of water i.e. for domestic use, crop production, aquaculture, agro forestry and livestock, can improve water productivity and reduce poverty. However, intensification of multiple use of water in the catchment may affect downstream flow. So it is highly essential to make adequate water balance study of complete watershed area to avoid water shortage to downstream farmers and maintain proper ecosystem. There is a need for proper understanding and to greater in-depth knowledge and the linkages between water management activities and aquatic ecosystems ((Meinzen-Dick and van der Hoek, 2001 and Bakker and Matsuno, 2001).

In eastern region, the IGB provides the economic base for agriculture, forestry, fisheries, livestock, including urban and industrial water requirements for about a billion people. In IGB about 91.4% of the annual water use is for agriculture purpose followed by 7.8% for domestic use. Growing water scarcity and competing water demands with industrial sector is the major concerned as the productivity with single system is decreasing at faster rate. 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.

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, it is 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).

In eastern region of India particularly in the state of Bihar, West Bengal, Jharkhand, Orissa, Chhattisgarh, and rice is dominated crop and water exhaustive also. However the productivity is quite low, though the amount of rainfall received is high as compared to other region of the country. To improve water productivity in this area sufficient efforts are being made to introduce multiple use of water. During rabi and summer season, where surface water is not available to sustain multiple water use system, the farmers are using ground water and pumping the ground water for growing multiple items and improving water productivity. In this area the ground water development as on March, 2004 is only 18 % in Orissa, 21 % in Jharkhand, 39 % in Bihar , 20 % in Chhattisgarh and 42 % is West Bengal but national average is quite high .

I)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 a tube well based irrigation systems at ICAR Research Complex for Eastern Region (ICAR-RCER),Patna , 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). In this place also the productive utilization of waterlogged areas, a research project was initiated with various multiple use options. 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) Multiple use of water in Waterlogged area

Near Patna medium deep waterlogged lands (0.5 – 1.0 m) was modified in the form of a reservoir or pond .It was made for multiple uses. The excavated soil was spread around the periphery to form a bund with crest level at least 50 cm above the highest water level to ensure that water do not overflow the bunds. High value horticultural/vegetable production on bunds utilizing seepage water with little supplemental water to produce good profit from the land, which generally remains fallow or poorly utilized. In association, good fish production was achieved with water quality management through water routing for irrigation purpose. Two options like routing of water with provision of water exchange and control reservoir without water exchange were tried. The routed water containing good amount of nutrients h enhanced yield and quality of agricultural produce. They further suggested introducing ducks, poultry, piggery, etc. can increase additional benefits.

b) Fish trench-cum-raised bed

The field having standing water with more than 1.0 m are not much beneficial for rice-fish culture. If trenches are made in such field by excavation and bund with soil can store more water for fish cultivation. To evaluate this concept, two types of layout of the fish trenches, viz., 1) meandering type trenches simulating river condition; and 2) continuous trenches surrounding island of raised bed simulating pond type conditions was undertaken.

c) Benefit from Fish , rice , horticultural crop In ICAR 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 % . Net income from rice-wheat system with fish refuge in the center was in the tune of Rs 29694 per ha per year, out of which 11 % was contributed by fish and 89% by rice and wheat. 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.

d) Multiple use of water bodies in Makhana based farming system

Makhana (Euryale ferox Salisb.), a monotypic genus belonging to the family Nymphaeceae, is grown as a cash crop in the littoral parts of the flood plain wetlands of North Bihar. Traditionally makhana is grown as a sole crop and water bodies are utilized for only seven months from February to August for growing makhana. Hence, efforts were made to maximize the productivity of water bodies through multiple uses of water by makhana- cum-fish integration. In this technology, a refuge covering 10 % area of net water bodies as a central vacant space created in makhana ponds is considered. The stunted carp fingerlings of 10-18 g are integrated in the refuge area of the ponds in the month of April in makhana –cum-fish integrated system, and in September also after harvest of makhana. The fishes are harvested in the month of December-January before emergence of makhana seedling on water surface. The integration of fishes with makhana resulted in fish yield of 1.83 to 4.03 q/ha and makhana seed yield of 10.64 to 20.63 q/ha. The net income from integrated makhana based farming system ranged from Rs 44, 686/ to Rs 51,216 per ha/year. Besides this, for alternate income generation, activities such as seasonal vegetables and fruits on the bunds of makhana ponds, vermin-compost unit, poly houses for vegetable and fruit nursery, apiculture, poultry farming etc. are also being tried at farmer's pond for increasing water productivity as well as per unit area productivity.

e) Multiple uses of rainwater harvesting reservoir in medium uplands in plateau region (Jharkhand)

In the experimental farm of Horticulture and Agro-forestry Research Programme, Ranchi ,(Jharkhand) a rainwater harvesting pond was constructed with a water capacity of 1200 m3. The command area of the pond consists of 100 x 70 m (0.7 ha) area, in which litchi based multi-tier horticultural system was adopted. Fish production in the pond, vegetable / fruits /pulse production on the bunds measuring 3.0 m width around the ponds, supplementary irrigation to cereal production on a limited area of 50 x 25 m (0.125 ha) with surplus runoff storage during monsoon season, and irrigation through gravity fed drip irrigation to multi-tier horticulture with harvested rain water was followed. An analysis of climatic data indicated that after initial irrigation for plant establishment to 60 plants of litchi, 180plants of guava up to end of June, enough water will be available for vegetable cultivation on about 1000 m2 for two season (November-March and March-May). About 46.9% of water from 1.8 m deep pond will go as surface evaporation losses. Alternatively, the vegetables for the two seasons can be grown on 1500 m2 without irrigation to any plant of fruit trees. Adoption of such system on large scale basis by the state agriculture department can boost up overall water productivity.

f) 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.

g) 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 m3 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 command area with three crops was quite high instead one crop as most of the farmers follows due to inadequate water supply. In case of rice+ fish + vegetable cropping system in pond area, the water productivity was also high and it was Rs 30.1 per m^3 of water. In case of rice + brinjal with conjunctive use (rain water + ground water) , the WP was
Rs 22.8 per m^3 of water. In rice + green gram as rainfed it was only Rs 6.0 per m3 of water. 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. During rabi season when the crops were irrigated with canal water for short period and to some extent with open well water, the WP in case of vegetables was Rs. 7.52 per m^3 of crop ET and in paddy it was Rs 1.62 per m^3 crop ET. In other crops also, the WP during rabi season was lower than the experimental site where efficient water management practices were followed .

B) ***Conjunctive use of water and Water Productivity***

Conjunctive use 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, Tyagi 2005, 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.

i) Eastern Region

In eastern part of India, the rainfall amount during kharif season is generally higher than crop water demand. But during rabi and summer season it s deficit and this deficit amount of water is compensated with ground water and harvested rain water wherever it is possible. The farmers of Northern Bihar and West Bengal are exploiting ground water during rabi and summer season at potential rate as the cropping intensity is very high but in Chhattisgarh and Jharkhand , where maximum area is hard rock, they are using only harvested rain water from pond and with limited irrigation through canal water.

In state of Orissa, 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 98.5 mm

(6.6%) during April and May. However the annual evaporative demand is 1657.8 mm. This total annual crop evaporative demand (ETo) is higher by only 11% over the water available through rain alone. But the water supply through rain is highly erratic during different seasons and it affects the overall production in both coastal and non-coastal districts of Orissa. The evaporative demand during June to October (kharif season) is only 627. 3 mm and rainfall is 1295.7 mm, showing surplus of 106.5 % over demand. During rabi season, the evaporative demand is 604.3 mm resulting a deficit of 83.7 % and during summer month (April –May) the evaporative demand is 426. 3 mm , resulting a deficit of 76.9%. So to fulfill crop water demand during off season, it is highly essential to exploit ground water and improve cropping intensity.

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 to assess 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 .In linear model they considered 35 decision variables (25 crop variables and 10 water resources) with nine different probability level of exceedences . The water balance 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 . The optimum cropping and ground water management yielded the cropping pattern for three different situations studied. The model when imposed with a constraint of 20 % of existing surface and ground water supply level, showed the allocation towards all resources(surface and ground water) for both the growing season.

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 by 21%. 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.

ii) Use of bad quality ground water with fresh water.

In coastal belt area, the ground water is saline with high concentration of chloride and sulphate ions of sodium, calcium and magnesium. Utilization of such saline water for crop is possible with good quality water. However in northern belt area where rainfall is not enough to dilute the saline water and due to arid and semi-arid climate , the ground water quality is sodic in nature and plant cannot survive for longer period unless it is used with good quality canal water. The profitability analysis was carried out for wheat irrigated with saline groundwater at a given level of canal-water supply for a watercourse command area in the Kaithal district(Haryana) to see how far the application of saline water would remain economically viable (Anon., 2001). Two levels of canal water supply (10 and 15 cm /ha) were considered. It was found that the profit decreased from Rs 12,000 per ha to Rs 7000 /ha when the canal-water supply was decreased from 15 cm to 10 cm with a groundwater (EC = 6 dS/ m) use of 15 cm. At Central Soil Salinity Research Institute Karnal, lot of work has been done on use of bad quality ground water with canal water as well as in isolation on perennial crops, grasses, a forestation of waterlogged soil with underground saline water (biosaline) and made very good achievement on this aspect (Singh and Dagar 2009) . So the bad quality water can be used in various crops at permissible level of tolerance.

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8) All data collected and used in the analysis, results and inferences: Yes

9) Conclusion / Recommendations

- During kharif cropping season (June to November), on an average, the canal running period was 125 days and the water availability was 1805.4 ha-m against crop water demand of 555.6 ha-m. Besides, the release of excess canal water along with rainfall caused waterlogged situation in the canal command area.
- During rabi and summer season (up to May), on an average of 36 days canal running period, the water availability was 405.9 ha-m against crop water demand of 532.1 ha - m. As there is a good amount of water deficit during rabi and summer season, the groundwater was exploited to irrigate field crops.
- The conjunctive use study shows that during long dry spell period in kharif season and non availability of canal water at tail end the farmers used ground water up to 20 % of the crop water demand with enhancement of crop yield up to 21 %.
- During rabi and summer season, due to non availability of canal water at tail end, the farmers utilized groundwater to irrigate vegetable and oil seed crops (brinjal, potato, tomato, onion ,chilli, ladies finger , radish, cucumber , groundnut) The water requirement was also worked out after considering the effective rainfall and it varied from 290 mm for cucumber to the highest value of 716.2 mm for brinjal. The water requirement of summer crop (bitter gourd) was 508 mm.
- Studies were also carried out utilizing open well water for irrigation and its command area for three crops (short duration rice- potato/ radish- bitter gourd) in a year and recorded net return of Rs 87368/ha. Under two crops in year (rice - brinjal), the net return was Rs 90,031/ha. The reason for getting more return in two crops in a year was due to pruning and continuing the same crop with best management practices till onset of monsoon. In rest of the six crop combinations (rice- tomato, rice –onion, rice-chilli, rice-bhendi, rice-french bean, and rice-groundnut) the net returns were comparatively lower than the above combinations.
- The periodic study on fluctuation of groundwater table were carried out during the project period which varied during pre-monsoon in the range of 2.0 m to 3.18 m, during post monsoon period it ranged from 2.0 m to 3.2 m and it remained about 2 m during monsoon season. Due to presence of groundwater at shallow depth throughout the year, it could be exploited with minimum expenditure.
- Studies on groundwater quality and soil quality were carried out and it was observed that the quality of both groundwater and soil were consistent throughout the year. The values of EC and pH were within the prescribed norms.
- Further, the aquifer properties were also studied through recuperation study and it was observed that this value varied in the range of 2.6 cm/hr to 3.5 cm/hr for pre-monsoon to post monsoon period, respectively which shows the good prospect of groundwater utilization in the study area.
- Studies were also conducted to optimize the water use, enhancement of water productivity through multiple use and it was observed that the combination of paddy, vegetables and fish resulted the water productivity (in terms of net return) Rs. 30.1per

m^3 of water whereas the water productivity of the suggested cropping pattern (rice-brinjal) with conjunctive use was Rs. 22.8 per $m^3$of water and farmers practices (rice-rainfed green gram) was Rs. 6.0 per $m^3$of water...

10) How do the conclusion / recommendations compare with current findings:

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.

11) **Field test conducted:** Entire study was done by involving 18 farmers in bore well command area and 5-6 farmers in open well command area in tail reach of the distributory no.5.

12) **Software generated, if any**: Beyond the scope of the project

13) **Possibilities of any patent /copyrights. If so, then action taken:** All these technologies are in public domain and it may be taken up by the concerned line department.

14: **Suggestion for further work:** The findings of the project could be utilized by the concerned state agencies for its larger dissemination to the farmers. .

Signature of the Principal Investigator, Co-Investigators:

This is to certify that the final report has been submitted in full consultation with the project workers as per the approved objectives and technical programme

R.B. Singandhupe

Principal Scientist (Agronomy) Principal Investigator

Co- Investigator

1) Mrs R.R.Sethi Scientist SS

(Soil and Water Conservation Engg).

2) H. Chakraborty, Scientist

(Soil Physics)

3) R.K. Mohanty Sr. Scientist

(Fishery)

4) B.K. James Principal Scientist

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Comments and reply of INCID PROJECT (CONJUNCTIVE USE)

Sr. no.	Comments	Reply
1	Contents like headings and sub-heading with page number may be given at the beginning of the report.	The content like major heading followed by sub-heading of the text with page number has been given in tabular form at the beginning of the report.
2	The water use efficiency and water productivity terms should be well defined in methodology.	The water use efficiency and water productivity terms has been defined, explained and given in page no. 9 in report.
3	The results may be discussed at the end with reference to the earlier research work done in the host institute, other institutes of the state and outside the state under similar ecology.	The results of the findings has been discussed in- depth with references at the last page of the report (before conclusion and recommendation of the major research findings) in page no.78-84.
4	With regard to availability of irrigation water through canal system the results may be confirmed with the concerned irrigation officials	During the study period, we have collected the design discharge data from the concerned department located at Balichandrapur (Jajpur District). The availability of irrigation water in different distributories at the head and tail end has been measured and it has also been verified.
5	With regard to development of ground water for conjunctive use, the project has invested 50% of the cost towards bore-wells, open-wells and ponds. The implication of such initiative on a project scale needs to be thoroughly analyzed.	In selected project site the ground water structure like open well and bore wells and ponds were made on participatory mode to use ground water during canal off period for both kharif and rabi season crops . This project has shown very good response and farmers are sharing ground water for growing rabi and summer crops . The cropping intensity has been increased (The result has been given in objective no.2 and 3 in page 31-69).The Directorate of Ground Water Survey and Investigation, Directorate of Agriculture, Govt. of Orissa, Department of Minor Irrigation have done good work on this aspect. The statistical data of Govt. of Orissa revealed that every year ground water development is increasing at faster rate (9% in March 1997 to 18.7 % in March ,2004 as per statistics of Ground Water Survey and Investigation).

		So the developed ground water structures like bore well, open wells is being potentially used as a irrigation sources for increasing irrigation intensity and cropping intensity of the areas.
6	The marketing implications of growing brinjal and tomato on a large scale need to be practically analyzed	There is no problem of marketing farm produce. It is easily being disposed off in nearby market yard. Under large scale production of tomato, being a perishable produce is being used in industries but in limited number. Thus it requires further expansion of such industries in village areas so that all produces are properly processed and preserved for long period and sold in market thereafter. Besides these enterprises, Reliance Fresh Industries is entering into such enterprises and procuring perishable farm produce at village levels, but it is also not extensively popularized. It is not major problems as the state govt. machinery can take up such type of activities so that the farm produce is feasibly and quickly transported and by-product is developed at taluka or block level.
7	The format and presentation of the report may be made more reader friendly. The material may be formatted better with various sections and sub-sections numbered in hierarchical pattern.	The experimental findings are presented in appropriate order year wise as per objectives of the project and number has been given to section and sub-section in appropriate order accordingly.
8	Calculation of water productivity figures seems to have been done with grossly under estimated crop ET values (for example on page 8 of the report in which the ET figures used for rice was 339 mm in Kharif and 339 mm in rabi. This is true for the calculations in the tables in the later part of the report also). The actual quantities of irrigation water used combined with effective rainfall which can give more realistic picture may be used	The ETo (reference ET) calculation has been made based on climate data and subsequently multiplied with crop coefficient to derive ET crop. In case of rice crop the effective rainfall has not been calculated as collection of soil moisture data during kharif crop was not possible due to submerged/ flooded for most of the crop growth period. During rabi and summer season, effective rainfall for all rabi and summer crops was considered for estimating actual water requirement of crop. Based on these value the water productivity was computed.

	in calculation of water production figures.	
9	Calculating water productivity by using the quantum of the economic product of crop (with grossly variable value) such as rice grain and potato tuber may not be appropriate. Instead a comparable unit such as the monetary value may be more valid.	Water productivity has been computed by considering net return of the produce of different crops tested in the project instead of yield of different crops which was elaborated in previous report.
10	The cost of establishing bore and open wells and their running and maintenance cost should be indicated in the report.	The total cost of bore well and open well as well as running and maintenance cost has been included and given in text (page no.31)
11	To evaluate the feasibility of extending the strategies tried in this study to more farmers in future, the cost benefit analysis should be included in the report.	Cost benefit analysis of the ground water structure has been computed and given in text(page no. 31 and detail result in page no.67-69). So the popularisaton of such activities are extended through various state government schemes.
12	Water deficits of 532 ha m assessed in the report appears to be a bit too high and needs to be reconciled.	The water deficit of 532 ha-m is given in report is based on rabi and summer crop water demand (November to May) which was calculated with climatic data by considering that whole command area is to be irrigated during rabi and summer season. As canal operation period during rabi season is very short(mid January to third week to end of February), the rabi water demand was not fulfilled by canal water. Similarly during summer season it was totally off. Hence there is large deficit of water demand. This high crop water demand period can be fulfilled with the help of bore well, open well water. In the present study, ground water structures were developed to fulfill crop water demand and were tested successfully in tail reach of distributory where shortage of canal water remained a permanent problem to the farmers.