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FARM-LEVEL CONSTRAINTS TO EFFICIENT USE OF CANAL WATER IN COASTAL ORISSA AND SOME TECHNOLOGICAL INTERVENTIONS TO ENHANCE CROP PRODUCTION

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BHUBANESWAR

WATER TECHNOLOGY CENTRE FOR EASTERN REGION
(Indian Council of Agricultural Research)
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CONTENT

Preface

The key to agricultural development in eastern India is scientific management of water resources. The agricultural production level and use efficiency of applied irrigation water in canal command areas of eastern India is very low. Several workers have reported different causes and constraints for this situation. However, the situation has remained the same in canal irrigation command because no attempt was made to analyse the constraints from the perspective of farmers. Among different stakeholders in irrigation system, farmers are the producers of agricultural outputs through the utilization of irrigation services provided to them. In-spite of being the most fundamental stakeholder, the farmers often receive the least attention. It is important to consider the issue of irrigation as a service provided to farmers. Therefore, in present study constraints analyses and performance evaluation of irrigation system have been considered from farmers' point of view and the results are reported in this bulletin. Though the farmers are well aware of the benefits of crop diversification, they are not able to practice the same because root zone soils of most agricultural farms at head and middle reaches of canal irrigation commands in this region remain saturated or over saturated through kharif as well as rabi season, and farmers can hardly grow any other crop than rice there. Since rice farming is not remunerative many farmers in this region do not like to grow two rice crops. Instead, they prefer to keep their land fallow during rabi season. Some technological interventions were made for crop diversification in such situations. Results are discussed in this bulletin. We hope information presented in this bulletin will be useful to the policy makers, scientists, scholars, development officials and others who are interested in enhancing crop production and use efficiency of irrigation water in canal command of this region.

The authors are grateful to the Director General, Deputy Director General (NRM) and Assistant Director General (IWM), ICAR for their encouragement, suggestions and support in carrying out this research work. Our sincere thanks are also due to all the colleagues and staff members of WTCER, Bhubaneswar for their help at the time of need.

AUTHORS

EXECUTIVE SUMMARY

The use efficiency of applied irrigation water in most of the canal command areas is very low, often 30 % or less. The agricultural production level in the canal-irrigated area of eastern India is also quite low. During a survey of 10 major canal command areas of India, Mahanadi canal command area of Orissa ranked at the bottom as far as the water use efficiency and productivity is concerned. Keeping all these in mind an attempt was made to generate information in command area of Nimapara Branch Canal under Puri Main Canal of Mahanadi Delta Irrigation Project with respect to socio-economic profile and attitude of the farmers, existing cropping pattern of the command, constraints and performance of the system from the perspective of farmers followed by examining effects of some technological interventions to enhance crop production in command area.

Socio-economic profile analyses have indicated that majority of the farmers are mainly engaged in cultivation with medium size land (1.0 to 2.0 ha) and assets (6 to 21 in term of tools and implements) holding. It was interesting to note that majority of the farmers were having only low (£ 2) to medium (3-7) livestock holding. Domination of poor livestock holding shows farmers' preference for crop farming. Monthly income of the farmers was found to be very low with most of them earning not more than Rs. 2000 per month.

Poor participation of farmers in the social organization and simultaneously average exposure to different communication sources are unhealthy signs. Present study revealed that 56 % of the respondents were having favourable attitude towards the usefulness of canal irrigation in cultivation. But an alarming 44 % of the farmers showed unfavourable attitude towards it. The favourable attitude may be attributed to many reasons like availability of adequate canal water, suitability of vegetable cultivation in dry season, benefits of irrigation in terms of yield and income, etc. On the other hand, unfavourable attitude may be due to faulty alignments of canals and outlets resulting into water scarcity during critical period and flood or water logging during rainy season, poor maintenance of canal distribution system, lack of monitoring by the officials, etc.

Rice-rice is the cropping sequence in 95 % of the command area if water is released during dry season. The cropping intensity is 180 %. If the water is not released during dry season then the cropping intensity is 120% with rice-black gram, rice-green gram and rice-horse gram sequence under residual moisture. Rice-fallow was found to be predominant system in the non-command area. Average yield of paddy in the command area is 2.1 and 2.92 t/ha in wet and dry season, respectively. Delayed planting, low input use and uncontrolled irrigation are the main reasons for the low productivity and cropping intensity.

Constraints analyses through preferential ranking technique have delineated as many as nine constraints related to canal irrigation with their relative priority from the perspective of farmers. These are (i) poor maintenance of canal / distribution system, (ii) no repair or untimely repair of distribution system, (iii) faulty alignment of distribution system, (iv) no monitoring of water supply by the officials, (v) lack of interest and attention on part of irrigation

department officials, (vi) geographical constraints (availability of water varies with the land situation i.e. whether it is at upper, medium or lower reach, etc.), (vii) untimely supply of canal water results into water scarcity during critical period and flood or water logging during rainy season, (viii) lack of adequate water at the critical period as there is less water in the reservoir and (ix) lack of community co-operation.

Present study has evaluated performance of irrigation system considering irrigation as a service to farmers, which avoids the need of quantitative data on water delivery and concentrates on performance assessment from the perspective of farmers. The utility of water delivery was assessed on the basis of three factors i.e. tractability, convenience and predictability and ten sub-factors under three factors. The analyses revealed that farmers' level of satisfaction with the factors in an increasing order was predictability, convenience and tractability. Head reach of the system recorded relatively higher utility values as compared to middle and tail reach of irrigation command. The most important factor was found to be predictability followed by tractability and convenience. There were differences in the opinions of the farmers about the water delivery system. These opinions, however, were closer in the importance attached by them to the individual sub-factors and factors.

Several technologies were tested to improve use efficiency of water and crop production in the command area. Modification of topography of field through construction of alternate raised and sunken beds improved the physical environment, particularly aeration status of the soil and created proper condition for growth of crops other than rice. This system also helped in increasing cropping intensity, profitability and water use efficiency. This led to generation of employment throughout the year, availability of balanced diet and production of vegetable along with staple food paddy. Hence crop diversification in high rainfall, shallow water table areas of canal command was possible with the adoption of alternate raised and sunken bed system.

Manipulation of time and method of sowing helped in improving the productivity of crops and water use efficiency in absence of canal water. Use of rice straw mulch @ 5 t/ha in *rabi* and summer crops helped in reducing evaporation by moderating temperature and conserving moisture of the soil. This practice enhanced availability of N by 87 %, P by 13% and K by 36% and improved tuber yield of sweet potato by 50 %. Growing of low duty crops like green gram, horse gram, black gram, etc. were good for utilizing residual soil moisture and conserving good amount of nitrogen for next crop.

Rise of ground water table is a common phenomenon in all the major irrigation command areas because of seepage from canal distribution network. Under this situation it was observed that about 30 to 40 % crop water requirement can be met through the upward flux from shallow water table. Irrigation through field channels and use of recommended dose of fertilizers gave significantly higher yield than that obtained by field to field irrigation using farmer's fertilizer dose in rice.

1. Introduction

Canals are very old and dominating source of irrigation in eastern India, but the use efficiency of water in most canal command areas is very low, often 30 per cent or less (Tanwar, 1998; Pandey and Reddy, 1988). Similarly crop productivity level in the canal-irrigated areas of this region is quite low than its potential. Scaled against ten major Indian canal commands by output impact per ha of irrigated area, Mahanadi command of Orissa ranked last. Also, in output per unit of water in the above canal commands, Orissa is at the bottom of the list with 14 kg per ha-cm. This compares poorly even with the second lowest productivity (26 kg per ha-cm), recorded in the Jayakwadi command of Maharashtra. This trend remained similar for different crop groups namely cereals, pulses, oilseeds and vegetables. Agricultural growth in Orissa averaged just over 1% per annum over the last two decades (Selvarajan, 2001).

For improving irrigation water use efficiency and crop productivity through technological interventions, a clear understanding of the socio-economic condition of the farmers, present cropping systems and constraints from the point of view of farmers is required. Among different stakeholders in irrigation system, farmers are the producers of agricultural outputs through the utilization of irrigation services provided to them. In-spite of being the most fundamental stakeholder, the farmers often receive the least attention for assessment of performance of water delivery system. It is important to consider the issue of irrigation as a service provided to farmers. A set of criteria for constraints and performance evaluation of irrigation system needs to be considered from farmers' point of view (Chambers, 1998; Svendsen and Small, 1990; Ghosh *et al.*, 2002).

An important factor of rural change is perception. The way farmers interpret certain aspects to which they are exposed by and large determines its acceptance (Muthaya, 1986). The adoption and decision making behaviour of farmers depend on their socio-economic situation. Farmers weigh socio-cultural considerations besides agronomic, economic criteria and attributes of any practice/technology to arrive at their own conclusions about the suitability and adoption of it in specific farming system (Singh, 1995).

In this context, a study was conducted in a canal command area of coastal Orissa with the following objectives:

- To analyse socio-economic profile, differential attitude of farmers and existing cropping pattern in canal command and adjacent non-command area
- To identify top-most constraints in canal irrigation through preferential ranking technique
- To assess the performance of irrigation system from the perspective of farmers
- To examine effects of some technological interventions to enhance crop production in command area

2. Location of the study and site characteristics

The study was carried out in command area of Nimapara Branch Canal under Puri Main Canal of Mahanadi Delta Irrigation Project in the State of Orissa, India. Command area of three minors, viz. Saripur, Gringo and Garedipanchan of the Nimapara branch canal at Balipatna block of Khurda district was selected by following random sampling method. This irrigation scheme is in the eastern region of our country (Figure 1). The latitude and longitude of the area covered under this irrigation command are 19.7^0-20.4^0 N and 85.8^0-86.2^0 E, respectively. The system has an irrigation potential of 38,510 ha cultivable area. The command area largely consists of small farmers with average holding size 1 ha or less.

Topography of the command area is relatively flat with general slope varying from 0.03 to 0.25 per cent. Soils of the command area vary from loamy sand to clay loam in texture. pH of the soil to a depth of 120 cm varies between 5.5 and 7.2. Most of the soils are low in organic carbon (less than 0.5%) and non-saline in nature with electrical conductivity (EC) values ranging from 0.5 to 0.7 dS/m. Mean annual rainfall in this command area is 1480 mm with nearly 80 per cent of it being received during monsoon period spreading over 100 rainy days. Maximum and minimum daily temperature ranges from 35^0 to 39^0 C and 13.5^0 to 18.6^0 C, respectively.

3. Socio-economic profile of the farmers

A total of 100 farmers representing head, middle and tail reaches of the Nimapara branch canal command area of Khurda district were selected as respondents following stratified random sampling method. Simultaneously two blocks, viz. Jatni and Khurda of the same district were selected as non-command area and a total of 50 farmers were selected from two villages of each block as respondents following random sampling method. The socio-economic profile was studied with the help of an interview schedule developed for this study. The respondents were further classified under each variable with the help of mean and standard deviation.

A perusal of the data presented in Table 1 indicates that the largest percentage of farmers belonged to the middle age category in both canal command and non-command area. It was found that the village youth preferred occupations other than cultivation. In command area majority of the respondents had education up to primary (30%) or secondary level (28%) while in non-command area twenty and thirty-four per cent of the respondents were illiterate and functional literate, respectively. Evidently, seventy and eighty per cent of the respondents were mainly engaged in cultivation in command and non-command area, respectively. Rest of them took cultivation as supporting or subsidiary occupation. Social participation of the farmers was found to be poor.

Majority of the farmers had medium sized land holding (1.0 to 2.0 ha) in both canal command and non-command area. More than 80% of the farmers in command area and 60% of farmers of non-command area had medium assets holding (6 to 21) in term of agricultural tools and implements. Only 15% of them had relatively high holding of agricultural tools and implements. It was interesting to note that majority of the farmers were having only low (£ 2) to medium (3-7) livestock holding. Domination of poor livestock holding shows farmers' preference for crop farming. They do not consider dairying as worth investing venture. Monthly income of the farmers was found to be very low with most of them earning not more than Rs. 2000 per month.

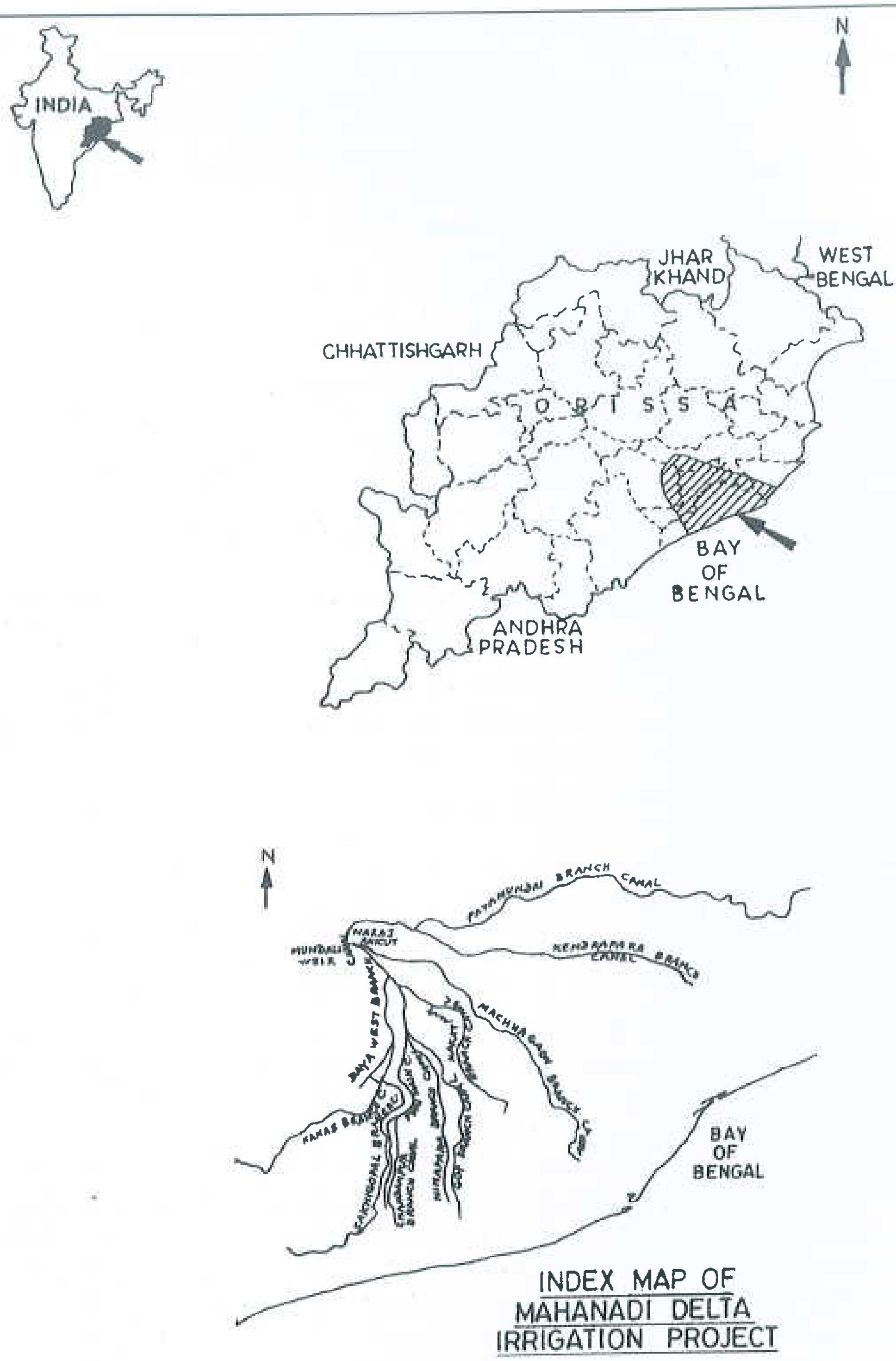

Fig. 1 : Location Map of Study Area

Table 1: Socio-economic profile of the farmers of canal command and adjacent non command area

Sl. no.	Variables	Frequency of farmers of the canal command and non-command area				
		Command area (N=100)	Non command area (N=50)	Pooled Mean	Pooled SD	Range
1.	Age (in years) :			55.44	12.33	30-86
	Young (<43)	14	5			
	Middle (43-67)	70	35			
	Old (>67)	16	10			
2.	Education :			-	-	-
	Illiterate	6	10			
	Functional literate	14	17			
	Primary	30	10			
	Secondary	28	11			
	Higher education	22	2			
3.	Occupation :			-	-	-
	Wage labour	-	3			
	Cultivation	70	40			
	Salary group	27	6			
	Self employment	-	1			
	Trade	3	-			
4.	Occupation of cultivation :		-	-	-	
	As main	70	40			
	As subsidiary	30	10			
5.	Social participation :			3.63	1.76	0-8
	No participations	48	35			
	Low (<3.63)	23	8			
	High (>3.63)	29	7			
6.	Land holding (in ha) :			3.60	1.40	0.25-20
	Small (<1.0)	34	10			
	Medium (1.0-2.0)	53	27			
	High (>2.0)	13	13			
7.	Assets (tools & implements) holding :			13.25	7.87	2-36
	Low (<6)	7	5			
	Medium (6-21)	86	30			
	High (>21)	7	15			

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	Low (<6)	7	5			
	Medium (6-21)	86	30			
	High (>21)	7	15			

8.	Livestock holding :			4.30	2.3	0-18
	Low (<2)	22	17			
	Medium (3-7)	67	21			
	High (>7)	11	12			
9.	Monthly income (Rs.) :			-	-	-
	Less than 1000	47	10			
	1000-2000	24	16			
	2000-3000	11	5			
	3000-4000	8	14			
	More than 4000	10	5			
10.	Use of communication sources :			9.47	4.98	1-30
	Low (<4.49)	6	23			
	Medium (4.49-14.45)	62	27			
	High (>14.45)	32	-			
11.	Attitude towards the usefulness	Command area		26.33	4.02	14-32
	of canal irrigation in cultivation :	Non command area		23.55	2.09	20-30
	Favourable	56	35			
	Unfavourable	44	15			

Use of communication sources by the farmers in term of personal localite, personal cosmopolite and mass media was studied. Personal localite sources included neighbours, friends, fellow farmers, village leaders, etc. Personal cosmopolite involved agricultural development officers, agricultural extension officers, village level workers, etc. Mass media sources included radio, television, and newspaper. It could be noted from the Table 1 that the farmers in non-command area were low to medium user of communication sources, however, 32 % of them in command area were high user of communication sources.

4. Farmers' attitude analyses

The farmers' attitude was studied with the help of a scale and schedule developed for this purpose. According to this study, 56 % of the respondents were having favourable attitude towards the usefulness of canal irrigation in cultivation. But an alarming 44 % of the farmers showed unfavourable attitude towards it. In contrast, 70 % of the farmers of non-command area expressed the needs of canal irrigation. The favourable attitude may be attributed to many reasons like availability of adequate canal water, suitability of vegetable cultivation in dry season, benefits of irrigation in terms of yield and income, etc. On the other hand, unfavourable attitude may be due to faulty alignments of canals and outlets resulting into water scarcity during critical period and flood or waterlogging during rainy season, poor maintenance of canal distribution system, lack of monitoring by the officials, etc. It is also to be mentioned here that attitude of the farmers varied with their land situation at upper, middle and tail end of the minors. More than 70 % of the farmers of command area perceived reasons of not getting adequate water as canal / distribution system is not well maintained, and faulty alignment of distribution system and untimely repair of distribution system (Table 2). Most of the farmers keep the land fallow in dry season and cultivate only in wet season, few of them give light irrigation to tide over the critical period and switch over to low duty crops (Table 3). Farmers represent to the irrigation officials and wait for them to visit the area for taking necessary action to provide irrigation. Farmers perceived constraints in term of lack of fund and interest on part of the irrigation department to improve the existing situation (Table 4 and 5).

Table 2: Reasons of not getting adequate irrigation water as perceived by the farmers of command area

Reasons as perceived by the farmers	Percentage (%)
There is less water in the reservoir	25.00
Canal / distribution system is not well maintained	77.50
Faulty alignment of distribution system	72.50
Untimely repair of distribution system	70.00
No monitoring of water supply	60.00

Table 3: Farmers' alternative measures to overcome unavailability of irrigation water of command area

Alternative measures to overcome unavailability of water	Percentage (%)
Supplementary irrigation from other sources	32.50
Giving light irrigation to tide over the critical period	42.50
Grow early variety crops	30.00
Switching to low duty crops	40.00
Keeping the land fallow (growing no crops) in dry season and cultivating only in wet season mainly depending on rain water	62.50

Table 4: Action taken by farmers of command area in case of getting insufficient water through canal

Action taken by the farmers	Percentage (%)
Represent to the officials of irrigation department	80.00
Wait for the officials to visit the areas	85.00
Forcibly take water when it is available	20.00
Irrigate fields on turn basis	35.00
Irrigate the fields from other sources	32.50

Table 5: Farmers' perceived constraints related to irrigation department

Constraints related to irrigation department	Percentage (%)
Lack of interest on part of the officials	75.00
Geographical constraints (land situation, etc.)	55.00
Lack of community co-operation	65.00
Financial constraints	82.50

5. Existing cropping pattern

The cropping pattern was studied with the help of a schedule developed for this purpose. Rice-rice was the cropping sequence in 95 % of the command area. If water is released during dry season, the cropping intensity is 180 %. If the water is not released during dry season, then the cropping intensity is generally 120% with rice-black gram, rice-green gram or rice-horse gram sequence under residual moisture. Rice-fallow was found to be predominant system in the non-command area. Rice varieties mostly grown during the wet season are CR-1017, CR-1009, *Swarna, Padmini, Moti, Tulasi*, CR-1014, IR-1242 and *Lalat*. In dry season, 90 per cent of the farmers in the command area grow rice variety *Samalei*.

Cultivated area, input use in term of fertilizers, and rice yield under canal command and non-command area are presented in the Table 6. Average size of cultivated plot in command and non-command areas were 1.16 and 2.12 ha, respectively. Average nitrogen use in wet season (56.5 kg/ha) is lower than the dry season (71.0 kg/ha) in command area. Average use of phosphorus is 22.5 and 32.8 kg/ha in wet and dry season, respectively. Average application of potash in wet and dry season is 48.5 and 60.5 kg/ha, respectively. In contrast, average application of N, P, and K in non-command area was found to be 25.8, 10.0 and 15.5 kg/ha, respectively.

Average yield of paddy in the command area is 2.1 and 2.92 t/ha in wet and dry season, respectively. The yield ranges from 1.0 to 3.0 t/ha in wet season and from 1.8 to 5.0 t/ha in dry season. The yield in the non-command area was found to be 1.96 t/ha in wet season. Low input use, absence of field channel and uncontrolled irrigation, late transplanting in wet season contributed to the low average yield in the canal command as well as non-command area. About 50% and 75% of the farmers of command and non-command area, respectively, go for nursery sowing during the second fortnight of June to first fortnight of July because of lack of water sources for raising nursery. In dry season, most of the farmers of command area were compelled to go for late sowing of nursery, often in the first fortnight of January. Consequently, the crop often undergoes water stress in the later stage (Table 7). Harvesting time varies from first fortnight of December to first fortnight of January in wet season and first fortnight of April to second fortnight of May in dry season (Table 8).

6. Constraints analyses

There is enormous gap between potential created and potential utilised in canal com-

Table 6. Area, productivity and fertilizer use pattern in canal command and non command area

Variables	Canal command area		Non command area		Pooled Mean		Pooled SD		Range	
	Wet season n=100	Dry season n=94	Wet season n=50	Dry season -	Wet season N=150	Dry season N=94	Wet season	Dry season	Wet season	Dry season
Area cultivated (ha)	1.16	1.00	2.12	-	1.48	1.00	1.04	0.62	0.06 -8.00	0.06 -4.00
Small	20	08	02	-						
Medium	73	79	37	-						
Large	07	07	11	-						
Nitrogen (kg/ha)	56.5	71.0	25.8	-	46.3	71.0	20.8	19.9	12.5-112.5	32.5-137.5
Low	05	14	25	-						
Medium	74	64	25	-						
High	21	16	-	-						
Phosphorus (P_2O_5) (kg/ha)	22.5	32.8	10.0	-	18.3	32.8	12.8	10.7	0-52.5	12.5-70.0
Low	06	20	37	-						
Medium	64	66	13	-						
High	30	08	-	-						
Potash (K_2O) (kg/ha)	48.5	60.5	15.5	-	37.5	60.5	26.5	25.4	17.5-75.0	20.0-150.0
Low	04	04	32							
Medium	70	66	18							
High	26	24	-							
Yield of rice crop (t/ha)	2.08	2.92	1.96	-	2.04	2.92	0.74	0.76	1.12-3.12	1.81-5.00
Low	08	12	05	-						
Medium	81	63	40	-						
High	11	19	05	-						

Small/Low: < Mean-SD;Medium: Mean-SD to Mean+SD;Large/High: > Mean+SD

mand area due to various constraints experienced by the farmers. In this context, present study was conducted in canal command area of Khurda district of Orissa with the objective to identify top most constraints in canal irrigation through preferential ranking technique.

Table 7: Time of sowing of rice during wet and dry season in canal command and adjacent non-command area.

Wet season			Dry season		
Sowing time	Percentage of farmers		Sowing time	Percentage of farmers	
	Command area	Non command area		Command area	Non command area
I fortnight of June	37	14	II fortnight of Dec.	45.2	-
II fortnight of June	05	40	I fortnight of Jan.	39.4	-
I fortnight of July	48	36	II fortnight of Jan.	7.5	-
II fortnight of July	10	10	I fortnight of Feb.	5.4	-
			II fortnight of Feb.	2.5	-

Table 8: Harvesting time of rice during wet and dry season in canal command and adjacent non-command area.

Wet season			Dry season		
Time of harvest	Percentage of farmers		Time of harvest	Percentage of farmers	
	Command area	Non command area		Command area	Non command area
I fortnight of Dec.	17	32	I fortnight of April	15.9	-
II fortnight of Dec.	50	52	II fortnight of April	38.3	-
I fortnight of Jan.	26	16	I fortnight of May	24.5	-
II fortnight of Jan.	07	-	II fortnight of May	21.3	-

6.1 Preferential ranking technique

The constraint analyses through Preferential Ranking Technique involved following steps (Sabarathnam, 1988)

1. Identification of key informants (KI): Key informants, who were conversant with the existing situations, like Panchayat President, local leaders, and progressive farmers were first identified. Six KIs were selected and asked individually to list out the constraints faced by the farmers in canal irrigation along with the respective rank, approximate affected area and economic loss caused by each constraint

2. Identification of farmers: Thirty farmers were identified with the help of KIs and responses were taken in a similar way

3. Quantification of data: Rank Based Quotient (RBQ) was calculated for each constraint both for KIs and farmers with the formula: $RBQ = [\Sigma F_i (n+1-i) / N n] \times 100$

where, Fi is the frequency of farmers / KI for the i^{th} rank of constraint; N and n denote the total number of respondents and total number of constraints identified, respectively.

To choose a single RBQ value for each constraint, rank correlation (R) coefficient was worked out to know the degree of association between the KIs and farmers in prioritizing the constraints.

$R = 1 - (6 \Sigma d_i^2 / n^3 - n)$

where, d_i is the difference in the ranks between the key informants and farmers for the ith constraint; n is the number of constraints

If the R-value was significant at 5 per cent level, the average RBQ value was taken, else RBQ value of the farmers was taken as final one.

4. Calculation of magnitude value of the constraint and final ranking: It was calculated for each constraint and final ranking was made.

Magnitude Value = RBQ x Average Economic Loss in % x Average Area Affected by respective constraint. Based on this magnitude value of the constraints, the topmost problem (possessing the highest magnitude value) was delineated.

6.2 Prioritised constraints

The constraint analyses through preferential ranking technique identified as many as nine constraints. They were: (a) lack of adequate water at the critical period as there is less water in the reservoir, (b) poor maintenance of canal / distribution system, (c) faulty alignment of distribution system, (d) no repair or untimely repair of distribution system, (e) no monitoring of water supply by the officials, (f) lack of interest and attention on part of irrigation department officials, (g) geographical constraints (availability of water varies with the land situation, i.e. whether it is at upper, medium or lower reach, etc.), (h) lack of community co-operation, and (i) untimely supply of canal water results into water scarcity at critical crop growth stages and flood or water logging during rainy season. Rankings given to these constraints by different key informants and farmers along with the frequency are outlined in Table 9 and Table 10, respectively. A perusal of these facts indicated that poor maintenance of canal / distribution system was given the first rank by 5 key informants and 23 farmers. Likewise, faulty alignment of distribution system was given the first rank by one key informant and two farmers.

Based on the ranks given by key informants and farmers to different constraints, the rank based quotient (RBQ) was calculated for each constraint and presented in Table 11. It could be inferred that the calculated RBQ values ranged from 24.07 to 92.59 in case of key informants and from 31.48 to 92.22 in case of farmers. The lowest value in case of key informants was found for lack of adequate water at the critical period, as there is less water in reservoir while that in case of farmers was for lack of community co-operation. However, the highest value in both the cases corresponded to poor maintenance of canal / distribution system. In order to arrive at a single RBQ value for all the problems in the next stage, the rank correlation value was derived and found to be 0.976. As the rank correlation value is highly significant, average values of RBQ to the individual constraints were taken as the final RBQ values for further analyses.

Table 9: Ranking of the constraints in canal irrigation as given by the key informants (n= 6)

Constraints	Ranks given by the key informants (n= 6)								
	1	2	3	4	5	6	7	8	9
1. Lack of adequate water at the critical period as there is less water in the reservoir						1	1	2	2
2. Poor maintenance of canal / distribution system	5				1				
3. Faulty alignment of distribution system	1	2	1	1			1		
4. No repair or untimely repair of distribution system		4	2						
5. No monitoring of water supply by the officials			2	2	1				1
6. Lack of interest and attention on part of irrigation department officials			1	2	2			1	
7. Geographical constraints (availability of water varies with the land situation i.e. whether it is at upper, medium or lower reach, etc.)				1		1	2	1	1
8. Lack of community co-operation						2	1	2	1
9. Untimely supply of canal water results into water scarcity during critical period and flood or water logging during rainy season					2	2	1		1

Table 10: Ranking of the constraints in canal irrigation as given by the farmers (n= 30)

Constraints	Ranks given by the farmers (n= 30)								
	1	2	3	4	5	6	7	8	9
1. Lack of adequate water at the critical period as there is less water in the reservoir	2				1	7	8	3	9
2. Poor maintenance of canal / distribution system	23	3		1		3			
3. Faulty alignment of distribution system	2	15	5	1	5		2		
4. No repair or untimely repair of distribution system	2	8	14	3	2	1			
5. No monitoring of water supply by the officials		3	6	16	3		1	1	
6. Lack of interest and attention on part of irrigation department officials			3	7	7	5		4	4
7. Geographical constraints (availability of water varies with the land situation i.e. whether it is at upper, medium or lower reach, etc.)	1		1		7	4	6	5	6
8. Lack of community co-operation		1	1		3	3	5	11	6
9. Untimely supply of canal water results into water scarcity during critical period and flood or water logging during rainy season				2	2	7	8	6	5

Table 11: Rank Based Quotient of the constraints given by key informants and farmers

Constraints	Mean rank of KI	Mean rank of farmers	Overall mean	RBQ of KI	RBQ of farmers	Mean RBQ
1. Lack of adequate water at the critical period as there is less water in the reservoir	7.83	7.00	7.14	24.07	33.33	28.70
2. Poor maintenance of canal / distribution system	1.67	1.70	1.70	92.59	92.22	92.41
3. Faulty alignment of distribution system	3.16	3.00	3.03	75.93	77.78	76.6
4. No repair or untimely repair of distribution system	2.33	2.93	2.83	85.19	78.52	81.86
5. No monitoring of water supply by the officials	4.67	3.93	4.05	59.26	67.41	63.34
6. Lack of interest and attention on part of irrigation department officials	4.83	5.67	5.53	57.41	48.15	52.78
7. Geographical constraints (availability of water varies with the land situation i.e. whether it is at upper, medium or lower reach, etc.)	6.83	6.63	6.66	35.19	37.41	36.30
8. Lack of community co-operation	7.34	7.16	7.19	29.63	31.48	30.56
9. Untimely supply of canal water results into water scarcity during critical period and flood or water logging during rainy season	6.34	6.96	6.86	40.74	33.70	37.22

Mean affected area and mean economic loss due to individual constraints have been presented in Table 12. Mean affected area ranged from 28.89 to 59.46 ha. The highest affected area was due to poor maintenance of canal / distribution system followed by no repair or untimely repair of distribution system. Mean economic loss ranged from 20.00 to 33.33 per cent. The highest loss was found to be due to no repair or untimely repair of distribution system followed by no monitoring of water supply by the irrigation department officials. In the same table, the magnitude value of each constraint was worked out taking into consideration the mean RBQ value, mean affected area and mean economic loss for the each identified constraint. It may be noticed that the maximum magnitude value was attributed to the poor maintenance of canal and distribution system followed by no repair or untimely repair of distribution system and faulty alignment of distribution system. Thus, preferential ranking technique was successfully utilised for delineating and prioritizing the constraints in canal irrigation.

Table 12: Farmers' perceived constraints in canal irrigation delineated through preferential ranking technique

Constraints	Mean RBQ	Affected area (ha)		Economic loss (%)		Magnitude	Preferen-tial ranking
		Mean	Standard deviation	Mean	Standard deviation	Value (,000)	
1. Lack of adequate water at the critical period as there is less water in the reservoir	28.70	47.12	17.28	20.83	8.35	28.17	VIII
2. Poor maintenance of canal / distribution system	92.41	59.46	25.84	31.83	12.65	174.92	I
3. Faulty alignment of distribution system	76.86	50.46	19.04	32.00	11.28	124.10	III
4. No repair or untimely repair of distribution system	81.86	54.53	22.85	33.33	8.08	148.78	II
5. No monitoring of water supply by the officials	63.34	51.88	19.33	31.83	10.03	104.59	IV
6. Lack of interest and attention on part of irrigation department officials	52.78	46.33	18.42	27.83	10.20	68.07	V
7. Geographical constraints (availability of water varies with the land situation i.e. whether it is at upper, medium or lower reach, etc.)	36.30	43.21	20.72	30.83	12.28	48.37	VI
8. Lack of community co-operation	30.56	34.44	17.26	20.00	12.61	21.05	IX
9. Untimely supply of canal water results into water scarcity during critical period and flood or water logging during rainy season	37.22	28.89	14.05	27.50	13.15	29.57	VII

7. Performance of irrigation system

Present study used the fuzzy set theory approach to evaluate performance of irrigation system from the perspective of farmers in a manner described earlier by El-Awad (1991) and Sam-Amoah and Gowing (2001). A methodology based on farmers' assessment of the utility of water supply under irrigation system was followed where the concept of fuzzy set theory is applied to analyse the responses from farmers concerning their perceptions of the irrigation service provided to them.

The utility of water delivery service in the distribution system was measured on the basis of different factors:

(a) *Tractability:* It refers to the ease with which farmers can control and satisfactorily apply water to their land. It is sometimes referred to as controllability (El-Awad, 1991). In the present study it was assessed on the basis of three sub-factors, viz., quantity of supply of water, point of delivery of water and stream size of water.

(b) *Convenience:* It refers to the timing of water delivery as preferred by farmers to enable them to plan other activities. Convenience of water supply was determined on the basis of four sub-factors, viz., timing of arrival of water, flow rate of water, duration of supply of water and frequency of getting water.

(c) *Predictability:* It relates to the farmer's degree of confidence with respect to water delivery service. It refers to the question of how much information is available to the farmer about the water supply schedule and degree of uncertainty associated with this information. Predictability can improve water use decisions. It can also be referred as reliability (El-Awad, 1991). It was measured on the basis of three sub-factors, viz., knowledge of future supply of water, management decisions influenced by water supply and certainty of water availability.

In the present study, a stratified random sampling method was followed to select the farmers as respondents. The command area was divided into three strata, i.e., head, middle and tail following geographic criteria; and a total of 30 farmers, 10 each from above-mentioned three strata, were selected by following random sampling procedure. Stratification was done to have a comparative analysis of utility of water delivery in head, middle and tail reach of irrigation system.

An interview schedule was developed to assess the utility of water delivery on the basis of three factors and the sub-factors of each factor. Pre-testing of the interview schedule and its validation were carried out with the group of farmers. Final formulation of the schedule was done through incorporation of farmers' perspectives on performance evaluation of irrigation supply.

The farmers were then interviewed on an individual basis. Each farmer put forward his judgement with respect to each sub-factor under each of the three factors (tractability, convenience and predictability) and its importance to own situation in the form of linguistic expressions. These expressions ranged from very good/ very high to very bad/ very low. A total sample of thirty farmers, ten each from head, middle and tail reach of the irrigation system was interviewed. Fuzzy set mathematics was applied with respect to each farmer's judgement towards individual sub-factors under each of the three factors and its importance to his own situation in term of his linguistic expressions. At first step, aggregation of opinions of farmers as well as diversity index (DI) was derived followed by calculation of farmers' utility (FU) values with respect to each sub-factor under three factors, i.e. tractability, convenience and predictability. The results are presented in Table 13, Table 14 and Table 15, respectively. Thereafter, farmers' opinions were considered for all the sub-factors under each factor together to derive aggregation and diversity of individual factors followed by calculation of farmers' utility values. The result is indicated in Table 16.

Data in Table 13 show farmers' assessment of the performance of irrigation service with respect to three sub-factors of the factor 'tractability'. It is evident that farmers' judgements and utility values at the head reach is found to be comparatively better than middle and tail reach with respect to quantity of water supply and stream size of water. The opinions for point of delivery of water are average in all three reaches with utility values 0.50-0.51. The divergence of farmers' opinions seemed to be higher in case of their judgements; however, their opinions are closer in the importance attached by them to individual sub-factors. It is interesting to note that the level of suitability of stream size of water to the farmers is expressed as the highest and therefore, importance attached by them to this sub-factor is the least.

Table 13: Aggregation and divergence of farmers' opinions on the sub-factors under factor tractability and their importance

Sub-factors	Judgement			Importance		
	Expression	DI	FU	Expression	DI	FU
Head reach						
Quantity of water supply	More or less good	0.48	0.70	More or less high	0.48	0.74
Point of delivery of water	Average	0.78	0.51	More or less high	0.48	0.72
Stream size of water	More or less good	0.48	0.73	Medium	0.48	0.64
Middle reach						
Quantity of water supply	Average	0.80	0.50	More or less high	0.53	0.74
Point of delivery of water	Average	0.78	0.50	More or less high	0.53	0.73
Stream size of water	Average	0.78	0.51	More or less high	0.53	0.72
Tail reach						
Quantity of water supply	Average	0.78	0.50	High	0.00	0.89
Point of delivery of water	Average	0.78	0.51	More or less high	0.48	0.72
Stream size of water	Average	0.78	0.52	More or less high	0.48	0.70

Farmers' opinions on the performance of water delivery with respect to four sub-factors of the factor 'convenience' are reported in Table 14.

Table 14: Aggregation and divergence of farmers' opinions on the sub-factors under factor convenience and their importance

Sub-factors	Judgement			Importance		
	Expression	DI	FU	Expression	DI	FU
Head reach						
Timing of arrival of water	Average	0.78	0.53	Medium	0.58	0.49
Flow rate of water delivery	Average	0.78	0.51	More or less high	0.48	0.70
Duration of supply of water	Average	0.48	0.63	More or less high	0.48	0.70
Frequency of getting water	Average	0.78	0.52	More or less high	0.48	0.73
Middle reach						
Timing of arrival of water	Average	0.48	0.62	Medium	0.58	0.48
Flow rate of water delivery	Average	0.78	0.49	More or less high	0.53	0.68
Duration of supply of water	Average	0.48	0.62	Medium	0.48	0.64
Frequency of getting water	Bad	0.78	0.51	More or less high	0.53	0.70
Tail reach						
Timing of arrival of water	Average	0.78	0.51	Medium	0.58	0.48
Flow rate of water delivery	Average	0.80	0.51	More or less high	0.48	0.70
Duration of supply of water	Average	0.48	0.63	Medium	0.48	0.63
Frequency of getting water	Bad	0.78	0.41	High	0.53	0.75

It is revealing that farmers' judgements with respect to timing, flow rate and duration of water supply are average in all three reaches with utility values ranging from 0.49 to 0.63. Farmers have judged frequency of getting water at higher reach as average while that is expressed as bad at both middle and tail reach of the irrigation system with the level of importance attached to this sub-factor as maximum. It is interesting to note that the timing of water arrival has received the least importance. This may be explained by the fact that timing of water supply usually depends on the rainfall and management decisions of the irrigation department. Therefore, farmers have no choice but to conform in this regard. There are differences in opinions of the farmers; diversity index ranges from 0.48 to 0.80 and 0.48 to 0.58 in case of their judgements and importance given to the sub-factors, respectively.

A perusal of data in Table 15 indicates farmers' views on water delivery with respect to three sub-factors of the factor 'predictability'.

It may be noticed that farmers have opined knowledge of future supply of water as bad and they attached highest importance to it with least diversity of opinions among them (DI ranges from 0 to 0.07). Management decision influenced by water supply is expressed as more or less bad at higher reach, and bad at both middle and tail reach. Farmers judged certainty of water availability as average at both higher and middle reach, and more or less bad at tail reach of the irrigation system.

Table 15: Aggregation and divergence of farmers' opinions on the sub-factors under factor predictability and their importance

Sub-factors	Judgement			Importance		
	Expression	DI	FU	Expression	DI	FU
Head reach						
Knowledge of future supply of water	Bad	0.78	0.39	High	0.00	0.89
Management decision influenced by water supply	More or less bad	0.78	0.40	More or less high	0.48	0.72
Certainty of water availability	Average	0.78	0.51	More or less high	0.48	0.70
Middle reach						
Knowledge of future supply of water	Bad	0.53	0.25	High	0.00	0.89
Management decision influenced by water supply	Bad	0.78	0.36	More or less high	0.48	0.74
Certainty of water availability	Average	0.78	0.49	More or less high	0.53	0.73
Tail reach						
Knowledge of future supply of water	Bad	0.80	0.36	High	0.07	0.90
Management decision influenced by water supply	Bad	0.48	0.28	More or less high	0.48	0.73
Certainty of water availability	More or less bad	0.48	0.37	More or less high	0.48	0.70

Table 16: Aggregation and divergence of farmers' opinions on individual factors and their importance

Sub-factors	Judgement			Importance		
	Expression	DI	FU	Expression	DI	FU
Head reach						
Tractability	More or less good	0.78	0.61	More or less high	0.48	0.72
Convenience	Average	0.80	0.52	Medium	0.78	0.53
Predictability	Average	0.78	0.48	More or less high	0.48	0.73
Middle reach						
Tractability	Average	0.80	0.51	More or less high	0.53	0.73
Convenience	Average	0.78	0.50	Medium	0.80	0.59
Predictability	Bad	0.80	0.38	More or less high	0.53	0.74
Tail reach						
Tractability	Average	0.78	0.54	More or less high	0.48	0.73
Convenience	Average	0.80	0.52	Medium	0.80	0.52
Predictability	Bad	0.80	0.39	More or less high	0.53	0.73

Overall utility of irrigation service provided to farmers is assessed in respect of three factors of utility, i.e., tractability, convenience and predictability. It is evident from data presented in Table 16 that farmers' level of satisfaction with the factors in an increasing order was predictability, convenience and tractability with the utility values ranging from 0.38 to 0.61. Head reach of the system recorded relatively higher utility values (0.48 to 0.61) as compared to middle and tail reach of irrigation command. These results confirm the view that farmers at head reach of water delivery system under the irrigation scheme have an advantage in terms of water allocation over their fellow farmers down the laterals. The most important factor is found to be predictability followed by tractability and convenience. The higher values of DI (0.78 to 0.80) is indicative of differences in the judgements of the farmers. However, it is found to be least with the importance attached by them to the factors predictability and tractability of water delivery of the irrigation system.

8. Technological interventions to enhance crop production

Efforts were made to alleviate some of the farm-level constraints of a canal command area of coastal Orissa by some technological interventions for enhancing crop production in farmers' fields. Brief accounts of these technologies and their impacts on crop production are given in the following pages.

8.1. Land modification for crop diversification in canal command area

Water logging and shallow water table in the canal command of high rainfall area create anaerobic condition in soils and force farmers to grow rice in both wet and dry season. Moreover, paddy cultivation is not so remunerative due to our present agricultural policy. And farmers now look for more remunerative alternate crops. Modification of topography of field through construction of alternate raised and sunken beds improves the physical environment, particularly aeration status of the soil and creates proper condition for growth of crops other than rice (Singh *et al.* 2003a; Singh *et al.* 2003b; Kannan *et al.* 2003a and Kannan *et al.* 2003b). This technology was applied during 2001-2002 dry and wet seasons at Balipatna Canal Command in Khurda district of Orissa to grow different vegetable crops adjacent to rice in the same field. For this purpose, the field was modified into alternating raised and sunken beds by digging soil of one strip (5m x 30 m) to a depth of 30 cm and putting the dug-out soil over the adjacent strip (5m x 30m). The raised beds were thus 60-cm higher than the adjacent sunken beds (Fig. 2). For demonstration of this technology in farmers' fields, different vegetable crops and crop sequences were grown with rice and these crop sequences were treated as different treatments. The treatments were: T1, conventional system (only rice crop grown with no land modification); T2, alternate raised and sunken bed system (rice grown in the sunken bed and cabbage in the raised bed); T3, alternate raised and sunken bed system (rice grown in the sunken bed and cabbage followed by malabar spinach grown in raised bed); T4, alternate raised and sunken bed system (rice grown in the sunken bed and brinjal grown in the raised bed); and T5, alternate raised and sunken bed system (rice grown in the sunken bed and tomato followed by ridge gourd grown in the raised bed). Rice variety "Lalat" was transplanted at 20cm x 10cm spacing in the sunken bed. All the vegetable crops were irrigated at the time of transplanting or sowing only. The calendar sowing/planting time and harvesting time of all the crops are given in Fig.3. Yields of various crops, their rice equivalent under different treatments and the economics were worked out on the basis of prevailing market price.

Rice equivalent yield (REY) of all the crop sequences were significantly higher in alternate raised and sunken bed system than rice yield in non-modified field (Table 17). It was due to high yield obtained from different vegetable crops grown in the raised beds. Different cropping systems consumed varied quantities of irrigation water (Table 17). Total irrigation water use was maximum in rice alone in unmodified land (T1). This was followed by rice + tomato-ridge gourd sequence, and rice + cabbage-malabar spinach sequence. The highest water use under rice alone system was due to high water requirement of rice crop compared to other vegetables. The highest irrigation water use efficiency (WUE) was recorded in the treatment T3. This was due to higher production potential and low water requirement of cabbage and malabar spinach, which replaced 50 % rice crop in the total area. This was followed by rice + cabbage, and rice + tomato-ridge gourd sequences. Low WUE of rice + brinjal treatment was due to low yield recorded in brinjal compared to other vegetables. But it recorded four times higher water use efficiency compared to mono cropping of rice (T1) that recorded the least irrigation water use efficiency.

The highest net return and benefit cost ratio (BCR) were recorded in rice + cabbage-malabar spinach sequence. It was followed by the rice + tomato- ridge gourd sequence. The BCR of rice + cabbage was comparable to rice + tomato-ridge gourd sequence, because of higher price of cabbage compared to tomato during the season (Table 18). The least BCR and net return were recorded in the conventional system (T1). In the raised and sunken bed system, rice + brinjal sequence produced lesser. However, this BCR was significantly higher than that recorded for rice only in unmodified land (Table 18).

During wet season, cropping sequences tested in farmers' fields were: T1, non-modified land with medium duration rice variety (*Swarna*); T2, long duration rice variety (*Sarala*) in the sunken bed and brinjal- cauliflower sequence in the raised bed; T3, rice in the sunken bed and brinjal-knolkhol (*Brassica oleracea var gongylodes*) sequence in the raised bed; T4, rice in the sunken bed and vegetable cowpea (*Vigna unguiculata*)- early season cauliflower sequence in the raised beds; T5, rice in the sunken bed and cucumber (*Cucumis sativus*)- early season cauliflower sequence in the raised bed; T6, rice in the sunken bed and ladies finger (*Hibiscus esculendus*)-leafy vegetable sequence in the raised bed.

Rice equivalent yields of all the cropping sequences involving vegetables in the raised bed and rice in sunken bed were significantly higher than the non-modified field where rice is grown in the entire land (Table 19). This high productivity was possible due to double cropping in the raised bed, as it needed less turn around time between two vegetable crops. Among different crops sequences in modified land, rice + brinjal-knolkhol sequence produced the highest rice equivalent yield. This was followed by rice+ brinjal-cauliflower sequence and it was comparable with T4. Rice + ladies finger-leafy vegetable produced the least REY among all the modified land systems due to low yield of ladies finger and leafy vegetable. But its REY was significantly higher than the conventional system where only rice was grown without any modification of land.

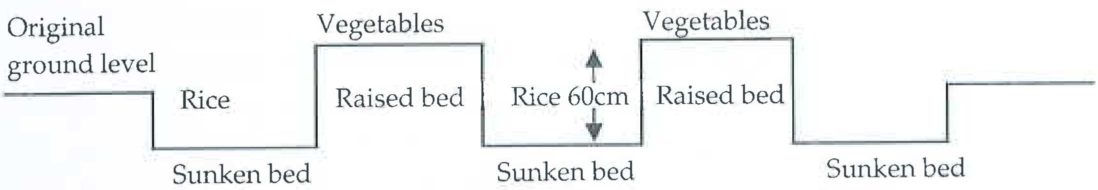


Fig. 2: Schematic diagram of alternate sunken and raised bed system

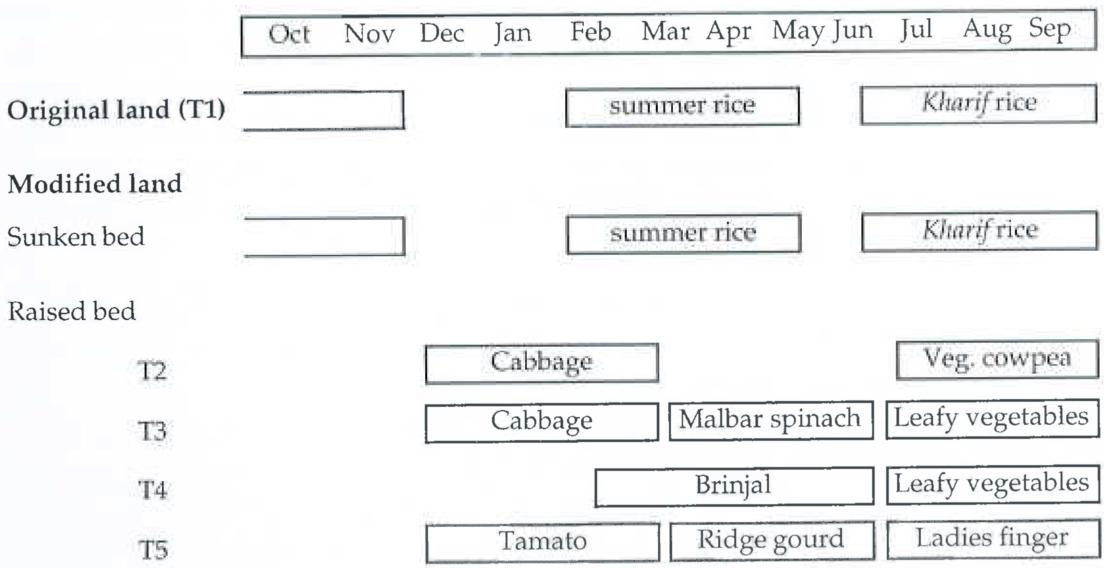


Fig.3: Crop calendar under different systems of cultivation

Table 17: Productivity and WUE of different crop sequences under conventional and modified cultivation methods. Balipatna, Khurda district, Orissa. Dry season, 2002.

Treatments	Yield, t/ha	System yield (50:50), t/ha	Rice equivalent yield (REY), t/ha	Total system REY, t/ha	Irrigation water use, mm/ha	Irrigation water use efficiency, kg/ha-cm
Conventional T1: Rice	3.19	3.19	3.19	3.19	1200	26.6
Modified land T2: Rice + Cabbage	2.95 27.32	1.48 13.66	1.48 13.66	15.14	760	186.91
T3 Rice + Cabbage - Malabar spinach	2.96 27.32 34.4	1.48 13.66 17.25	1.48 13.66 6.46	21.61	1015	212.86
T4 Rice+ Brinjal	2.93 17.79	1.46 8.89	1.46 11.12	12.58	920	129.74
T5 Rice+ Tomato- Ridge gourd	2.99 33.20 11.167	1.49 16.60 5.58	1.49 12.45 2.79	16.74	1060	157.88

Table18: Economics of different crop sequences grown under two systems of cultivation. Balipatna, Khurda district, Orissa. Dry season, 2002.

Treatments	Total Cost, Rs/ha	Gross return, Rs/ha	Net return, Rs/ha	BCR
Conventional T1: Rice	11700	13252	1552	1.13
Modified land T2: Rice + Cabbage	23123	60790	37666	2.62
T3: Rice + Cabbage-Malabar spinach	28717	86427	57710	3.01
T4: Rice + Brinjal	23550	50340	26790	2.13
T5: Rice + Tomato-	24200	66944	42744	2.76

Table 19: Productivity, and WUE of different crop sequences under conventional and modified cultivation methods. Balipatna, Khurda district, Orissa. wet season, 2002-2003.

Treatments	Yield, t/ha	System yield (50:50), t/ha	Rice equivalent yield (REY), t/ha	Total system REY, t/ha	Irrigation water use, mm/ha	Irrigation water use efficiency, kg/ha-cm
T1: Conventional Rice	3.86	3.86	3.86	3.86	300	128.60
T2: Rice +	5.23	2.61	2.61	30.60	570	536.84
Brinjal-	12.23	6.11	12.17			
Cauliflower	33.76	16.88	15.81			
T3: Rice+	5.23	2.61	2.61	32.95	570	578.04
Brinjal	12.34	6.17	12.33			
Knolkhol	36.66	18.33	18.33			
T4: Rice+	5.23	2.61	2.61	29.38	270	1088.14
Cowpea-	8.16	4.08	7.09			
Cauliflower	3.66	15.33	20.27			
T5: Rice+	5.23	2.61	2.61	27.62	270	1022.96
Cucumber-	9.50	4.75	4.75			
Cauliflower	30.60	15.30	20.27			
T6: Rice+	5.23	2.61	2.61			
Ladies finger-	3.77	1.88	2.78			
Leafy vegetable	1033	5.16	2.58			

Average price during the season taken for the calculation of REY were Rice: Rs 4.00/kg, cauliflower (early): Rs 5.00/kg, cauliflower (late): Rs 3.75/kg, cowpea: Rs 7.00/kg, knolkhol: Rs 4.00/kg, cucumber: Rs 4.00/kg., leafy vegetable: Rs 2.00/kg, ladies finger: Rs 5.00/kg. and brinjal: Rs 8.00/kg

During the drought year 2002, water level in the rice field was monitored weekly from the last week of July (Fig. 4). In spite of the drought, water level in the rice field of modified land (sunken bed) was sufficient for timely transplanting and better crop growth. In unmodified land, water level in the fields stood between 1 and 3 cm during August, and the fields were saturated to under saturated during September-October, which coincided with flowering and high water requirement of the rice crop.

8. 2. Use of Water Saving Technology in Canal Command Area

Agricultural production level in the canal-irrigated area of eastern states is quite low than its potential. The lack of dependability and reliability of irrigation water is one of the major constraints in realizing the production potential. In eastern states, majority of the canal command farmers cannot get adequate and timely supply of irrigation. Tail end farmers always get

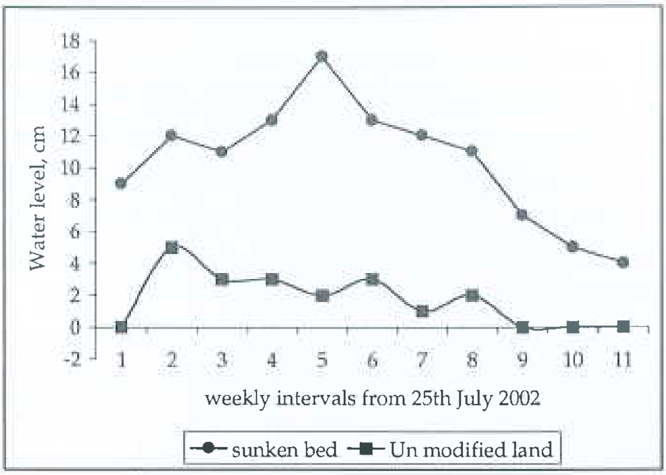


Fig. 4: Ponded water depth in rice field

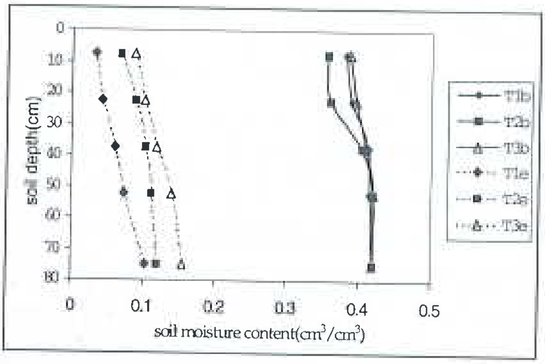
less water and many times they do not get any water. Some time canal network needs repair and maintenance work and water is not released in the command area. In these situations use of water saving technologies may prove very effective for getting higher production with less water. We tried some of water saving technologies in Nimapara branch canal command at Balipatna block of Khurda district of Orissa. The findings are as follows:

8.2.1.Optimum time and method of sowing

To find out optimum time and method of sowing for utilization of residual soil moisture, horse gram was chosen as test crop. Two sowing time (early sowing, 15th October and late sowing, 1st November) and two methods of sowing viz. pyra cropping (spreading of seeds in standing rice crop) with & without tillage were selected for this purpose. The treatments were early sowing (15th October) with minimum tillage (T1), late sowing (1st November) with minimum tillage (T2) and pyra cropping on 15th October (T3). Soil moisture depletion pattern showed that contribution of top 0-30 cm soil layer in moisture extraction was higher (Fig. 5). The per-cent of residual soil moisture removal from 0-30 cm soil depth were 90.2, 79.2 and 75.83 respectively for treatments T1, T2 and T3. Per cent of soil moisture removal from 30-90 cm soil depth was the least (66.94) in pyra cropping compared to early sowing (80.8) and late sowing (72.) This might be due to poor root growth in this layer in pyra cropping (Fig.5). The highest consumptive water use was recorded in treatment T1 compared to other treatments. Though availability of residual soil moisture was same in T1 and T3 at sowing, the water use was lesser in pyra cropping (T3) due to poor plant and root growth (Fig.6). The least consumptive water use was observed in late sowing. It might have been due to poor residual soil moisture availability in later stage. Water use in pyra cropping was comparatively more than that in late sowing. But it was mainly attributed to evaporation rather than crop use. Water use efficiency (WUE) was the highest (60.2 kg seed /ha-cm) in early sowing with minimum tillage. This might be due to production of relatively higher grain yield. The least WUE (41.1-kg seed/ha-cm) was observed in pyra cropping due to poor yield and high water use. Water use efficiency of late sowing was better than early sowing as pyra crop. This might have been due to better crop growth and yield in late sowing compared to early sowing as pyra crop. The highest growth and yield attributes were recorded in early sowing. Maximum grain yield of 1.29 t/ha was observed in early sowing which was 21.5% and 70% more compared to T2 and T3. The highest water use efficiency (60.2 kg/ha-cm) was recorded in early sowing and the least water use efficiency (39.8 kg/ha-cm) was recorded in pyra cropping (Table 20).

Table 20: Growth, yield, water use and N uptake of horse gram as influenced by treatments

Treat-ments	Plant height, cm	Biomass at flowering, gm/m^2	Number of pods/ plant	Grain yield, t/ha	Hay yield, t/ha	Water use, mm	Water use efficiency, kg/ha -cm	N uptake, kg/ha
T1	57.0	620.3	60.8	1.29	3.16	214.3	60.2	79.12
T2	51.5	545.5	45.0	1.06	2.50	182.8	58.0	62.50
T3	44.5	450.2	38.0	0.75	2.11	188.6	39.8	52.81
CD P=0.05	4.32	51.65	5.78	0.13	0.27			



b- soil moisture at the beginning; e- soil moisture at the end of the crop growth

Fig.5: Moisture distribution in soil profile at the time of sowing and harvesting of horse gram under different treatments

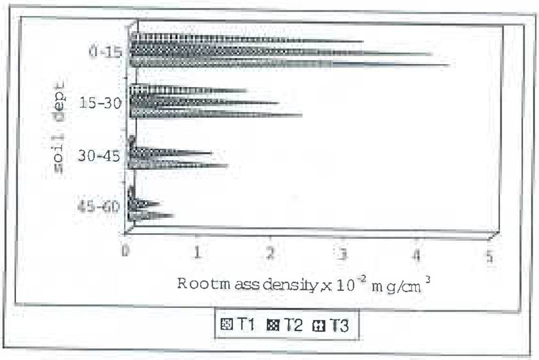


Fig. 6: Root mass density of horse gram under different treatments.

8.2.2. Use of mulch

Use of organic mulch helps in reducing evaporation by moderating temperature and conserving moisture of the soil. Mulching technology was used to assess the effect of paddy straw mulch, which is easily available for limited area, on moisture and nutrient availability, soil temperature regulation, tuber development and growth of sweet potato crop (a moderately drought-tolerant crop) in dry season. Various treatments tested were: T1 no irrigation and no mulch, T2 one irrigation of 3 cm given 4 weeks after planting, T3 one irrigation of 3 cm given 8 weeks after planting, and T4 mulching with paddy straw @ 5 t/ha applied just after planting. Sweet potato variety "Shankar" was planted using spacing of 60x20 cm in RBD with three replications. The crop was planted in last week of November and was harvested after 120 days. Rainfall during crop growing period was 33 mm (during 23rd to 30th Jan, 2002). The treatment of no mulch and no irrigation (T1) showed the lowest level of soil moisture at any given stage of the crop, in comparison with other treatments. Depletion of soil moisture was the slowest under mulching (T4) treatment that also showed highest soil moisture content throughout the period from 70 DAP onwards. However soil moisture under two irrigation treatments (T 2 and T 3) was found intermediate between T1 and T 4. Mulching also influenced the soil temperature. The mulch treatments showed soil temperature lesser by 2-3 ^{0}C compared to non-mulch treatment from 77-96 DAP, the phase coinciding with active early tuber bulking period. Penetration resistance under nonmulch treatments was higher than that under mulch treatment leading to better tuber growth and higher yield under mulching. Application of straw mulch (T4) increased availability of NH_4 plus NO_3 N by 87% and P by 13% and K by 36% in 0-45 cm soil profile (Table 22). Highest tuber yield 16.95 t/ha was obtained with mulch (T4) treatment followed by T2, T1 and the least tuber yield was observed in T3 treatment (Table 21).

Table 21:Tuber yield (t/ha) of sweet potato as influenced by irrigation and straw-mulch treatments. Each value is mean of three replications; least significant difference was calculated at 95% level of confidence

Treatments	Tuber yield (t/ha)
No irrigation and no mulch (T1)	8.15
One irrigation of 3 cm at 30 DAP (T2)	12.91
One irrigation of 3 cm at 60 DAP (T3)	7.84
No irrigation and straw mulch @ 5 t/ha (T4)	16.35
LSD (P = 0.05)	2.95

8.2.3. Cultivation of low duty crops

In tail end portion of canal command and when canal water is not available due to various reasons, growing of low duty crops like horse gram, black gram, green gram, etc. can be grown on residual soil moisture. Growing of low duty crops during dry (*rabi*) season can increase cropping intensity of such areas. Proper selection of crop and time of sowing are very important aspects of this technique.

Table 22: Effect of irrigation and mulching on N, P and K availability in a soil grown to sweet potato.

Treatment	Soil depth (cm)	Available N (kg/ha)			Avail. P (kg/ha)	Avail. K (kg/ha)
		NH_4	NO_3	NH_4+ NO_3		
No mulch no irrigation (T1)	0-15	3.7	5.1	8.8	3.7	55.5
	15-30	0	8.7	8.7	3.2	46.3
	30-45	0	6.1	6.1	5.0	47.7
	Total	3.7	19.9	23.6	11.9	149.5
No mulch, one irrigation of 3 cm after 4 weeks of planting (T2)	0-15	0	12.4	12.4	1.7	36.3
	15-30	2.8	0	2.8	1.3	35.3
	30-45	1.5	9.0	10.5	2.0	37.6
	Total	4.3	21.4	25.7	5.0	109.2
No mulch, one irrigation of 3 cm after 8 weeks of planting (T3)	0-15	2.4	2.4	4.8	3.7	44.7
	15-30	1.4	15.7	17.1	6.1	50.3
	30-45	2.9	2.9	5.8	8.4	88.5
	Total	6.7	21.0	27.7	18.2	183.5
Paddy straw mulch @ 5t/ha (T4)	0-15	1.2	12.4	13.6	2.5	94.0
	15-30	1.4	14.3	15.7	6.5	59.4
	30-45	4.4	10.5	14.9	4.4	49.9
	Total	7.0	37.2	44.2	13.4	203.3

This technique was applied on farmers field at Biswanathpur village under Balipatna block of Khurda district in Orissa during 1990-2000 and 2001- 20002. To utilize residual soil moisture, three leguminous crops, viz. horse gram, black gram and green gram were sown in the last week of November 2001 after harvest of *kharif* rice on medium textured soils. During crop growing season no rainfall occurred. Out of the legumes tried, horse gram produced maximum biomass (grain + straw yield 5.71 t/ha) followed by black gram (4.35 t/ha) and green gram (3.59 t/ha) (Table 23). These crops conserved 35 to 42 kg N/ha from soil. Besides economic use of grains, straw produced by the legumes could be incorporated into soil to recycle their nitrogen content. Growing of drought-tolerant legumes in post-rice dry season on residual soil moisture thus improved cropping intensity and conserved soil nitrogen for next crop.

8.2.4. Use of shallow ground water

Rise of ground water table is a common phenomenon in all the major irrigation commands because of seepage from canal distribution network and injudicious farm water management practices. Use of water from rising water table reduces irrigation needs, lower production cost, reduces deep seepage losses and stabilizes the productivity of the command area

Table 23: Biomass production and nitrogen uptake of three legumes grown after harvest of wet season rice

Legume crops	Dry-matter yield of above ground biomass (kg/ha)	N conc. in the biomass (%)	N uptake in above ground biomass (kg/ha)
Horse gram	5710 (2455+3255)*	2.80	159.9
Green gram	3590 (214+3376)	2.29	82.2
Black gram	4350 (250+4100)	2.59	112.7

* grain +straw yields given in parentheses

by reducing ill effect of high water table or water logging (Singh and Kundu, 2003). In Nimapara branch canal command area, water table depth varied from 1.0 m to 2.5 m during dry season. To utilize water of shallow water table, three crops viz. horse gram, green gram and sesamum were grown in farmers fields without irrigation during 2001-2002 dry season at Balipatna block. Soils at the study site belong to Ultic Haplustalf. Horse gram (*Dolichos biflorus*, var. Mukta) was sown on 15^{th} December 2000, green gram (*Vigna radiata* L.Wilczek, var.K-851) on 10^{th} January 2001 and sesamum (*Sesamum indicum L.*, var. Vinayak) on 31^{st} January 2001 in separate plots measuring 20m x 10 m. The seed rate was 40 kg/ha for horse gram, 20 kg/ha for green gram and 5 kg/ha for sesamum. The soil was clay loam in texture (33.1% sand, 33.4% silt and 35.5% clay) having pH 6.5-6.7, EC 0.10 dS/m and organic carbon 0.25-0.35%. Water flux under all the crops was found to be in upward direction. Under horse gram, total flux during the entire growth period (starting from 15 December 2000 to 21 March 2001) was 85.03 mm with the maximum rate of 1.15 mm/d observed in February and the minimum rate in March. Total 85.53 mm of upward flux was observed under green gram crop (grown during 10 January to 25 April 2001) with maximum rate of 0.98 mm/d observed in February and the minimum rate in April. Whereas under sesamum crop (grown from 31 Jan to 2 May 2001) total upward flux was 68.74 mm with the maximum rate of 1.16 mm/d observed in February and the minimum in April. Observed difference in upward flux may be due to different cropping times and growth duration, different atmospheric demand and fluctuation in water table depth. In case of horse gram, 41.7% of the total water use was contributed by the upward flux. The contributions of upward flux to green gram and sesamum were 38.2 and 33.2 percent, respectively. Since horse gram was sown earlier than green gram and sesamum, when the water table was closer to root zone, it could draw relatively more water from the ground water table.

Grain yield, straw yield, total ET, ET/E0 ratio, and water use efficiency for all the three crops are presented in Table 24. Highest grain yield of 6.25 q/ha was obtained with horse gram, while grain yield of 4.6 q/ha was obtained with both green gram and sesamum. Mean ET/E0 was the highest under horse gram followed by green gram and sesamum. It may be due to variation in their sowing time. Horse gram was sown earlier than green gram and sesamum. An advancement of sowing time by 30 to 45 days thus could increase the ET/E_0 ratio, upward flux, WUE and yield of unirrigated crops. For better utilization of residual soil moisture and efficient tapping of water from shallow ground water table in *rabi* season, short duration rice varieties should be grown in *kharif* season to facilitate early sowing of *rabi* crops. In terms of yield and WUE, horse gram was the best among the three test crops and it was followed by sesamum and green gram.

Table 24: Yield, evapotranspiration and water use efficiency of three dry season crops grown at Balipatna in Khurda district. 1999 - 2000.

Name of the crop	Grain yield (q/ha)	Straw yield (q/ha)	Grain to straw ratio	Total ET (mm)	ET to E_O ratio	Mean ET (mm/d)	WUE (kg/ha -mm)
Horse gram	6.25	16.56	0.38	203.75	0.56	2.10	3.07
Green gram	4.06	13.33	0.31	224.06	0.45	2.13	1.81
Sesamum	4.06	12.48	0.33	206.92	0.41	2.27	1.96

8.2.5. Control irrigation

Field to field irrigation and low input use in rice cultivation is common in the canal command area of Orissa. It often results in wastage of inputs applied, breaches in the bunds, unequal distribution and wastage of water, spread of pest and diseases and low yield. At head, middle and tail reaches of the Gringo minor which comes under Nimapara branch canal of Puri main canal system; effects of control irrigation and recommended fertilizers were tested. Various treatments tested were T1- controlled irrigation (field channel) with recommended fertilizer, T2- controlled irrigation with farmer's dose of fertilizer, T3- field to field irrigation with recommended fertilizer dose, and T4- field to field irrigation with farmer's fertilizer dose. The treatments were randomized with three replications. Rice variety *Gayatri* (CR 1018) was transplanted with the spacing of 15 X 15 cm during the second week of July 2001. The recommended dose of 80:40:40 kg $N:P_20_5:K_20$ was given with the treatments T1 and T3. Farmer's dose of 40:20:20 kg $N:P_20_5:K_20$ /ha was applied with the treatments T2 and T4.

Rice yield and yield attributes were significantly influenced by the treatments in all the land situations. The highest panicle/m^2 of 314.60, 319.0 and 354.20 was observed in the treatment T1 in head, middle and tail respectively which was followed by T2 (Table 25). However application of recommended dose of fertilizer did not influence the panicle number significantly in field-to-field irrigation except in the case of tail end. This may be due to washing out of applied nutrients. The highest grain yield was obtained from the treatment T1 (Fig. 7) in all the situations. Among different land situations, highest average yield (5.37 t/ha) was recorded in tail end followed by middle reach. The highest harvest index was recorded in the treatment T1 in the tail end of the canal.

Table 25: Effect of various irrigation and fertilizer treatments on rice yield attributes

Treatments	Head		Middle		Tail end	
	Tiller/m²	Panicle/m²	Tiller/m²	Panicle/m²	Tiller/ m²	Panicle/m²
T1	344.67	314.60	344.00	319.00	374.10	354.20
T2	281.10	247.70	291.37	261.80	312.17	282.70
T3	259.17	228.80	265.43	234.30	287.60	257.50
T4	246.83	216.70	255.80	225.50	272.53	243.10
CD(0.05)	15.12	16.62	17.96	13.01	11.86	16.90
Mean	282.94	215.95	289.15	260.15	311.6	284.37

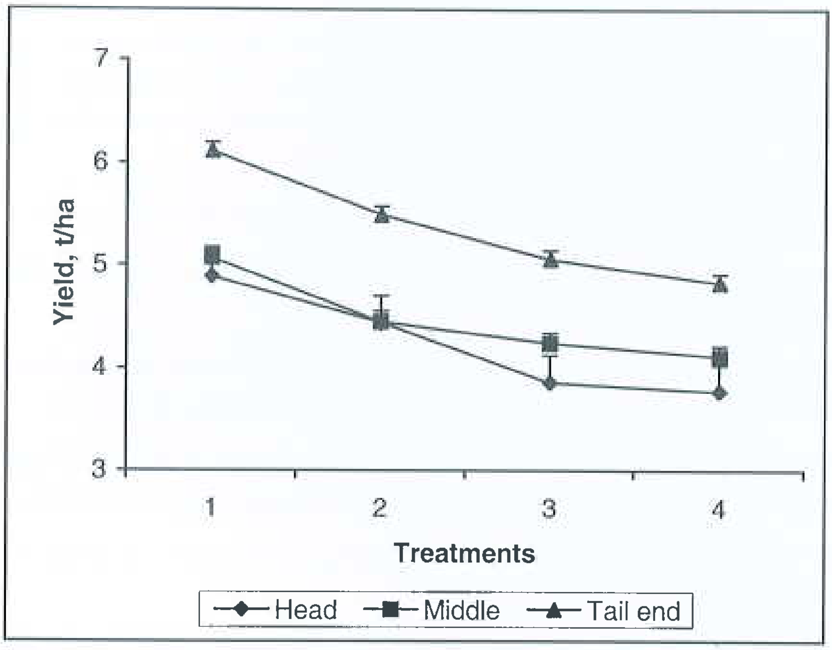


Fig.7 Effect of various treatments on rice grain yield in different reaches of canal command

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Farmers of the canal command showing poor water distribution system in their fields

Alternate raised and sunken bed system for crop diversification in lowland under canal command