भाकृ अनुप
ICAR

Research Bulletin 24

Management of excess rainwater in medium and lowlands for sustainable productivity

B. K. James, A. Mishra, Rajeeb K. Mohanty,
P. S. Brahmanand, P. Nanda, M. Das and K. Kannan

Water Technology Centre for Eastern Region
(Indian Council of Agricultural Research)
Bhubaneswar- 751 023, India

पू.ज.प्रौ.के.
BHUBANESWAR

WTCER

2005

Research Bulletin (NATP, RRPS-5)

Management of excess rainwater in medium and lowlands for sustainable productivity

B. K. James (Principal Scientist, SWCE & PI, NATP-RRPS-5)

A. Mishra (Principal Scientist, SWCE)

Rajeeb K. Mohanty (Scientist-SS, Fishery Science & CCPI, NATP-RRPS-5)

P. S. Brahmanand (Scientist-SS, Agronomy)

P. Nanda (Scientist-SG, Economics)

M. Das (Senior Scientist, Soil Science)

K. Kannan (Scientist, Agronomy)

Water Technology Centre for Eastern Region

(Indian Council of Agricultural Research)

Chandrasekharpur, Bhubaneswar, 751023

2005

Correct citation:

James, B.K., Mishra, A., Mohanty, Rajeeb.K., Brahmanand, P.S., Nanda, P., Das, M. and Kannan, K. (2005). "Management of Excess Rainwater in Medium and Lowlands for Sustainable Productivity." Research Bulletin No-24, Water Technology Centre for Eastern Region (ICAR), Bhubaneswar, India, 24p.

Published by

Director,

Water Technology Centre for Eastern Region,

(Indian Council of Agricultural Research)

Chandrasekharpur, Bhubaneswar, Orissa - 751 023, India.

Phone : 91-674-2300060, 2300010, 2300016

Fax : 91-674-2301615

Email : wtcer@stpbh.soft.net

Web site : www.wtcer.stpbh.soft.net

Printed by

Sanjukta Creations

Nua Sahi, Rasulgarh, Bhubaneswar - 10

Ph.: (0674) 3091422, 9861014236

Contents

INTRODUCTION

Agriculture is the lifeline of Indian economy. It contributes nearly one-fourth of the national GDP and sustains livelihood of about two-thirds of population. It is projected that by 2050, the global population will be 11 billion inclusive of India's population of 1.5 billion. To meet the food requirement of this population, at the global level, the food grain production has to increase by 185%. This is possible through enhancement of productivity and cropping intensity. At present India has about 16% of world's population, 4.2% of world's water and 2% of world's geographic area (Rai, 2003). This presents a grim picture of challenges and threats in relation to resources, their availability and utilization. Hence, there is an urgent need with high priority for development of location-specific technologies for efficient conservation, management and judicious utilization of the prime natural resources such as land and water.

The eastern region of the country is blessed with plenty of rainfall. Bulk of this rain (about 80%) occurs during monsoon. During this period, about 50% of the annual rainfall comes from few intense storms (Pisharoty, 1990). Water received from such intense storms is subjected to high runoff losses (Pal *et al.,* 1994). Added to this, is the erratic nature of the unset, distribution and the withdrawal of rains, which increases the probability of water stress at various crop growth stages of rice (Bhuiyan and Goonasekera, 1988). Therefore, the rainfed rice ecosystems (up, medium and low lands) have common characteristics of uncertain moisture supply. Field may have too much water, too little water or both within the same cropping season. This is one of the major reasons for which the average productivity of rice crop of eastern region is much less than the country's average rice productivity (Mishra *et al.,* 1998).

Fallow, after rice in about 12-16 million hectares of eastern India (130% to 140% cropping intensity) due to poor water resource development for irrigation is another important issue of water management including rainwater. Further, this region is prone to frequent occurrence of natural calamities such as flood, drought and cyclone, which repeatedly weakens the financial backbone of the farming community. Therefore, to ensure continuous flow of income throughout the year and minimize the risks associated with natural calamities affecting mono-cropping system, rice-based farming system through multiple/cascading use of water seems to be promising and viable technological option. Rice-based integrated farming systems are less risky due to their efficiency, derived from synergism among other components, their diversity of produce and environmental soundness. Although various combinations of integrated farming system have been introduced world-wide, integrated rice-fish system has shown greater potential, feasibility and efficiency to improve the use of agricultural resources (Mishra and Mohanty, 2004).

In the backdrop of this, the research effort was focused here on *in-situ* and *ex-situ* conservation of rainwater and adoption of integrated rice-based farming system in medium lands. Similarly, in lowlands, engineering interventions to reduce water logging and adoption of integrated rice-based farming system was attempted. The objective of these interventions was to enhance the land and water productivity and cropping intensity.

RATIONALE

When water flows down from medium lands to lowlands it gets accumulated in the bottom most topography after filling the pore space. If the concentration of the flow is more intensified, the water starts building up on these locations, creating an unfavourable situation for living habitats and in the race, most victimized habitat is the crops. If on its way back to lower topography, water is allowed to percolate down sufficiently in the medium land by creating optimum dyke height in the agricultural fields and conserving the excess rain water by constructing refuges, then the scarcity felt in medium lands for crop cultivation can be overcome. The rise of ground water in the low tracts can also be subsided to a great extent, there by the worst affected situations of waterlogging can be averted in the lowland topography. With the adoption of engineering measures like construction of surface drainage system and land modification, the accumulation of water in this topography can be minimized, there by creating a favourable edaphic environment for crop growth. Simultaneously, rice-fish integration in both medium and low lands in *kharif* along with horticulture followed by *rabi* crop can be a viable option in enhancing the overall productivity of land and water as well as the livelihood of rural poor.

BENCH MARK STUDY FOR 'SADEIBERINI' VILLAGE

A bench mark survey was carried out during the year 2001 to assess the agricultural and livelihood scenario just before commencement of the experimental work. The salient findings of the survey revealed that the total population of the village is 404 (206 males & 198 females as per 1991 census). The total number of households of the village is 73 out of which scheduled caste and agricultural labourers constitute 4% and 12% of total households respectively. Remaining 84% households depend upon agriculture as their primary occupation. The literacy rate of the village is found to be 69%. Twenty eight percent of households are below the poverty line. The number of marginal, small, medium and large farmers is 44, 16, 10 and 3 respectively (Table 1). The numbers of kuccha houses, pucca houses and small hutments are 35, 30 and 8 respectively. The average land holding and cultivable land holding per farming family is 1.4 and 1.1 hectare respectively. The total livestock population (inclusive of small and large ruminants) and milk production of the village is 370 and about 300 liters/day respectively. There is one pisciculture unit (backyard pond) in the village. The average livestock and bullock per household is 5.06 and 1.36 respectively.

Table 1. Class wise distribution of households

Size group	No. of households	% of households	Average cultivable land (ha)
Marginal farmer (1 ha)	44	60.27	0.38
Small farmer (1-2 ha)	16	21.91	1.32
Medium farmers (2-4 ha)	10	13.69	2.11
Large farmer (> 4 ha)	3	4.1	8.35

The entire village is rainfed and rice is the major crop grown in *Kharif* season which supports the livelihoods of the majority people. Backyard vegetable cultivation is taken up by 15% of villagers using water from dug wells through traditional water lifting devices. Saruchinamali, Bhutia, and Sarubhojani were common traditional rice varieties cultivated by the farmers. Similarly, the common cultivated HYV of rice were Annapurna, Lalat, Moti etc. The average productivity of *Kharif* paddy, pulses and oil seeds in the village was 1.6 t/ha, 0.7 t/ha and 0.1 t/ha respectively. The average yield of *kharif* rice in medium land was 1.8 t/ha and lowland was 1.4 t/ha. Use of bullock for ploughing and threshing was major farm power in the village and only 8% of farmers use hired tractor. Majority of the respondents possessed traditional farm implements, viz, wooden and mould bold plough, yokes, sickles, spades, axe, bullock cart etc. With regard to irrigation facilities, majority responded that they did not possess any irrigation facilities (either surface or ground water facility).

Need Assessment for Water Resources Development

A pre-project survey of households in the village revealed the following facts specific to water resource development and management.

- The need for having a water resource in the village was felt by all farmers. Most of the respondent (92%) have never requested the concerned authorities or tried to know the technical possibilities of *ex-situ* harvesting of rainwater. However, traditional bunding of fields is carried out in medium lands. The possibility of a second crop was ruled out in the up and medium lands due to non-availability of water. If assured irrigation water is made available, the farmers opined to grow non- paddy crops in uplands and HYV rice in medium and low lands during *kharif*. Similarly they also opined to grow vegetables, oilseeds and pulses during *rabi*.
- When asked about the problem of sharing water with neighbours, 45% of the respondents reported positively. The major reasons cited were too little of water to share followed by pressure for different crop water requirements and caste related conflict respectively.

- Regarding the benefits of irrigated agriculture, 62% of the respondents agreed that irrigated agriculture would bring change in cropping pattern as well as household food consumption pattern in the long run.
- In relation to training needs, 90% of the respondents needed training in crop water management. The key areas in which they wanted to be trained were crop water requirements (55%) and related agronomic and aquaculture practices (40%) respectively.

MATERIAL AND METHODS

Based on the bench mark study and problem identification, an intervention design was made by a multidisciplinary group of scientists (Mishra *et.al*., 1998) under *National Agricultural Technology Project* (RRPS 5) to alleviate the constraints of irrigation water scarcity through efficient conservation and utilization of rainwater in medium land and excess water disposal in lowlands through surface drainage, land modifications and aquaculture. Further, the intervention was aimed at improving the land and water productivity with integration of fish and horticultural components along with increasing cropping intensity.

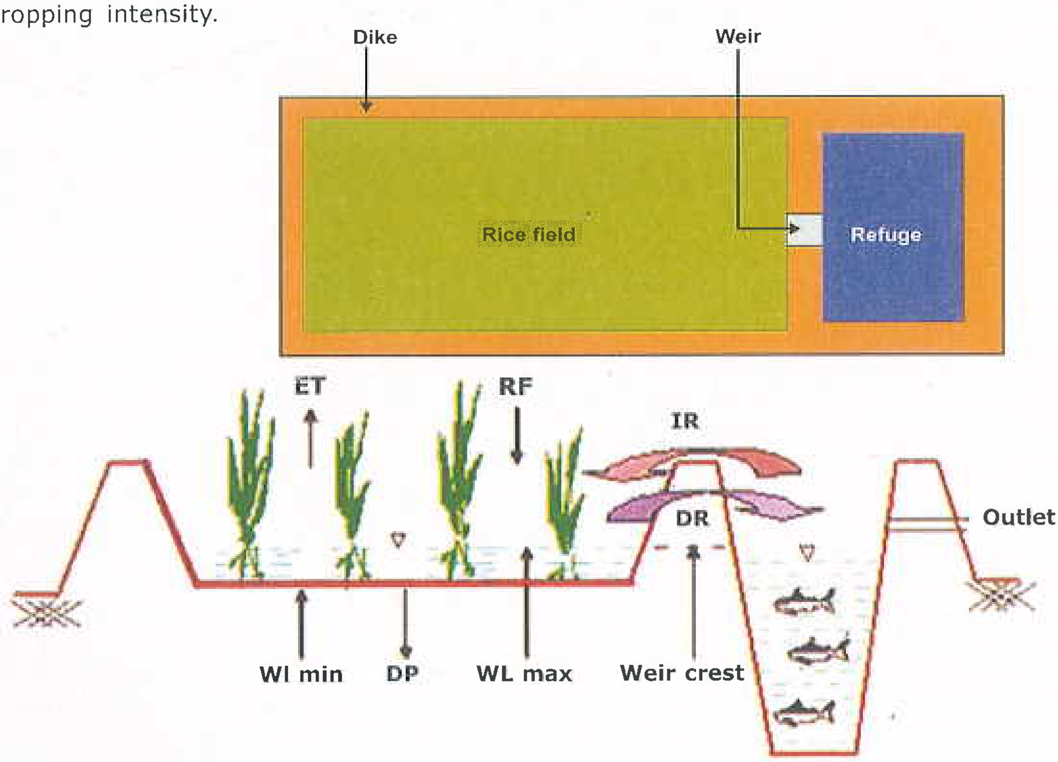

Fig. 1 Schematic diagram of rice-fish production system in medium land with various water balance components

The experimental study was carried out in five farmers' fields, located in the medium and lowlands at Sadeiberini village of Dhenkanal district, Orissa (Lat. 20°58′ N and Long. 83°51′ E) for three consecutive years (2001-02 to 2003-04). In medium lands, each rice plot was provided with a brick masonary broad-crested rectangular weir at the partition dike between the refuge and the rice field. By doing so, a portion of rainwater was allowed to store in the rice field up to the weir crest level (weir height). The excess rainwater above the crest level was allowed to spill over the weir for further conservation in the refuge (Fig. 1). Thus, for *in-situ* conservation of rainwater in the rice fields, three weir heights of 15 cm (T_1), 20 cm (T_2) and 25 cm (T_3) were considered as treatments with two replications each (total six plots). At the downstream end of each plot, a refuge was constructed, approximately occupying 5-8% of the individual plot size to harvest the excess rainwater during heavy downpour (Fig. 2). The average depth of the refuge was kept at 1.75 m with a side slope of 1:1. The excess water from the refuge was drained out through a hume pipe (fixed at weir crest level) with fine-meshed net to prevent escape of fish (Mishra *et al.*, 2003).

Fig.2 Fish culture refuge for harvest of excess rainwater.

In shallow lowland, drainage channels were constructed to dispose of the excess water (Fig.3). In semi-deep lowland, a large pond was constructed and the excavated soils were spread over the adjacent low lying fields (soil maneuvering) to raise their respective bed level, thereby making the ecosystem favourable for rice cultivation.

Fig.3 Drainage channel in shallow lowland

During rainy season, 'Saruchinamali' (farmer's choice), 'Jagannath' and 'Moti' cultivars of rice were grown in medium lands. In lowlands, 'durga' and 'savitri' along with local variety 'Saruchinamali' were grown. Transplanting of the rice was carried out during 3rd to 4th week of July with a spacing of 20 x 10 cm. Chemical fertilizer @ 80:40:40

(N: P: K) kg/ha was applied in three split doses along with bio-fertilizer *(Azosprillum)*. Fifty percent of N and full dose of P and K was applied at the time of puddling before transplanting. The remaining nitrogen was applied in two equal doses at 30 and 60 days after transplanting.

On the embankment of refuges/pond, horticultural crops such as Banana and Papaya were grown. During *rabi* season farmers grew winter crops such as *rabi* rice ('Lalat' and 'MW-10'), ladies finger *(Hibiscus esculentus* L.), greengram *(Phaseolus radiatus* L.) and blackgram *(P. mungo* L) using the conserved rainwater from refuges and pond.

Pre-stocking management of refuges, such as horizontal and longitudinal ploughing followed by liming with $CaCO_3$ at the rate of 700 kg ha^{-1} as basal dose, manuring with raw cattle dung (RCD) at the rate of 7000 kg ha^{-1} as basal dose was carried out. Fertilization was also carried out with urea and single super phosphate (as sources of nitrogen and phosphorus) at the rate of 75 and 15 kg ha^{-1} respectively, at monthly intervals. Periodic liming at the rate of 100 kg ha^{-1} and manuring with RCD at the rate of 1000 kg ha^{-1} were carried out at monthly intervals to maintain water pH and plankton population in the ecosystem.

Seven days after first manuring and fertilization, early fingerlings (<1.5 g) of *Catla catla, Labeo rohita, Cirrhinus mrigala* and *Cyprinus carpio* were stocked in the refuge with a species composition of 30:30:20:20, respectively. Stocking densities of 20,000-fingerling ha^{-1} were maintained in all the treatments and rearing continued for 180 days (3^{rd} week of August – 3^{rd} week of February). Supplemental feed (rice bran and groundnut oil cake at 1:1 ratio by weight, provided in the form of moist dough) at the rate of 6%, 5%, 4%, 3% and 2% of mean body weight (MBW) was given twice a day (7.00-8.00 h and 16.00-17.00 h), during 1^{st}, 2^{nd}, 3^{rd}, 4^{th} and 5^{th} month to harvesting, respectively. Monthly samplings were carried out for assessment of mean body weight, per day increment, condition factor, apparent feed conversion ratio, biomass, survival rate (Mishra and Mohanty, 2004) and general health of fish. For this purpose, 12 fish of each species from each replication were sampled, measured (in mm) and weighed (in g). Statistical analysis with regard to growth performance and yield between the treatments were tested through one-way ANOVA and means were compared using Duncan's Multiple Range Test to find out the difference at 5% ($p<0.05$) level (Duncan, 1955). To evaluate the production performance with more precision, performance index (PI) was calculated (Zacharia and Kakati, 2002). This index was calculated by combining the two responses such as growth and survival. PI = [(Growth rate in g day^{-1} at harvesting – initial mean body weight in g)/(rearing duration)] * final survival rate in %. Further, Production/size index (PSI) was also determined to evaluate production performance with respect to size (Tidwell *et al.*, 2003). PSI = Production in kg ha^{-1} * mean body weight in g /1000.

Monthly observations on water quality parameters such as temperature, pH, dissolved oxygen, total alkalinity, transparency, primary productivity, total suspended solids, dissolved organic matter, nitrite, nitrate, ammonia, phosphate etc. (samples were collected between 7.30 – 8.30 h) and on soil quality such as pH, available- N, P and organic carbon were recorded using standard methods (APHA, 1995 and Biswas, 1993). Field test instruments were also used to analyze *in-situ* water pH (Checker-1, HANNA, USA) by calibrating the pH meter against buffer solution at pH 4, 7 and 9.2, Soil pH (DM-13, Japan), and dissolved oxygen (YSI-55, USA). Estimation of Phyto- and Zoo-plankton was carried out in bi-monthly interval. Daily observation on depth of water stored in the refuges and pond was also recorded during the *kharif* season.

Final yield and yield attributes of crops were recorded at the time of harvest. To assess the output from the plot as a single unit, rice equivalent yield (REY) was computed considering the selling price of rice and fish as Rs.4.00 and Rs. 40.00, respectively and the proportional area devoted to rice and fish cultivation. Economic indices of water productivity was estimated keeping the total volume of water used (water contained in the harvested biomass + evaporation + deep percolation & seepage + average standing water volume + volume of water added from other source) in to account (Boyd, 2004). Economic indices of water productivity (Net consumptive water use index, Rs./m^3) = Total economic value of produce – Production cost / Total volume of water (m^3) used.

RESULTS AND DISCUSSION

Rain Water Conservation and Management

Fig. 4 presents the monthly rainfall scenario of the experimental site during monsoon season. In 2001, rainfall of 1535 mm and 1420 mm were received during the entire year and rainy season, respectively. In this year, an unusual rainfall during July amounting to 719 mm (2.2 times more than that of 20 years average value) was experienced. In spite of heavy rainfall during July and subsequent scanty rainfall during August and September, water levels in the refuges were observed to be sufficiently high till end of February 2002. In the year 2002, rainfall of 728 mm and 543 mm was received during the entire year and rainy season, respectively. Similarly, in 2003 rainfall of 1572.5 mm and 1451.5 mm was received during the entire year and rainy season, respectively. Twenty years average annual rainfall and rainy season's rainfall were 1415 and 1226 mm, respectively. Thus, from rainfall point of view, the first and third years were excess rainfall years and the second year was a drought year. Amongst these two excess rainfall years, the monsoon rain was well distributed in 2003 and was poorly distributed in 2001. However, in all these extreme cases, the water levels in the refuges/pond were observed to be sufficient enough (>1 m most of the period) till end February for short duration fish culture (Table 2).

As evident, highest depth of water was recorded in the month of August in all the refuges/pond. Gradual decrease in the depth of water stored was also noticed with the advancement of *kharif* season. The lowland pond has recorded more depth of water over medium land refuges. This is due to the location of the lowland pond which is situated relatively at a lower elevation than the refuges of medium land.

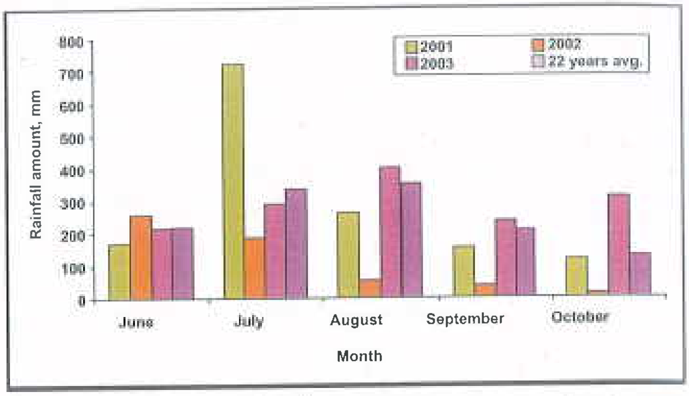

Fig. 4 Monthly rainfall scenario of the study site during *kharif* season

Table 2. Monthly average depth of standing water (m) in the refuges during the experimental period

	Weir height, cm	Year	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Reguges in medium land	15	2001-02	1.70	1.70	1.71	1.69	1.66	1.62	1.63
		2002-03	1.10	1.08	1.07	1.05	1.02	1.03	1.02
		2003-04	1.21	1.20	1.20	1.19	1.16	1.17	1.15
		Average	**1.34**	**1.33**	**1.33**	**1.31**	**1.28**	**1.27**	**1.27**
	20	2001-02	1.58	1.43	1.45	1.31	1.24	1.17	1.18
		2002-03	1.28	1.24	1.09	0.89	0.79	0.74	0.65
		2003-04	1.62	1.57	1.54	1.53	1.43	1.40	1.36
		Average	**1.49**	**1.41**	**1.36**	**1.24**	**1.15**	**1.10**	**1.06**
	25	2001-02	1.62	1.61	1.59	1.54	1.47	1.39	1.38
		2002-03	1.22	1.16	1.05	0.93	0.87	0.81	0.74
		2003-04	1.60	1.59	1.58	1.56	1.48	1.40	1.38
		Average	**1.48**	**1.45**	**1.41**	**1.34**	**1.27**	**1.20**	**1.17**
Low land pond		2001-02	1.88	1.89	1.88	1.82	1.83	1.81	1.80
		2002-03	1.55	1.48	1.26	1.23	1.27	1.24	1.20
		2003-04	1.29	1.27	1.27	1.28	1.27	1.28	1.29
		Average	**1.57**	**1.55**	**1.47**	**1.44**	**1.46**	**1.44**	**1.43**

Amongst the medium land refuges, in the very first year, more depths of water was stored in T_1 refuges than that of T_2 and T_3. This is because, at lower weir height, relatively less amount of water was stored in the rice field leading to more depth of water in the refuge. In subsequent years due to differential maintenance (removal of deposited sediments from the refuge bottom) by the farmers, higher depth of water was stored in T_2 and T_3 refuges. The farmers of higher weir height (T_2 and T_3) plots were in a tendency to excavate more to maintain a higher water depth. The average depth of water stored in the refuges of T_2 and T_3 were more or less same. Slightly higher depth in T_3 is probably due to lower bed elevation of these refuges in comparison to T_2 refuges which might have contributed more inter flow into T_3 refuges. Out of the three experimental years, even though 2002-03 was a drought year, the farmers were able to grow paddy during monsoon using the stored water from the refuges as life saving irrigations. They could also successfully carryout fish culture in the refuges. In this drought year the stored water depths in all the refuges and pond were lower in comparison to other two experimental years.

Perusal of the Table 2 indicates that in all the three years, sufficient amount of water (>1.0 m depth) was available till last week of February. This enables farmers to carry out successfully fish culture for a period of about six months. After the harvest of fish in February, on an average 1 meter depth availability of water in the refuge (refuges occupying 5 to 8% area of each field) provided about 7 cm depth of irrigation water to rest of the area for *rabi* crops.

Soil Characteristics

Table 3 presents the hydro-physical properties of the soil of the experimental site at Sadeiberini village. In the medium land the bulk density of soil layer ranged from 1.62 to 1.79 gm/cm³. Similarly in the lowland it ranged from 1.38 to 1.81 gm/cm³. In both the

Table 3. Important hydro-physical characteristics of soil

Description of sample		Bulk density (gm cm⁻³)	Saturated hydraulic conductivity, Ks (cm min⁻¹)		Texture	Porosity (%)	Moisture content, θ (cm³ cm⁻³)		
Land type	Soil depth (m)		Horizontal	Vertical			0.033 Mpa	1.5 Mpa	0 Mpa
Medium Land	0-0.15	1.62	4.37E-03	4.2E-02	scl	38.86	0.37	0.21	0.72
	0.16-0.30	1.72	1.32E-03	6.3E-02	scl	35.09	0.36	0.21	0.76
	0.31-0.45	1.74	1.1E-02	4.78E-02	scl	34.34	0.40	0.24	0.83
	0.46-0.60	1.79	1.32E-03	4.9E-02	cl	32.45	0.38	0.23	0.82
Low Land	0-0.15	1.38	4.7E-02	2.69E-01	sl	50.56	0.17	0.01	0.42
	0.16-0.30	1.73	4.1E-02	6.2E-01	sl	34.72	0.18	0.02	0.54
	0.31-0.45	1.81	3.01E-02	8.26E-01	sl	31.70	0.23	0.09	0.56
	0.46-0.60	1.78	2.3E-02	3.6E-02	sl	32.83	0.23	0.09	0.65

scl: Sandy clay loam; cl: clay loam; and sl: sandy loam.

land types, the lower layers have been found heavier than that of top layer. The lowland soil was sandy loam in texture while medium land was predominantly sandy clay loam. The mean porosity of medium and lowland was determined as 35.18% and 37.45% respectively. The average moisture content at saturation, field capacity and wilting point was determined as 0.78, 0.38 and 0.22 respectively for medium land soil. Similarly, the average moisture content at saturation, field capacity and wilting point was determined as 0.74, 0.33 and 0.18 respectively for lowland soil.

Agricultural Crop Management

Kharif crop

In 2001-02 *kharif*, the highest grain yield (5.4 t/ha) was recorded in 20 cm weir height plots, which is significantly superior to that of 15 cm and 25 cm weir height plots. This was mainly contributed by higher number of panicles/m^2 (329.6). However, the highest number of filled grains/panicle was observed in 15 cm dike height (Table 4). Among the varieties, Jagannath yielded the maximum (5.8 t/ha) followed by Moti (4.33 t/ha) and Saruchinamali (3.81 t/ha) irrespective of weir height. This might be contributed by significantly higher number of panicles/m^2 (350.3) and number of filled grains/panicle (142.2).

Table 4. Yield and yield attributes of *kharif* rice, 2001-02

Weir height	Panicles/m^2	No of filled grains/panicle	Grain yield (t/ha)
15 cm	282.6	138.7	4.40
20 cm	329.6	125.6	5.40
25 cm	282.6	118.9	4.15
CD (0.05)	***17.5***	***14.8***	***0.464***
Variety			
V_1 (Saruchinamali)	262.6	102.6	3.81
V_2 (Moti)	281.5	138.3	4.33
V_3 (Jagannath)	350.3	142.2	5.80
CD (0.05)	***9.56***	***8.41***	***0.276***

In *kharif* 2002-03, 25 cm weir height plots recorded the highest grain (5.83 t/ha) followed by 20 cm weir height (5.31 t/ha) and 15 cm weir height plots (4.63 t/ha). The variation in yield at different weir height was not statistically significant (Table 5). Similarly, there was no significant difference in panicles/m^2 among various weir heights. However, significantly higher number of filled grains/panicle was recorded with 25 cm weir height plots (196.0) followed by 20 cm weir height (186.7). Among varieties, Jagannath recorded the highest grain yield (5.97 t/ha) followed by Moti (5.21 t/ha) and Saruchinamali (4.6 t/ha). This was primarily due to highest number of filled grains/panicle.

Table 5. Yield and yield attributes of *kharif* rice, 2002-03

Weir height	Panicles/m²	No of filled grains/panicle	Grain yield (t/ha)
15 cm	282.6	166.7	4.63
20 cm	197.6	186.7	5.31
25 cm	240.4	196.0	5.83
CD (0.05)	*NS*	*10.9*	*NS*
Variety			
V_1 (Saruchinamali)	218.51	171.0	4.60
V_2 (Moti)	296.0	186.6	5.21
V_3 (Jagannath)	206.1	191.8	5.97
CD (0.05)	*NS*	*11.6*	*0.861*

Kharif rice in the third year i.e. 2003-04 (Fig. 5), the highest grain yield was observed in 20 cm weir height plots (5.19 t/ha) followed by 15 cm weir height (4.76 t/ha) and 25 cm weir height (4.52 t/ha). The variation in yield at different weir height was not statistically significant (Table 6). Similarly, there was no significant difference among treatment means in both panicles/m² and number of filled grains/panicle. Among the three rice varieties, highest grain yield (5.96 t/ha) was recorded in Jagannath followed by Moti (4.56 t/ha) and Saruchinamali (3.96 t/ha). The highest number of filled grains/panicle (135.3) and panicles/m² (304.0) contributed to higher grain yield in Jagannath.


Fig.5 *Kharif* rice

There was sufficient rainfall in first and third year in which maximum yield was recorded in 20 cm weir height plot. The second year i.e., 2002-03 was a drought year. In this year highest yield was recorded in 25 cm weir height plot which clearly specifies the effect of *in-situ* conservation of rainwater as a function of weir height on crop growth and yield. Three years pooled yield data of *kharif* rice revealed that highest yield is obtained at 20 cm weir height and among varieties Jagannath was most productive (Table 7, 8 and 9).

In 2001-02 and 2002-03, Savitri performed better in terms of grain yield (5.5 t/ha and 5.4 t/ha respectively) followed by that of Durga and local variety (Saruchinamali). However, Durga recorded higher grain yield (4.91 t/ha) in the third year followed by Savitri (Table 10). Throughout the experimental period, Durga and Savitri recorded

Table 6. Yield and yield attributes of *kharif* rice, 2003-04

Weir height	Panicles/m^2	No of filled grains/panicle	Grain yield (t/ha)
15 cm	251.0	117.10	4.76
20 cm	275.6	119.30	5.19
25 cm	250.6	136.10	4.52
CD (0.05)	*NS*	*NS*	*NS*
Variety			
V_1 (Saruchinamali)	234.0	120.0	3.96
V_2 (Moti)	239.3	117.2	4.56
V_3 (Jagannath)	304.0	135.3	5.96
CD (0.05)	*NS*	*NS*	*NS*

Table 7. Average rice yield (t/ha) of different varieties irrespective of treatments in medium lands

Rice variety	1st year	2nd year	3rd year	Pooled
Jagannath	5.80	5.97	5.96	5.91
Moti	4.33	5.21	4.56	4.70
Saruchinamali	3.81	4.60	3.96	4.12

Table 8. Average rice yield (t/ha) at different weir heights irrespective of varieties in medium lands

Treatment	1st year	2nd year	3rd year	Pooled
15 cm(T_1)	4.40	4.63	4.76	4.60
20 cm (T_2)	5.40	5.31	5.19	5.30
25 cm (T_3)	4.15	5.83	4.52	4.83

Table 9. Average yield and yield attributes of *kharif* rice in medium land (2001-02 to 2003-04)

Treatment	Panicles/m^2	No of filled grains/panicle	Grain yield (t/ha)
15 cm	272.1	140.8	4.59
20 cm	267.6	143.9	5.30
25 cm	257.9	150.3	4.83
CD (0.05)	*NS*	*NS*	*0.556*
Variety			
V_1 (Saruchinamali)	238.4	131.2	4.12
V_2 (Moti)	272.3	147.4	4.7
V_3 (Jagannath)	286.8	156.4	5.91
CD (0.05)	*NS*	*NS*	*0.382*

superior grain yield than that of Saruchinamali. This might be due to high adaptable nature of these varieties under shallow to medium waterlogged / lowland condition.

Table 10. Yield of *kharif* rice in lowland during 2001-02 to 2003-04

Year	Yield (t/ha)		
	Durga	Savitri	Saruchinamali
2001-02	4.0	5.5	3.1
2002-03	5.3	5.4	3.6
2003-04	4.91	4.09	3.16

Rabi crop

In the first year (2001-02 *rabi*) two rice varieties i.e. MW-10 and Lalat were grown and recorded yield of 2.34 t/ha and 2.70 t/ha, respectively. Ladies finger was also grown in the same year which resulted in productivity of 1.85 t/ha. In the second year rice variety MW-10 recorded 3.5 t/ha grain yield. In this year, ratooning was practiced in Savitri and Durga varieties. Savitri resulted in good productivity (2.73 t/ha). Pulse crops like blackgram and greengram were also cultivated in second year, which registered pod yield of 0.34 t/ha and 0.45 t/ha respectively. In the third year rice varieties MW-10 and Lalat were also cultivated resulting in grain yield of 1.23 t/ha and 1.3 t/ha respectively. In addition to rice, blackgram and greengram were also grown, which resulted in better yield compared to that of previous year (Table 11).

Table 11. Yield of different *rabi* crops grown during the experimental years (2001-02 to 2003-04)

Crop	Yield (t/ha)		
	2001-02	2002-03	2003-04
Rice (MW-10)	2.34	3.50	1.23
Rice (Lalat)	2.70	-	1.30
Rice ratoon (Savitri)	-	2.73	-
Rice raton (Durga)	-	0.50	-
Ladies finger	1.85	-	-
Blackgram	-	0.34	0.42
Greengram	-	0.45	0.56

On-dyke horticulture

On the embankment of the refuges/pond, dwarf variety of papaya, banana and drum stick were grown at a spacing of 1 to 1.5 m (Fig. 6) as an additional component. Irrigation to these plants was given using the conserved rainwater from the refuges. Among these three horticultural plants, banana performed the best in terms of yield and survival.

These plants (specifically drum stick) were subjected to severe damage by cattle grazing in *rabi* and summer because of adjacent fallow fields of other farmers in that locality. The yield of banana and papaya was recorded as 1600 kg/ha and 200 bunch/ha respectively.

Fig.6 On-dyke horticulture

Cropping intensity

Before intervention, the study site was only a mono-cropped area. After intervention, the cropping intensity of the site increased from 100% to 131%, 176% and 200% in the 1st, 2nd and 3rd year of experiment, respectively. In the first year of experiment, farmers were not willing to go for a second crop. However, after some persuasion and observing the benefit of second crop (Fig.7), they developed interest and subsequently in the third year of the experiment the entire area was brought under second crop.

Aquaculture and its Management

Water quality in relation to fish production

Fig.7 View of *rabi* crop

The recorded mean minimum and mean maximum values of various water and sediment quality parameters along with standard deviation (± SD) for the experimental years are presented in Table 12. Total suspended solid and dissolved oxygen concentration showed a decreasing trend with the advancement of rearing period while, slightly higher values of nitrite, nitrate, ammonia and total alkalinity were recorded towards the latter part of the experiment. At any given point of time, the remaining water quality parameters and plankton population did not register any specific trend between the treatments. Phytoplankton population was dominated mainly by diatoms and green algae while, zooplankton population by copepods and rotifers. In all the treatments, average primary production in the first month of rearing ranged between

88.8 - 141 mg C m^{-3} h^{-1}, which improved further (502.5 ± 58.4 mg C m^{-3} h^{-1}) with the advancement of rearing period.

Various hydro-biological parameters prevailing in different treatments were within optimum ranges and did not show any distinct trend. This was probably due to similar levels of input in all the treatments in the form of organic manure, inorganic fertilizer and periodic liming. The decreasing trend of dissolved oxygen in all the treatments with the advancement of rearing period, attributed to fluctuation in plankton density and gradual increase in biomass, resulting in higher oxygen consumption. Gradual increase in nitrite, nitrate, ammonia in all the treatments were attributed by intermittent fertilization, increased level of metabolites and decomposition of unutilized feed in absence of water replenishment. In general, poor growth performance of cultured species takes place at pH < 6.5 (Mount, 1973) while, higher values of total alkalinity (> 90 ppm) indicates a better productive ecosystem and increased plankton density reflects higher nutrient status of the water body. The availability of CO_2 for phytoplankton growth is related to total alkalinity (Mohanty, 2003), while water having 20-150 ppm total alkalinity produce suitable quantity of CO_2 to permit plankton production. However, the recorded minimum and maximum range of total alkalinity during the experimental period was 68 and 139 ppm respectively, which was maintained due to periodic liming.

Plankton has a profound effect on water quality and is the major source of productivity in aquatic ecosystem, having a direct relationship with fish production. However, no perceptible trend in the total plankton density (6.6×10^2 - 1.3×10^4 units l^{-1}) was observed between treatments attributable to the regular fertilization schedule at monthly intervals. Low primary production (88.8 - 141 mg C m^{-3} h^{-1}) in the initial phase of rearing was probably due to fixation of nutrient ions by suspended soil/clay particles as well as rich organic matter (Mohanty, 2003). In general, water reaction process is low during monsoon (July - August) due to dilution of alkaline substances or dissolution of atmospheric CO_2 (Mohanty *et al.*, 2002). Sediment characteristics of different treatments (pH, organic carbon and available phosphorus) were however, indicative of a medium productive soil group (Banerjea, 1967).

Growth performance and yield of fish

Irrespective of stocking density, faster growth rate was recorded for *C. carpio* followed by *Catla catla* and *C. mrigala* during 180 days of culture. Comparative growth performance (Table 13) of all species in terms of per day increment or average daily growth rate decreased with increase in weir height that reduces water availability in the refuge. Overall survival rate (inclusive of all species) was high in T_1, while species-wise, no such trend was marked among treatments. Condition factor (Ponderal index) of fish was less than 1.0 (0.87-0.98) at the initial three weeks of rearing (monsoon phase) and

Table 12. Variation in water and sediment quality parameters in rainwater storage refuge (2001-02 to 2003-04)

Parameters	Medium land refuge			Lowland pond
	T_1	T_2	T_3	
Water pH	7.19-7.79 (7.51)	7.62-8.25 (7.85)	7.49-8.29 (7.84)	7.17-8.4 (7.7)
D O (ppm)	3.6-9.3 (5.5)	3.3-8.8 (6.1)	3.7-9.2 (4.9)	4.2-9.2 (6.3)
Temperature (^{0}C)	26.8-31.2 (28.4)	26.7-31.3 (28.3)	26.8-31.3 (28.4)	26.8-31.3 (28.5)
Total alkalinity (ppm)	69-121 (98)	68-131 (118)	73-139 (106)	81-138 (121)
D O M (ppm)	0.3-4.5 (3.2)	0.55-4.8 (3.6)	1.1-5.2 (4.1)	1.7-6.0 (5.2)
TSS (ppm)	81-282 (213)	72-277 (225)	55-256 (187)	79-268 (209)
Nitrite – N (ppm)	0.014-0.066 (0.031)	0.011-0.072 (0.037)	0.009-0.044 (0.026)	0.014-0.084 (0.46)
Nitrate – N(ppm)	0.26-0.51 (0.37)	0.29-0.42 (0.36)	0.21-0.63 (0.36)	0.35-0.71 (0.45)
Phosphate – P (ppm)	0.07-0.64 (0.33)	0.16-0.73 (0.39)	0.13-0.58 (0.26)	0.22-0.53 (0.32)
Total plankton (units/l)	$1.03x10^3$-$4.3x10^3$ ($3.04x10^3$)	$2.4x10^3$-$1.3x10^4$ ($5.3x10^3$)	$6.6x10^2$-$3.7x10^3$ ($2.07x10^3$)	$1.7x10^3$-$4.9x10^3$ ($3.3x10^3$)
Available-N (mg 100 g soil $^{-1}$)	8.1-11.1 (9.3)	7.9-11.6 (9.8)	9.3-12.2 (10.6)	10.1-12.9 (11.8)
Available-P (mg P_2O_5-P 100 g soil $^{-1}$)	1.83-3.29 (3.04)	1.78-3.56 (3.21)	1.93-3.48 (3.17)	1.63-3.72 (3.39)
O C in soil (%)	1.16-1.5 (1.41)	1.36-1.61 (1.49)	1.47-1.58 (1.52)	1.63-1.84 (1.72)
Soil pH	6.84-7.06 (7.02)	6.98-7.13 (7.05)	6.69-6.9 (6.88)	6.98-7.11 (7.05)

Figures in the parentheses indicate average values. DO-dissolved oxygen, DOM-dissolved organic matter, TSS-total suspended solid, OC-organic carbon.

improved thereafter (1.04-1.23) with gradual improvement in water quality (post-monsoon). Fish yield (Table 13 and 14) in terms of production (kg ha^{-1} 180 days^{-1}) in T_1 (1693.6) was however, significantly higher ($p<0.05$) than the yield at T_2 and T_3. However, there was no significant variation between yields at T_2 (1265.3) and T_3 (1279.4). Poor yield of 685.4 kg ha^{-1} 180 days^{-1} in low land pond was however, mainly due to repeated poaching.

Highest performance index (PI) was recorded for *C. mrigala* while lowest for *L. rohita* in all the treatments. Species-wise, significant variation in PI ($p<0.05$) was recorded for *Catla catla* (surface feeder) and *C. mrigala* (bottom feeder) between T_1 -T_2 and T_1 -T_3, while no such trend was observed between T_2 and T_3. However, no significant variation in PI was observed for *L. rohita* (column feeder) and *C. carpio* (exotic carp) among treatments. Overall production/size index (PSI) was significantly higher (236.8 + 8.2) in T_1 followed by T_2 and T_3 (Table 15). However, no trend in species-wise PSI was recorded among treatments.

Table 13. Average growth, survival and yield of cultured fish species in excess rainwater storage refuge (2001-02 to 2003-04)

Treatment	Species reared*	Initial MBW (g)	Final MBW (g)	PDI (g)	FSR (%)	Yield (kg)	Productivity (kg ha^{-1} 180 days^{-1})
T_1	*C. catla*	0.98	160.6	0.88	64.7	5.3	1693.6[a]
	L. rohita	0.92	74.6	0.41	68.6	2.6	
	C. mrigala	0.92	146.5	0.80	85.3	4.2	
	C. carpio	1.20	177.6	0.98	38.2	2.3	
T_2	*C. catla*	0.98	125.5	0.69	53.4	5.9	1265.3[b]
	L.rohita	0.92	69.2	0.37	59.1	3.6	
	C. mrigala	0.92	120.8	0.66	64.4	4.6	
	C. carpio	1.20	187.5	1.03	40.7	4.5	
T_3	*C. catla*	0.98	121.3	0.66	56.4	3.7	1279.4[b]
	L. rohita	0.92	68.3	0.37	74.5	2.8	
	C. mrigala	0.92	118.5	0.65	72.9	3.2	
	C. carpio	1.20	134.0	0.74	40.5	2.0	
Lowland pond	*C. catla*	0.98	158.1	0.87	25.3	29.25	685.4[c]
	L. rohita	0.92	113.7	0.62	27.2	22.30	
	C. mrigala	0.92	125.2	0.69	27.3	16.4	
	C. carpio	1.20	246.5	1.36	12.8	14.30	

Means having different superscripts in a column differed significantly by DMRT ($p<0.05$). SD = 20,000 ha^{-1}, MBW- Mean Body Weight, PDI- Per Day Increment, FSR-Final Survival Rate, *Species composition - 30:30:20:20 (*C.catla:L.rohita:C.mrigala:C.carpio*).

Growth is the manifestation of the net outcome of energy gains and losses within a framework of abiotic and biotic conditions (Mohanty, 2004). In this experiment, the effect of weir height on production performance (production/size index, PSI) was highly significant ($p<0.05$) between T_1-T_2 and T_1-T_3, while there was no significant variation among PSI between T_2 and T_3. This indicates optimum production performance at lower weir height, T_1, where yield is significantly higher ($p<0.05$) than yield at T_2 and T_3. In fact, under crowded condition at lower water depth, fish suffers stress due to aggressive feeding interaction and eat less resulting in a retardation of growth (Zonneveld and Fadholi, 1991 and Bjoernsson, 1994). Further, as highest and lowest performance index (PI) was recorded for *C. mrigala* and *L. rohita* in all the treatments, manipulation in species composition for stocking is essential. Increase and decrease in the stocking rate of *C. mrigala* and *L. rohita* respectively, would definitely enhance the fish yield

Fig.8 Harvested fish from refuge

(Fig.8) from an unit water area under short-duration production system.

Irrespective of treatments, growth rate of *C. carpio* was highest followed by *C. catla* and *C. mrigala*. Bottom feeders (*C. carpio* and *C. mrigala*) registered better growth rate than that of *L. rohita* (column feeder) due to its superior feed utilizing capability and high degree of tolerance to fluctuation of oxygen concentration and suspended solids. Among bottom feeders, growth performance of *C. carpio* appears to be much better than *C mrigala* due to their superior feed utilizing capability. Moreover, faster growth rate of *Catla catla* (surface feeder), *C. carpio* and *C. mrigala* (bottom dwellers) were attributed to effective utilization of ecological niches and rich detrital food web that was maintained through periodic manuring, liming and fertilization. Observations on apparent feed conversion ratio (AFCR) also supports the conclusion of effective utilization of ecological niches, as mean AFCR was 1.68 $\pm$ 0.18, 1.74 $\pm$ 0.57 and 1.79 $\pm$ 0.224 at T_1, T_2 and T_3 respectively. AFCR increased with increase in weir height. This might be due to less availability of stored water in the tanks with higher weir heights, inadequate availability of natural food, higher degree of metabolic deposition / organic load (Mohanty, 2001), low dissolved oxygen concentration and relatively increased level of ammonia towards latter stage of rearing attributed by gradual increase in biomass

Table 14. Treatment wise fish yield (kg/ha) in different years in medium land refuges

Weir height (cm)	1st year	2nd year	3rd year	Pooled
15 cm	1232.40	1988.80	1859.60	1693.60
20 cm	1004.8	1553.00	1238.10	1265.30
25 cm	1109.90	1478.35	1250.00	1279.40

Table 15. Performance index (PI), production/ size index (PSI) and apparent feed conversion ratio (AFCR) of cultured fish species

Treatment	Species reared*	Performance index, *PI*	Species-wise production/ size index, *PSI*	Overall *PSI*	AFCR
T_1	*C. catla*	56.9 ± 2.9	99.5 ± 3.1	236.8± 8.2	1.68± 0.18
	L. rohita	28.1 ± 3.7	22.7 ± 4.6		
	C. mrigala	68.2 ± 1.6	72.8 ± 3.7		
	C. carpio	37.4 ± 2.2	47.9 ± 4.9		
T_2	*C. catla*	36.8 ± 2.5	50.4 ± 5.4	159.1± 7.7	1.74± 0.57
	L.rohita	21.8 ± 4.0	16.9 ± 2.2		
	C. mrigala	42.5 ± 2.9	37.7 ± 6.9		
	C. carpio	41.9 ± 2.6	57.4 ± 1.8		
T_3	*C. catla*	37.2 ± 1.8	49.5 ± 4.7	141.4± 4.8	1.79 ± 0.22
	L. rohita	27.5 ± 2.3	20.8 ± 2.2		
	C. mrigala	47.4 ± 2.4	41.2 ± 4.7		
	C. carpio	29.9 ± 3.3	29.2 ± 4.1		
Lowland pond	*C. catla*	22.0 ± 0.9	38.5 ± 2.9	110.2± 5.6	2.58± 0.33
	L. rohita	16.9 ± 3.1	21.1 ± 1.4		
	C. mrigala	18.8 ± 4.0	17.1 ± 2.0		
	C. carpio	17.4 ± 2.3	29.4 ± 7.8		

(Mohanty, 2004). Further, in this experiment, reductions in growth, which occurred at higher weir heights, did not appear to be due to poor water quality, as water quality did not differ significantly among various treatments. Thus the reduced survival and growth appears to be a behavioral interaction or physiological response to density itself at low water availability, not to water quality.

Rice Equivalent Yield

Considering the sale price of rice as Rs. 4.00/kg and fish as Rs. 40.00/kg, the rice equivalent yield for all three treatments in medium land was calculated. The highest rice equivalent yield (Table 16) was recorded in 20 cm weir height plots (5.74 t/ha) followed by 25 cm weir height plots (5.44 t/ha). The bench mark survey of study site revealed that before interventions the average yield of rice was 1.8 t/ha from medium land. Thus, there is a 3.2 fold increase in *kharif* rice productivity in the medium land of the study site due to rainwater conservation measures, integration of fish culture component and adoption of improved rice crop cultivation practices. Similarly, rice equivalent yield of lowland was computed as 5.61 t/ha.

Table 16. Treatment wise rice, fish and rice equivalent yield (three years pooled data)

Treatment	Rice area (m^2)	Refuge area(m^2)	Total area(m^2)	Rice yield (t/ha)	Fish yield (kg/ha)	Rice equivalent yield (REY), (t/ha)
T_1(15 cm weir height)	3202.4	171	3373.4	4.6	1694	5.23
T_2(20 cm weir height)	4595.2	294	4889.2	5.3	1265	5.74
T_3(25 cm weir height)	2217.2	184	2401.2	4.83	1279	5.44
Lowland	1167	1200	2367	4.34	685.4	5.61

Water Productivity

In the medium land, the total water utilized per hectare (average of three treatments) was estimated at 8204.5 m^3. Considering the selling price of rice, fish, banana, papaya, black/green gram and ladies finger as Rs. 4, 40, 50/bunch, 4, 15 and 7/kg, respectively the net return from mono-crop rice, rice + fish, rice + fish + on-dyke horticulture and rice + fish + on-dyke horticulture + rabi crop was calculated. The economic index of gross water productivity was computed as 2.76, 2.94, 4.94 and 5.87 Rs/m^3 for mono-crop rice, rice + fish, rice + fish + horticulture on embankment, rice + fish + horticulture on embankment + rabi crops, respectively. Similarly, the economic index of net water productivity for different farming system was computed as 2.06, 2.17, 3.07, and 3.76 Rs/m^3 for mono-crop rice, rice + fish, rice + fish + horticulture on embankment, rice + fish + horticulture on embankment + rabi crops, respectively (Fig. 9). The percentage increase in net water productivity for rice + fish, rice + fish + on-dyke horticulture and rice + fish + on-dyke horticulture + rabi crop over mono-cropped rice was 5.34%, 49.03% and 82.52%, respectively. Thus, the highest water productivity in rice + fish + on-dyke horticulture + rabi crop combination indicates the most efficient way of multiple use of conserved rainwater which is nearly double than that of mono-cropped rice.

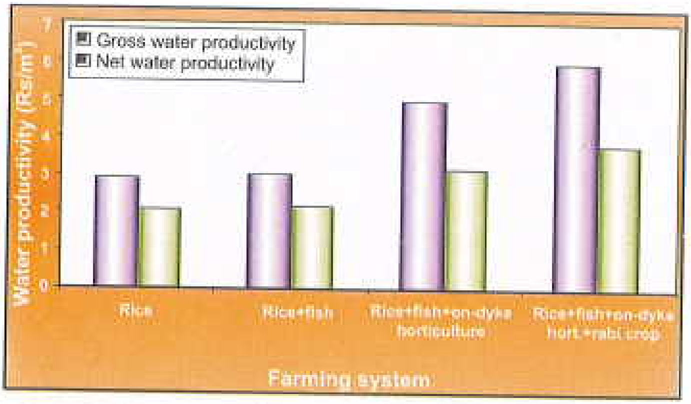

Fig. 9 Economic index of water productivity in different farming systems

Economics

In the medium land, the economics of the integrated farming system at three different weir heights were estimated. The highest gross returns of Rs. 46,238.00 and net returns of Rs. 29,617.00 were recorded with 20 cm weir height followed by 25 cm weir height (Table 17). The cost A, cost B and cost C were computed for all the three weir height treatments. The highest benefit cost ratio of 2.78 was obtained with 20 cm weir height followed by 2.70 with 25 cm weir height (Table 18). The cost difference between different weir heights was not significant, hence it was not taken into consideration. The gross returns were calculated by adding the returns generated from *kharif* rice, fish and *rabi* crops. The returns from banana and papaya were also included. The existing market rate per unit quantity of different crops was taken into consideration while estimating the gross returns. The cost of cultivation of all these crops and rearing of fish was also added. The net return was estimated by subtracting cost of cultivation from gross returns. While, estimating cost of cultivation, different costs like cost A, cost B and cost C were calculated as follows:

Cost A = Cost of all culture practices from land preparation to harvesting and marketing of produce; Cost B = Cost A + imputed value of land or value of leased land; and Cost C = Cost B + imputed value of family labour. The values of cost A, cost B and cost C were presented in Table 19. Different micro economic indicators like farm business income, family labour income and net income were computed (Table 20) for all the three weir height treatments using the following formulae.

Farm business income = Gross income - cost A; Family labour income = Gross income - cost B; and Net income = Gross income - cost C.

The highest farm business income of Rs. 32,319.00 and family labour income of Rs. 30,899.00 are recorded with 20 cm weir height plots. The highest net income (Rs. 29,617.00) and benefit cost ratio (2.78) were also obtained in the same treatment. Therefore, 20 cm seems to be the optimum weir height for the study region and the system under consideration.

Economics of best treatment and variety

Irrespective of variety, 20 cm weir height proved to be the best treatment in terms of overall grain yield of rice, rice equivalent yield, and net return. Again, Jagannath variety

Table 17. Gross returns, net return and cost of cultivation of integrated farming system in one ha. land

	Gross returns (Rs./ha)					Net return (Rs./ha)				
	Kharif rice	Fish	*Rabi* crop	Horti-culture	Total	*Kharif* rice	Fish	*Rabi* crop	Horti-culture	Total
T_1	18354 (-5630)	3360 (-870)	5878 (-1121)	16400 (-9000)	43992 (-16621)	12724	2490	4757	7400	27371
T_2	20924 (-5630)	3036 (-870)	5878 (-1121)	16400 (-9000)	46238 (-16621)	15294	2166	4757	7400	29617
T_3	18622 (-5630)	3889 (-870)	5878 (-1121)	16400 (-9000)	44829 (-16621)	13032	3019	4757	7400	28208

The values in parenthesis indicate cost of cultivation.

Table 18. Benefit cost ratio of the integrated farming systems (average of three experimental years)

Treatment	Gross returns (Rs./ha)	Cost of cultivation (Rs./ha)	Net returns (Rs./ha)	B:C ratio
T_1	43,992	16,621	27,371	2.65
T_2	46,238	16,621	29,617	2.78
T_3	44,829	16,621	28,208	2.70
Jagannath at best treatment (T_2)	48,567	16,621	31,946	2.92

Table 19. Cost A, Cost B and Cost C (in Rs./ha) of the systems (Average of three years)

Treatment	Cost A	Cost B	Cost C
T_1	13,919	15,339	16,621
T_2	13,919	15,339	16,621
T_3	13,919	15,339	16,621

Table 20. Average farm business income, family labour income and net income (in Rs./ha) of the system (Average of three years)

Treatment	Farm business income (gross income-cost A)	Family labour income (gross income-cost B)	Net income (gross income-cost C)
T_1	30,073	28,653	27,371
T_2	32,319	30,899	29,617
T_3	30,910	29,490	28,208

has out performed over other varieties in terms of grain yield (6.0, 5.95 and 5.72 t/.ha in 1st, 2nd and 3rd year respectively) in the best weir height treatment of 20 cm. Therefore, keeping the best weir height (20 cm) and best variety (Jagannath) in consideration, the gross return (Rs.48,567.00), net return (Rs.31946.00) and benefit cost ratio (2.92) were estimated (Table 18).

CONCLUSIONS

In the rainfed medium land, *in-situ* and *ex-situ* conservation of rainwater, short-duration pisciculture in the excess rain water harvesting refuges/pond, integration of horticulture on the embankment and utilization of conserved water for growing light duty *rabi* crops seems to be a viable solution for increasing the income of small and marginal farmers. The stored water can also be utilized for meeting the supplemental irrigation requirement of *kharif* rice during dry spells. In the lowland, construction of drainage channel, soil maneuvering and integration of fish culture is proven to have the potential of increasing the land and water productivity and cropping intensity significantly. This dual production system (rice and fish) in *kharif*, perennial horticulture and light duty *rabi* crops generate additional income, employment opportunity and nutritional security. In addition, this also minimizes of the risks due to natural calamities. The system is eco-friendly and promotes synergism between different components.

REFERENCES

APHA. (1995). "Standard Methods for Examination of Water and Waste Water." 19th edn. *American Public Health Association*. Washington, D.C., U.S.A., 874p.

Banerjea, S.M. (1967). "Water quality and soil condition of fishponds in some states of India in relation to fish production." *Indian J. Fish*., 14:115-144.

Bhuiyan, S.I. and Goonasekera, K. (1988). "Rainwater management for increasing production of rice and upland crops." Paper presented at the International Rice Research Conference, IRRI, Los Banos, Philippines.

Biswas, K.P. (1993). "Fisheries Manual". *Bhagabat press and publishers*, Cuttack, Orissa, India.

Bjoernsson, B. (1994). "Effect of stocking density on growth rate of halibut (*Hippoglossus hippoglossus* L.) reared in large circular tanks for three years." *Aquaculture*, 123:259-271.

Boyd, C.E. (2004). "Methods for lessening water use in fresh water prawn culture". *Shrimp Matters*, 48(4): 1-2.

Duncan, D.B. (1955). "Multiple range and multiple f-test". *Biometrics*, 11:1-42.

Mishra, A., Ghorai, A.K. and Singh, S.R. (1998). "Rainwater, soil and nutrient conservation in rainfed rice lands in Eastern India." *Agricultural Water Management*. 38: 45-57.

Mishra, A and Mohanty, R. K. (2004). "Productivity enhancement through rice-fish farming using a two-stage rainwater conservation technique". *Agricultural Water Management*, 67:119-131.

Mishra, A., Mohanty, R.K., Kannan, K., James, B.K., and Nanda, P. (2003). "Rainwater conservation and management for integrated rice (Oryza sativa)-fish farming in the rainfed medium and low land ecosystems". *Indian Journal of Agricultural Sciences* (ICAR), 73(11): 605-608.

Mohanty Rajeeb K. (2001). "Feeding management and waste production in semi-intensive farming of Penaeus monodon (Fab.) at different stocking densities". *Aquaculture International*, 9(4): 345-355.

Mohanty Rajeeb K. (2003). "Feed intake pattern and growth performance of Indian Major Carps and freshwater prawn in a rice-fish integration system". J. Asian *Fisheries Science*, 16:307-316.

Mohanty, Rajeeb K. (2004). "Density-dependant growth performance of Indian major carps in rainwater reservoirs". *Journal of Applied Ichthyology*, 20 (2): 123-127.

Mohanty, Rajeeb K., Mishra, A., Verma, H.N. and Brahmanand, P.S. (2002). "Rainwater conservation and rice-fish integration for enhancing land and water productivity". *Research Bulletin* No-11, Water Technology Centre for Eastern Region (Indian Council of Agricultural Research), Bhubaneswar, India, 24p.

Mount, D.I. (1973). "Chronic exposure of low pH on fathead minnow's survival, growth and reproduction". *Water. Res.*, 7:987-993.

Pal, A.R., Rathore, A.L. and Pandey, V.K. (1994). "On-farm rainwater storage systems for improving riceland productivity in eastern India: opportunities and challenges". In: On-farm Reservoir Systems for Rainfed Ricelands (S.I. Bhuiyan eds.), IRRI, Los Banos, Philippines, 105-125.

Pisharoty, P.R. (1990). "Indian rainfall and water conservation. Proc. of the All India seminar on modern techniques of rainwater harvesting, water conservation and artificial recharge for drinking water, aforestation, horticulture and agriculture". Directorate of Ground Water Surveys and Development Agency. Rural Development Department, Govt. of Maharastra, India, 55-53.

Rai, M. (2003). "Address of the Chief Guest." 49th Annual Convocation of the Indian Institute of Technology, Kharagpur, July 19th 2003, 1-13.

Tidwell, J.H., Coyle, S.D., Bright, L.A., VanArnum, A. and Weibel, C. (2003). "The effect of size grading and length of nursery period on growth and population structure of freshwater prawns stocked in temperate zone ponds with added substrates". *Aquaculture*, 218:209-218.

Zacharia, S. and Kakati, V. S. (2002). "Growth and survival of Penaeus merguiensis postlarvae at different salinities". *The Israeli Journal of Aquaculture - Bamidgeh*, 54(4):157-162.

Zonneveld, N. and Fadholi, R. (1991). "Feed intake and growth of red tilapia at different stocking densities in ponds in Indonesia". *Aquaculture*, 99:83-94.