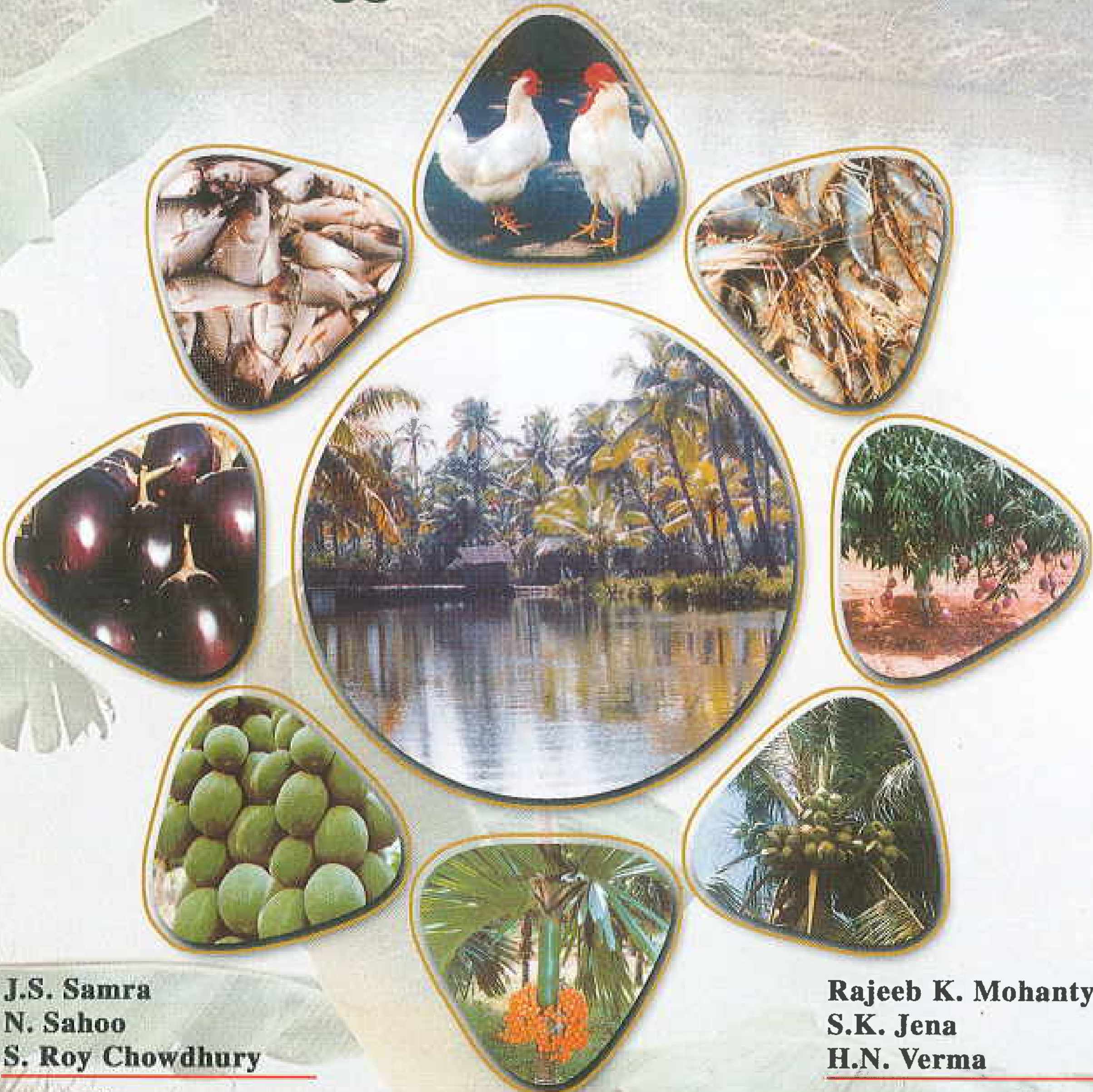
Publication No. 14

WTCER

Research Bulletin

Sustainable Integrated Farming System for Waterlogged Areas of Eastern India



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2003

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Correct citation:

Samra, J.S., Sahoo, N., Roy Chowdhury, S., Mohanty, Rajeeb K., Jena, S.K., and Verma, H.N. 2003. Sustainable Integrated Farming System for Waterlogged Areas of Eastern India. *Research Bulletin No. 14.* Water Technology Centre for Eastern Region *(Indian Council of Agricultural Research)*,Chandrasekharpur, Bhubaneswar, Orissa, 751023, India.

Published by

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FOREWORD

High amount of rainfall, inflow from highland canal irrigation and saucer shaped physiography near the coast in deltaic alluvial region are most important reasons for water logging in 3.28 M ha land in India. Planners, scientists and farmers are increasingly concerned about changes in land ecology due to rise of water table and related environmental process. Increased allocation for reclamation of waterlogged area in the Xth five-year plan emphasizes the concern of development priorities. Apart from environmental impacts, the modified edaphic factors, lead to very low productivity. Lack of crop diversification due to restricted situations for agriculture has resulted in rice monoculture as a compulsory option. Falling prices of rice in the open market and imbalanced nutrition has further compounded the livelihood concerns of agrarian society. Under this backdrop it is essential to look for an alternative farming/land use system to increase production, productivity and profitability for a vibrant livelihood. The Impact of value addition is clearly perceived when traditional farming activities are integrated with pisciculture, horticulture, and other enterprising venture. A diversified broad based farming system has a tremendous potential to provide a range of nutritional sources for ensuring rural health and generate employment all round the year. Farming system described in this write-up is based on the ecological principles of multiple cycling of nutrients and other energy fluxes with minimized environmental loading. The selected site is one of the lowest productive areas of Orissa state in our country, prone to chronic water logging and poverty. All the data were collected from a farmer in a participatory endeavor and is a very practical model being managed under real situation.

Diwali, 25th October 2003 **AUTHORS**

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SUMMARY

Population of India is projected to grow up to 2050 AD before stabilization at 1.3 to 1.5 billions and livelihood aspirations are expected to be realized from shrinking resources by maximizing resource productivity and input use efficiency. Threats of water logging, high rainfall and excessive ground water resources can be converted into poverty alleviating opportunities in many parts of eastern India. Diversification of rice monoculture into integrated farming system will be environmentally sustainable, economically viable and risk avoiding strategy. Keeping these in view, an integrated farming system was evaluated in a farmer's field. Out of 2.47 ha waterlogged area of the farmer, 1.64 ha was converted into grow-out pond for fish and prawn culture while vegetable, flower and fruits were grown on 0.83 ha of raised embankment all around the pond since 1989. Poultry sheds were also constructed for rearing 4000 birds in such a way that their droppings could fall into pond as organic manure and feed for fish. The average productivity of low land high yielding paddy was 3.5 t ha^{-1} as compared to 9.4 t ha^{-1} per annum fish equivalent (fish + prawn). Gross and net returns from fish and prawn culture alone during 2002 were Rs. 6,17,160 (Rs. 3,76,317 per ha) and Rs. 3,31,065 (Rs. 2,01,868 per ha) respectively. This accounted to Rs. 14.00 per m^3 of water productivity in the pond system alone. Whereas the gross and net returns from the whole system of 2.47 ha during the year 2002 were Rs. 6,51,110 (Rs. 2,63,607 per ha) and Rs. 3,62,515 (Rs. 1,46, 767 per ha) respectively. The farmer initially invested Rs. 1,23,910 in 1988 towards construction of the pond plus infrastructure and earned a net return of Rs. 40,554 per ha of whole system in 1989, which gradually increased up to Rs. 1,32,894 per ha in 1997. He again invested Rs. 1,30,000 towards stone pitching in 1998 and Rs. 3,20,000 towards poultry shed and the net return (after adjusting investment) was Rs. 2,17,600 (Rs. 88,097 per ha) during 1998 and a net loss of Rs. 1,16,900 during super cyclone year in 1999. The net returns per ha again increased steadily after cyclone from Rs. 27,465 in 2000 to Rs. 1,37,894 in 2001 reaching up to Rs. 1,46,767 (35 times higher of the paddy cropping) in 2002.

Adjacent to the developed integrated farming system, the farmer is cultivating 2.4 ha waterlogged paddy field giving net return of Rs. 4,166 per ha only (2.8% of the integrated farming system). WTCER has designed a deep water high density rice-fish integrated system of 1.2 ha out of the 2.4 ha waterlogged paddy field system and it is estimated that it will give net return of Rs. 1.5 to 1.6 lakh per ha per year. Revival of poultry component and addition of milch cattle in the system is going to make it more profitable and more sustainable utilizing surface and ground water of the waterlogged area. This is going to be a replicable integrated farming model for the coastal Orissa. It may also be replicated in irrigated alluvial land of other regions.

1.0. Introduction

Orissa state derives its livelihood, food, nutritional and environmental services from 0.70 M ha of upland area and 0.92 M ha of alluvial plains including 0.08 M ha of waterlogged soils. In spite of 1482 mm of average rainfall, Orissa's rice productivity in 2000-2001 was 1127 kg ha^{-1} compared to 1540 kg ha^{-1} of Bihar and 3346 kg ha^{-1} of Punjab. According to 1999-2000 estimates, Orissa had highest poverty of the country (47.15% population), followed by Bihar (42.6%) as compared to 26.1% of national average and 6.16% of Punjab. Water was declared one of the five pillars of sustainable development at Johannesburg (WSSD, 2000). Even though it is abundant in this state, highest poverty ratio is still a unique situation. Similar is the case in many other states of eastern India. In most of the waterlogged fertile alluviums of East India, water stagnates above ground for nearly six months in a year and only one anaerobic paddy crop is raised. Mono-cultures are risky and farmers are growing anaerobic rice with 50% probability of crop failures and 40% probability of harvesting less than 1 ton per ha. Diversification is essential to alleviate poverty and risks, increase income from diverse commodities, expand range of livelihoods and sustain integrity of natural resources. Water table during post rainy season hardly goes beyond 2 m below ground level and can be pumped out with minimum investments and energy inputs. Lack of marketing infrastructure and procurement policy leads to distress sale of paddy and poverty perpetuation. Diversification into cultivation of vegetables, fruits, pulses, oilseeds and other cash crops is not feasible due to waterlogged conditions during most part of the year. Traditional rice-fish culture is subsistence in nature and is non competitive in the market driven liberalized economy of WTO regime. They need a farming system, which converts threats of water abundance into greater livelihood, employment generation and poverty reduction opportunities. Fish being a rich source of animal protein will enhance nutritional status and human health. Integrated farming system ensures input use efficiency, minimizes cost of production and environmental loading. In view of above, an integrated farming system of fish and prawn culture, cultivation of paddy, vegetables, fruits and poultry rearing was evaluated on a farmers field for 15 years.

Integrated farming system approach of diversifying risks, self employment, flow of income throughout the year and recycling of energy and nutrient fluxes provide sustainable resource use. Integrated farming can be classified into three major systems with twelve major models. The most popular models preferred in India and suitable for waterlogged situations are mainly pond-dyke integration, fish-rice-duck/ poultry-vegetable and fish-cow/ pig-duck/ poultry-vegetable. In addition to economic consideration, these systems are based on multiple recycling of carbon, energy and nutrients from biomass to livestock-poultry/ piggery/ fishery etc. and minimize environmental loading with pollutants. The over all system is most efficient for the absorption of inputs and production of goods and services. In these systems, marginal lands/ wet lands are generally brought into productive use, where pond serves as a focal point for direct or indirect links between other components. It is reported that 50 kg of fish biomass can produce enough pond humus to fertilize nearly 6500 m^2 of cropland. Further, under standard aquaculture practice, 10-25 cm silt per year is deposited at the pond bottom which is enriched with organic matter (2.4%), total nitrogen (2.0-2.1%), phosphorous (0.16-0.2%) and potassium (1.0-2.39%). Approximately 250 kg of pond sediment can produce enough fodder, which can be utilized to produce 2-3 kg of grass carp. In this system animal/ poultry wastes are used to fertilize fishpond and crop lands. The land in return produce crops, which serve as food for animal, fish and human beings. Keeping all these aspects in view, an integrated farming system developed at farmer's field was evaluated for its productivity, sustainability, profitability and also to understand the needs for further modifications. Water productivity in the sense of its multiple uses has also been attempted.

2.0. Location of Project Site

An on-farm integrated farming system model was developed by Mr. Radhakanta Sahoo, a farmer in the village Isani Berhampur (area locally called Khentalo) of Nischintakoili Block in the district of Cuttack in his waterlogged fields. The site is 35 km away from Cuttack and 65 km away from Bhubaneswar. It is situated at a distance of 0.5 km from Mahanadi river bund. The location map of the project site as well as lay out of the farm is given in Figure 1.

2.1. Hydrology

The average annual rainfall of Khentalo for last 12 years (1991-2002) is 1476 mm and the monsoon (June to October) rainfall is 1249 mm, which accounts for 84% of annual rainfall. On an average the water level appears above surface from 3rd week of June, reaches maximum during first week of August and starts receding after that and remains above ground for nearly six months in a year. Water table depth below ground level varies from 5 cm to 167 cm during post monsoon period (December to June). The weekly rainfall, surface ponding and water table depth is presented in Figure 2. The steep rise and fall in water table may be due to its drainage into river Mahanadi and Paika during low flow period and quick recharge of ground water during high flow period. In a surface drainage experiment in waterlogged area of Puri district it was observed that surface water ponding starts from 3rd week of June and increases maximum up to 162 cm in last week of August and reduces to surface level in December. Water table observation in that area has also given similar trend. So this type of hydrology is prevalent in 67% of the waterlogged area (84,800 ha) of Orissa state and 38% (3.28 M ha) of total waterlogged area (8.52 M ha) of the country. So the technology feasible in this particular situation can be applied to 3.28 M ha (38%) waterlogged

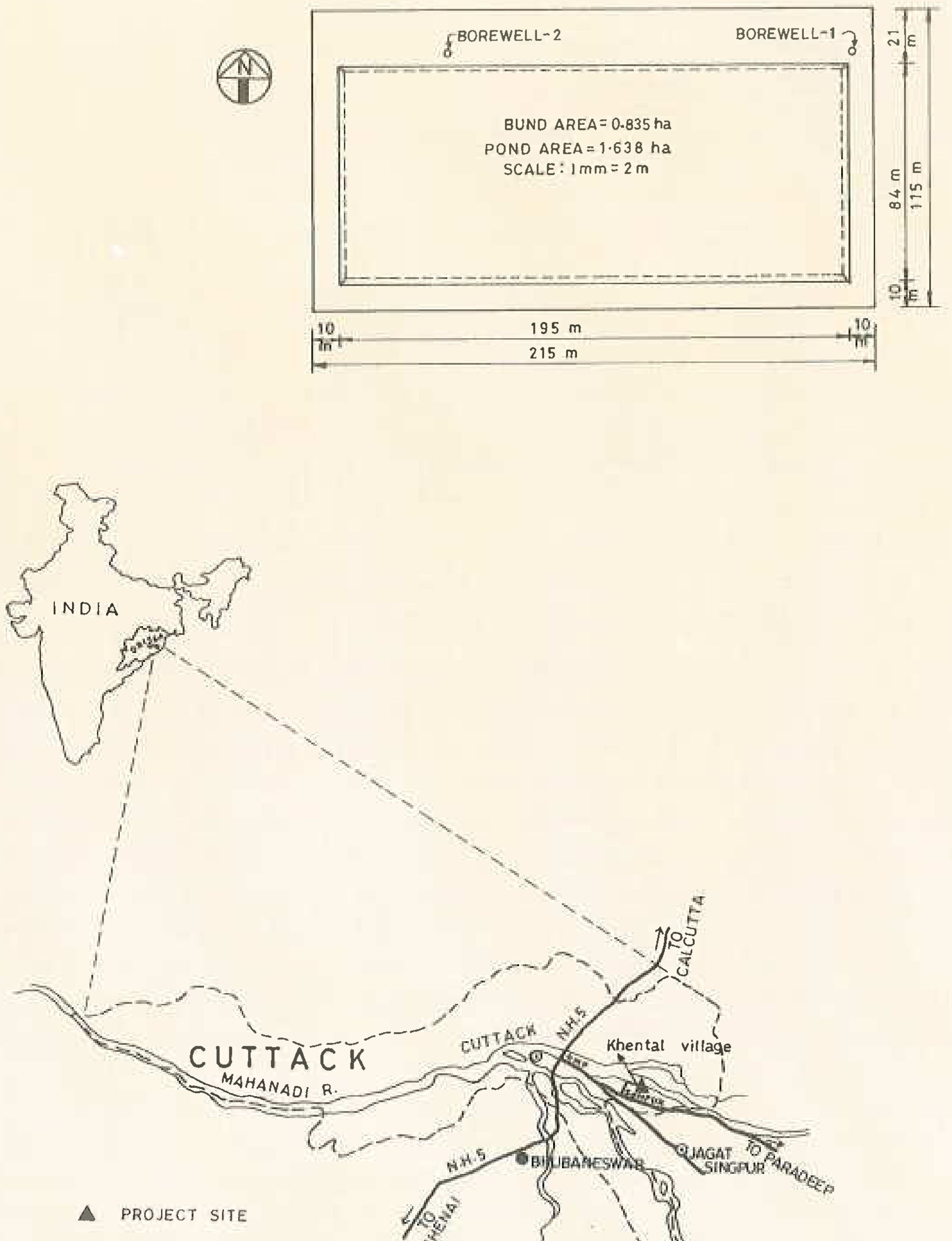


Fig. 1. Location map of the project site

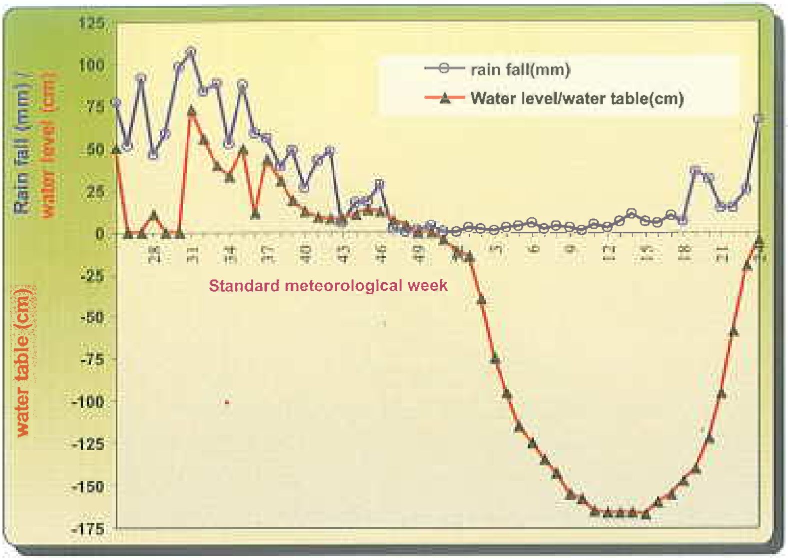


Fig. 2. Weekly rainfall, surface ponding and water table depth of the project site.

area of the country. Under this situation pond will get enough water through subsurface inflow during July-October and needs ground water wells for filling the tank for first crop season and lean periods of the year.

2.2. Water Quality and Soil Characteristics in Relation to Fish Production

Water quality changes in response to daily and seasonal climate rhythms and beyond a certain level, create stress for fish and prawn. Water and soil quality variables generally determine the production potentiality of the water body for any aquaculture system (Table 1), as several *biotic* and *abiotic* factors play a key role in enhancement of productivity. Therefore, intensive hydro-biological studies prior to site selection are essential. Texture and properties of soil, its water retention capacity and suitability as a constructional material to build up the surrounding dykes should be determined. Generally soil with higher percentage of clay and pH ranging from 6.5 to 7.5 is considered suitable. The lands having higher water table and with suitable drainage system may be selected. Poor growth performance of fish/ prawn usually takes place at pH < 6.5, dissolved oxygen < 4 ppm, temperature < 20^{0}C and transparency < 15 cm, while higher values of total alkalinity (>90 ppm) indicate a better productive ecosystem. Further increased plankton density reflects higher nutrient status and productivity of water body. However, the average recorded various hydrological parameters of the study site (grow-out pond) ranged between 7.29 $\pm$ 1.17 (pH), 5.7 $\pm$ 2.8 ppm (dissolved oxygen), 112 $\pm$ 31 ppm (total alkalinity), 221 $\pm$ 59 ppm (TSS), 4.2-6.1 ppm (dissolved organic matter), 0.033 $\pm$ 0.007 ppm (nitrite-N), 0.025 $\pm$ 0.008 (nitrate-N), 31 $\pm$ 11 cm (transparency), 6.5 $\pm$ 2.8 ppm (CO_2) and 0.18 $\pm$ 0.04 ppm (ammonia) respectively. Similarly, various water quality parameters of ground water (average value) used for aquac-

Table 1. Classification of productive water bodies based on water and soil characteristics.

Parameter	*Unproductive*	*Low productive*	*Highly productive*
1. Water			
pH	< 6.8	6.8 – 7.5	7.5 – 8.5
Total alkalinity (ppm)	< 30	30 – 90	> 90
Inorganic nitrogen (ppm)	< 0.1	0.1 – 0.3	0.3 – 0.7
Orthophosphate (ppm)	< 0.05	0.05 – 0.2	0.2 – 0.6
Dissolved oxygen (ppm)	< 4.0	4.0 – 6.0	6.0 – 9.0
Plankton (number/l)	< 35	35 – 70	> 70
2. Soil			
pH	< 6.5	6.5 – 7.5	7.5 – 8.5
Available Nitrogen (mg/100g)	< 15	15 – 35	35 – 90
Available Phosphorus (mg/100g)	< 6	6 – 20	20 – 50
Exchangeable calcium (mg/100g)	< 50	50 – 150	150 – 300
Bottom fauna (g/m^2)	< 15	15 - 20	20 - 50

ulture were 6.8 (pH), 48 ppm (total alkalinity), 12 ppm (TSS), 0.007 ppm (nitrite-N), 0.003 ppm (nitrate-N), 0.05 ppm (phosphate) respectively. The recorded minimum and maximum values of various pond water quality parameters even after dilution with groundwater were within or nearly the optimum range for fish/ prawn culture. The area with respect to soil type falls under alluvial zone. Extent of alluvial zone is around 50% of the coastal districts of Orissa. Soil analysis shows that textural class is clay having acidic pH (5.53). The average texture of the soil was clay and the composition of sand, silt and clay was 36.6, 19.0 and 44.4% respectively. Similarly the average soil pH, EC (dS m^{-1}), OC (g kg^{-1}), total N (g kg^{-1}), Olsen P (kg ha^{-1}), available K (kg ha^{-1}), CEC [C mol (p+) kg^{-1}] and DTPA extractable Zn (mg kg^{-1}) was 5.53, 0.177, 8.09, 1.08, 17.5, 390, 26.16 and 1.20 respectively.

2.3. Population Growth

Usually coastal districts are highly populated, but the population density in such kind of waterlogged area is low. Land availability (0.115 ha per person) is higher than that of non-waterlogged area (0.06 ha per person). Irrigated area is only 10% though plenty of water is available underground for taking a good *rabi* crop after December. People below poverty line (BPL) are more (70.4%) than other areas (60.1%) in coastal tract of Orissa. Majority of people in this area fall under malnutrition category. Environment is quite unhygienic in this area due to continuous ponding of water around the habitats.

2.4. Family Background of the Farmer

The farmer Mr. Radhakanta Sahoo (Figure 3) hailed from a family with farming background. He has three brothers, three sisters and mother. All brothers and sisters are settled elsewhere. He has two sons and two daughters. Both the daughters were married after full operation of the integrated farming system project. One of his sons is law graduate and is presently looking after the farming system leaving aside his law profession.

Fig. 3. WTCER scientist's interaction with the farmer (centre)

2.5. Background of the Project

The original total area of the system (2.47 ha) consisted of 1.5 ha swampy *'Kia'* forest and rest 0.97 ha waterlogged area was cultivated with long duration variety of local paddy. However, as the yield of paddy was very poor (1.1 t ha^{-1}), high yielding long duration waterlogging tolerant variety of paddy like *Panidhan*, *Tulasi* and *Utkal Prabha* were tried. Though the yield of improved rice varieties were comparatively better (2 to 3.5 t ha^{-1}), average net income from that area through rice cultivation was poor (Rs. 3157 per ha).

While visiting a tourist resort at Puri, the farmer thought of converting the entire land into a tourist resort, as it was located on the bank of Mahanadi. The purpose of developing tourist resort with a centrally located lake type pond was to lease it out for recreation like picnic, holidaying, fishing and film shooting. After digging the pond, he realized that project might not be viable as the spot was too far from the main road. Considering all the pros and cons of suggested cropping system by agricultural scientists, finally integrated farming system approach was adopted converting part of the land into fishpond and rest into raised bunds. Embankment was planted/ cultivated with mango, teak (Figure 4), areca nut (Figure 5), coconut and horticultural crops such as banana, papaya, pineapple, mushroom etc. Poultry was also introduced on the pond embankment in the year 1999 to make the system more integrated and economically sound.

3.0. Integrated Farming System

Out of 2.47 ha of low productive swampy lowland, a fishpond was constructed in 1.64 ha and the dug out earth was put on the bund to raise it for horticultural crops. The bund area is 0.83 ha. The width of bund in north side is 21 meter and 10 meter each in east, south and west side. The pond dimension is 195 m x 84 m. The depth of pond is 2.0 m. The entire plot dimension is 215 m x 115 m. The lay out of the pond-dyke integration system is given in Figure 1. The entire developmental operation took two years to complete. The project is now more than a decade old. Super cyclone in October 1999, uprooted many horticultural plants on raised bund and threw them in the pond. The majority of fish population in the pond died due to pollution. To clear the pond and renovate the system, once again the farmer invested a sum of Rs. 1,50,000. Recently further improvements over the existing system was started by Water Technology Center for Eastern Region (ICAR), Bhubaneswar, with introduction of rice-fish integration system, adjacent to the site, to provide sufficient stocking material (fingerling) for the main grow-out pond of the system and also for the nearby fish farmers. The area under additional new rice-fish integrated system is 1.2 ha including 0.2 ha dyke area. Addition of this system has increased total area of the integrated farming system to 3.67 ha.

Fig. 4. View of farmer's cottage with teak and other tree plantation.

Fig. 5. Areca nut and other fruit plantation on pond embankment.

3.1. Pond System

The main pond of 1.64 ha (Figure 6) was constructed with an initial investment of Rs. 1,23,910 using a tractor and hired labour. In the western part of the tank stone lining was done to construct 16 numbers of poultry houses of 24 m^2 each. For this, the farmer with a subsidy amount of Rs. 1.2 lakh took a bank loan of Rs. 6 lakh. Apart from 16 numbers of on-pond poultry houses, the farmer constructed two more poultry houses adjacent to the pond dyke of 100 m^2 each, to meet poultry manure requirement of his crops. The pond system has three small nursery ponds (total 0.2 ha) for rearing of fry to advanced fingerling stage of Indian major carps. As cost of one fingerlings (>50 g) ranges between Rs. 5.00 - Rs. 5.50, the farmer was advised to purchase fry (Rs. 70 per 1000 fish fry) and stock in the nursery ponds @ 2 lakh ha^{-1}. The size of the fry usually ranges between 0.3 – 0.5 g each, and are reared in the nursery ponds after stocking in July end. After attaining 100 –110 g size of mean body weight in the small pond, the fishes are then transferred to the main grow-out pond of 1.64 ha in the month of January. The fishes are reared up to the month of May before harvesting. The pond was restocked in June and rearing continue up to mid November. The second crop is harvested at the end of November. So altogether two crops are taken in a single calendar year. During November-December the pond is drained out. The pond preparation for the next year crop is carried out during the 45 days gap period between November-

Fig. 6. Farmer with his pond system.

January. The three nursery ponds provide the required fingerlings for both the cultures. The nursery rearing produced a survival rate of 40-45%. The size of supplied fingerlings from nursery ponds for stocking in main pond range between 100-110 g for first crop during January and 150-160 g for second crop during June.

Prior to stocking, the main pond is treated following the standard pond preparation procedures such as drying, ploughing, liming (@ 200 kg ha^{-1} as basal), fresh cow dung (@ 7000 kg ha^{-1} as basal), SSP (@ 25 kg ha^{-1} as basal). However, periodic liming @25 kg ha^{-1} is carried out at every 15 days interval to maintain desired water pH and plankton density.

During stocking, a density of 7500 fingerlings per ha is maintained in the main pond with a species composition of 30:40:30 (*Catla catla: Labeo rohita: Cirrhinus mrigala*). In addition to this, prawn post-larvae of *Macrobrachium rosenbergii* (PL_{15-20}) are also stocked in the main pond for poly-culture with Indian major carps @ 15000 ha^{-1}. High-energy pelleted feed is given twice (1:1) a day (morning and evening) @ 2.5% of mean body weight throughout the culture period. Since cow dung is given as basal and poultry manure is supplied on daily basis, urea is not applied to the pond eco-system for fertilization purpose.

3.1.1. Culture performance

Every year, the first culture is of five months duration while second culture continued up to six months. The first culture is usually stocked with fingerlings of 100-110 g of mean body weight (MBW) while second culture with 150-160 g of MBW. Although second culture is stocked with larger sized fingerlings with longer rearing duration, growth performance remained more or less the same in both cases, because optimum temperature and other hydrological parameters were more conducive for higher growth during March-May. Water quality remained poor, most of the time in the second culture due to monsoon and winter season. In both the cases in a year, average growth of cultured species ranged between 500-550 g with a survival rate of approximately 95%. The average yield per culture was achieved between 3.6–3.9 t ha^{-1}, which corresponds to average 7.5 t ha^{-1} yr^{-1}. In the initial years, the feed conversion ratio (FCR) was high (1:2.2) as the pond was newly excavated and there were no poultry units over the pond. However, after development of muck and introduction of poultry, the feed input decreased by 35-40% and FCR improved significantly (average 1:1.45).

Every year, growth pattern of cultured fish species in the first and second crop was totally different in this system. In the first culture (January - May), per day increment rate (PDIR) or average daily growth (ADG) was minimum in the first month and gradually improved in subsequent months while the trend was totally reverse in the second culture during June - mid November (Figure 7). In the second case, ADG in

Fig. 7. Comparative average growth of cultured fish

comparison to first crop remained at higher side in the initial month and decreased slowly thereafter. However, as the stocking size in both the crops ranged between 100-160 g the survival rate, ponderal index, condition factor, yield and performance index of both the crops did not differ significantly.

As in case of fish, prawns were not grown twice a year and were stocked only once during the first crop and was harvested in the month of November. This was due to non-availability of seed and problem in complete draining of pond water for harvesting during on-going second crop period. Therefore, the prawn rearing continued for 8-9 months in a year. During this period, on an average, 35% of the stocked material was harvested, with an average mean body weight of 75 g. This corresponds to an average prawn yield of 640 kg ha^{-1} in addition to 7.5 t ha^{-1} yr^{-1} of fish production. Thus the total biomass production in terms of fish and prawn corresponds to 8.10 t ha^{-1} yr^{-1} (Figure 8), which is fish equivalent of 9.42 t $ha^{-1}yr^{-1}$. The annual operational cost and net return for the year 2002 of the pond system (1.64 ha) was evaluated and presented in Table 2.

The net return was estimated at Rs. 3,31,065 @ 2,03,107 per ha. Poor survival rate of prawn (35%) was probably due to smaller size at the time of stocking, cannibalism and adverse hydro-biological conditions during monsoon and winter season. Further, average growth of prawn (75 g) was mainly affected by heterogeneous individual growth (HIG) of male and female morphotypes. In general, *M. rosenbergii* is known to exhibit a complex social organizational hierarchy. The predominance of a definite social hierarchy among the male morphotypes increases the differential growth

Fig. 8. Harvested fish and prawn from the main grow-out pond.

Table 2. Annual operational cost and net return of the 1.64 ha pond system (year 2002).

Input material	*Quantity*	*Total input Cost (Rs.)*
Cost of fingerling production for stocking @ Rs. 2.00 per fingerling	12,285 x 2 time =24,570 nos.	49,140
Cost of prawn seed @ Rs.0.50 per post-larva	40,950 x 1 time = 40,950	20,475
Cost of ploughing by tractor @ Rs. 200 per hour	20 hours	4,000
Cost of cow dung @ Rs. 400 per ton	12 ton	4,800
Cost of lime @ Rs.4 per kg.	320 kg.	1,280
Cost of pellet feed @ Rs.8.50 per kg.	18.4 ton	1,56,400
Water exchange @ Rs.50 per hour of pumping	300 hours	15,000
Labour cost @ Rs. 50 per man day	350 man days	17,500
Cost of pond draining @ Rs.50 per hour	5 pumps x 10 hour per day x 7 days = 350 hour	17,500
Total input cost = Rs. 2,86,095 Selling of fish, 12,285 kg @Rs. 40 per kg = Rs. 4,91,400 Selling of prawn, 1,048 kg @Rs.120 per kg = Rs. 1,25,760 **Gross return = Rs. 6,17,160 (Rs. 3,76,371 per ha)** **Net return from the system of 1.64 ha (gross return – input cost) = Rs. 3,31,065** **Net return per ha = Rs. 2,03,107**		

pattern within the population. The three main male morphotypes (stunted male- SM, orange clawed male- OCM and blue clawed male- BCM) and two main female morphotypes (virgin female, VF and berried female, BF) are usually found in the harvested biomass ranging the mean body weight of 20 g – 220 g size. Once a set of prawn reaches the terminal morphotype, it inhibits the transformation of other morphotypes to successive stages. This leads to wide range variation in growth pattern among different morphotypes. The percentage contribution of different male morphotypes noted under this system ranged between 45% (SM), 8% (OCM) and 47% (BCM) while among female morphotypes VF and BF contributed 80% and 20% respectively. Similarly average weight distribution of SM, OCM, BCM, VF and BF ranged between 28-32, 35-45, 140-155, 35-42 and 43-49 g respectively.

3.1.2. Environmental monitoring of the pond system

The manure loaded fish ponds can be considered as a system to which mineral rich organic matter is added in the form of manure and produce fish biomass. However, as too much of waste loading reduces the light penetration, photosynthesis rate, reactive distance of fish and prawn, frequently fluctuating water parameters, reduced ventilation and oxygen consumption rate of fish/ prawn lead to out break of disease. Maximum amount of organic waste loading was maintained within 120-200 kg ha^{-1} day^{-1} (dry weight) or 72-130 kg ha^{-1} day^{-1} of organic matter. The estimation of waste loading rate squarely depends upon the rate kinetics of decomposition process and utilization of degraded products in pond eco-system, which is very much influenced by temperature, dissolved oxygen and intensity of solar radiation. Regular monitoring of dissolved oxygen and pH are therefore, very important from waste loading point of view. Further, to maintain a cleaner aquatic environment, regular water exchange was carried out which corresponds to 2 - 3% day^{-1}.

3.2. Poultry System

In the western part of the pond 16 poultry sheds were constructed (Figure 9) in the year 1999. The dimension of these poultry sheds were 6 m x 4 m each and 250 birds were reared in each shed. In addition, there were two more (20 m x 5 m size) sheds on the northern side bund and 1000 birds were kept in each shed. So total capacity of birds at a time was 4000. One feeder was provided per 50 birds, one drinker per 75 birds and two 40-watt tube lights were kept for 250 birds. 100-watt electric bulbs were used in brooders for first 15 days of the rearing of chicks. This activity was started by taking a loan of Rs. 6,00,000 from nationalized bank, out of which Rs. 1,20,000 was subsidy. In the year 1999 about 4000 birds were reared in each batch and very marginal profit of Rs. 2 per bird was obtained. But due to super cyclone during October 1999, more than 50% of bird died and the farmer incurred a heavy loss. The bank did

Fig. 9. A series of poultry sheds
on pond embankment.

Fig. 10. Renovated poultry sheds
after super cyclone

not sanction any loan for reviving the project for the second time. So to revive the project, the farmer repaired few poultry houses from his own resources (Figure 10) and started rearing chicks. But again there was a very little profit of around Rs. 2 per bird where as farmers of Andhra Pradesh are getting more profit due to cheap home made feed (Table 3). This prohibited the farmer for continuing poultry. The other important factors that prevented him for continuing poultry were requirement of more attention, high maintenance and costly feed in comparison to fish culture. He is being suggested to explore possibility of producing poultry feed at home and providing more managerial skill to revive the poultry component of the system.

Table 3. Comparative economic analysis of poultry system of Andhra Pradesh and Orissa.

Sl. no	*Item*	*Andhra Pradesh*	*Orissa*
1.	One day Chick cost	Rs. 10.00	Rs. 10.00
2.	Feed cost per bird	Rs. 24.00 (feed prepared by farmer)	Rs. 35.00 (feed purchased from market)
3.	Medicine cost per bird	Rs. 2.00	Rs. 2.00
4.	Maintenance cost per bird	Rs. 5.00	Rs. 5.00
Total expenditure incurred per bird		**Rs.41.00**	**Rs. 52.00**
Per bird yield 1.8kg @ Rs. 30.00 per kg		Rs. 54.00	Rs. 54.00
Net profit per bird		**Rs.13.00**	**Rs. 2.00**

3.3. Bund Plantation

In the initial years, the farmer planted papaya and banana on the bund along with mango, teak, areca nut and coconut. In the later years, papaya and banana were tried which did not grow well because of shade of other trees and were also vulnerable to high wind velocity. Different kinds of fruit trees in limited number like guava, pomegranate, sapota, litchi, jamun (hybrid) were also grown. Different spices such as bay leaf (*tej patta*), ginger and turmeric were taken as inter crop. Also floriculture was tried in the initial years but could not succeed due to marketing problem. The market for papaya and banana was also not encouraging. In the initial years vegetables were also grown on the bund as fruit and other trees were small with limited canopy. The total returns from vegetables alone were in the tune of Rs. 1,10,400 (Rs.1,33,012 per ha) in the first year and as the trees grew it came down to Rs. 23,000 (Rs 27,710 per ha) in the year 2002. Before cyclone the system had 365 coconut trees, 3000 areca nut trees, 100 teak plants and 100 mango plants. Revenue from selling tender coconut (green) and matured coconut was Rs. 1,05,000 (Rs. 80,000 from green and Rs. 25,000 from mature fruit). But after cyclone (1999) the system was left with only 39 coconut trees, 490 areca nut plants, 10 mango trees and only 3 numbers of teak trees. As a result of cyclone the farmer not only suffered loss due to damage to tree but also majority of fish population died due to pollution of pond water.

The detail year wise input and returns from the pond as well as bund system (Integrated farming system) is given in Table 4. The system suffered loss only in the year 1999 to the tune of Rs 1,16,900 due to devastating super cyclone. Further the cyclone impact affected the net return in the subsequent year 2000 in which the net return was only Rs. 67,840.The net return was Rs. 1,00,170 in the first year operation of the system, which has enhanced to the maximum of Rs. 3,62,515 in the year 2002. The comparative net return from the IFS and rice cultivation in rupees per hectare per year is presented in the Figure 11.

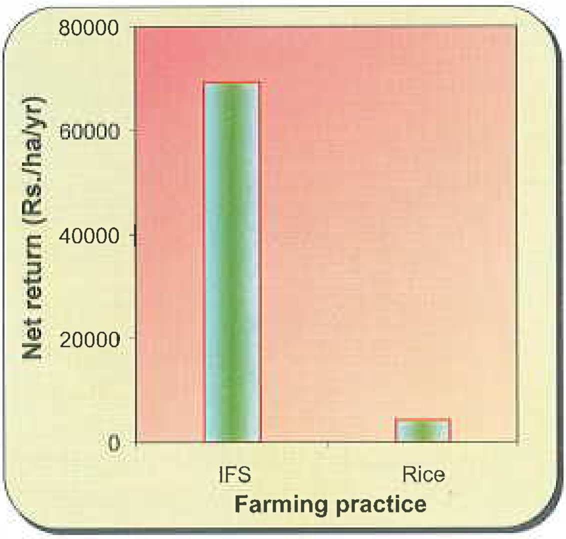


Fig. 11. Comparative net return from IFS and rice cultivation

Table 4. Details of year-wise expenditure and return of the integrated farming system (1.64 ha pond + 0.83 ha bund).

Year	*A: Input cost (Rs)*							*B: Gross return (Rs)*					*Net*	*Net*
	Pond construction & infra-structure	Horti-culture/ vegatable seed, fertilizer etc***	Fish and prawn seed	Fish feed	Labour	Miscellaneous. *	Total in rupees	Fruits & Vega-table	Fish & prawn	Coco-nut	Poul-try **	Total in rupees	*return in rupees (B-A)*	*return in Rs/ha*
1988	1,23,910 (excavation)	-	-	-	-	20,000	143910	-	-	-	-	-	-	
1989	-	12600	12000	28730	14000	13000	80330	110400	70100	-	-	180500	100170	40,554
1990	-	12000	14700	29750	14000	13500	83950	114000	88000	-	-	202000	118050	47,793
1991	-	12000	16400	31200	14000	14800	88400	98600	96750	-	-	195350	106050	42,935
1992	-	10400	18000	36900	17500	14500	97300	44000	172800	30000	-	246800	149500	60,526
1993	-	8700	23000	42850	17500	16000	108050	42800	199000	45000	-	286800	178750	72,368
1994	-	8900	28300	48700	17500	19000	122400	46000	269200	48500	-	363700	241300	97,692
1995	-	7500	30100	54225	21000	30500	143325	52100	329700	59000	-	440800	297475	1,20435
1996	-	3200	33200	64650	21000	28600	150650	47200	345000	76900	-	469100	318450	1,28,927
1997	-	2850	35500	81000	24500	29000	172850	35450	372400	93250	-	501100	328250	1,32,894
1998	130000 (stone lining)	2900	48900	86800	28000	23000	319600	48300	383900	105000	-	537200	217600	88,097
1999	320000 (poultry shed)	3000	53100	69500	28000	380000	753600	14000	218200	80500	324000	636700	(-) 116900	(-) 47,327
2000	-	2660	42200	92000	17500	31000	185360	1300	249500	2400	-	253200	67840	27,465
2001	-	2550	58700	106000	17500	34550	219300	12900	541000	6000	-	559900	340600	1,37,894
2002	-	2500	69615	156400	17500	42580	288595	23000	617160	10950	-	651110	362515	1,46,767
Grand Total on 15 year basis							29,57,620					55,24,260	25,66,640	10,39,125

* Miscellaneous includes lime, cow dung, pumping, irrigation system, masonry work etc.

** Poultry was added in the year 1999

*** Horticulture including banana, papaya, pineapple, mango, areca nut etc.

Average net return per ha per year on 15 year basis from IFS = Rs. 69,275

3.4. Irrigation System

The farm has two bore wells of 10 cm diameter each. Depth of each bore well is 33.5 meter. One is fitted with a 3.5 hp electric motor pump and the other is fitted with a 5 hp diesel pump. Though the well spacing is not designed properly yet it gives adequate water to feed the integrated farming system. The total discharge to the pond from tube well is 18 liters per second. For irrigation purpose the pump runs for 300 hours. Total volume of water put to pond is 300 x 18 x 60 x60 =1,94,40,000 liters = 19,449 m^3. The pond is having one outlet and from the outlet earthen field channel is laid out to cropped land of sugarcane, paddy and vegetables. The farmer does not irrigate the crops through tube well directly. The tube wells fed water into the pond, which helps in water exchange and the extra water above the out let pass through the field channel to irrigate the sugarcane and vegetable field.

3.4.1. Water marketing

At present water market is not there. People do not pay for the surplus water from the pond being drained out through field channel. During winter season when all the pond water get drained, it is not useful at that time to the neighbouring farmers as water is already available in their plot during November, since the plots are located in waterlogged situation. It is envisaged to study full use of these tube wells for growing fruits/vegetables on raised beds, low duty crops after harvest of water logged paddy and selling water to nearby farmers for raising low duty post monsoon crops.

3.5. System's Water Productivity and Rice Equivalent Yield

The water productivity of the system was estimated as the ratio of pond output in terms of rupees to the volume of pond water for the year 2002. The total volume of water available in the pond assuming average depth of 1.5 m is 24,570 m^3. Annual water exchange is about 19449 m^3. The total returns from the pond system alone was Rs.6,17,160 in the year 2002. This corresponds to a water productivity of Rs. 14.02 per m^3.

The average rice yield of low land high yielding variety paddy was 3.5 t ha^{-1} (= Rs. 17,500 per hectare), while average fish and prawn production from 1 ha pond area was 8.1 t ha^{-1} (fish equivalent of 9.42 t ha^{-1}). Hence the rice equivalent yield of the pond system was found about 75 t ha^{-1} during the year 2002. The gross and net water productivity of different cropping system were estimated for the area as presented in Figure 12. The integrated farming system gave highest water productivity followed by vegetable and irrigated paddy.

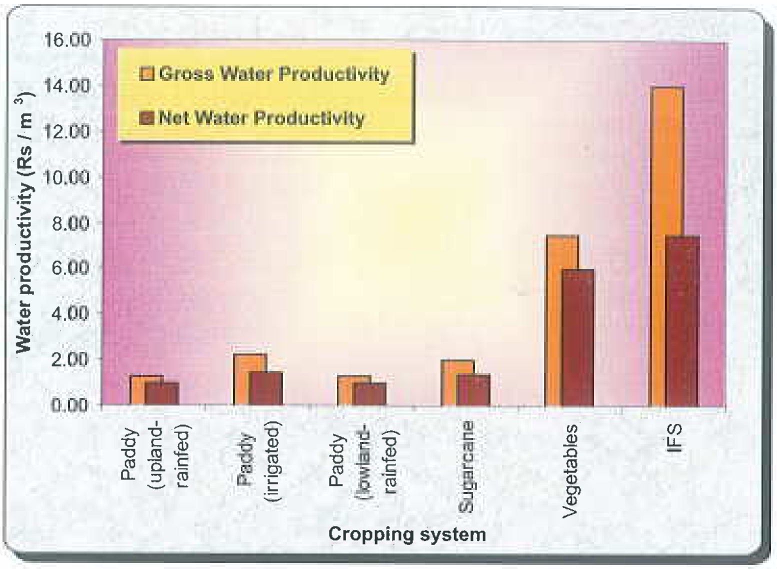


Fig. 12. Comparison of gross and net water productivity of different cropping system

4.0. Income Other than IFS

Beside the IFS the farmer has 3.6 ha of land out of which 2.4 ha is being cultivated for paddy crop under waterlogged situation. The depth of water varies from 30 cm in July to 1.2 m in September. Rest 1.2 ha land is utilized for sugarcane crop. The average earning from the rest of the system other than IFS is Rs. 30,000. From sugarcane total earning is Rs. 20,000 (Rs. 16,666 per ha) and from paddy it is Rs. 10,000 (Rs. 4,166 per ha) per annum.

5.0. System's Further Modification

The introduction of rice-fish integration system as a part of further modification was recommended by the expert team (Figure 13) to improve the economic output of the existing system and optimum utilization of the adjacent waterlogged area. WTCER, Bhubaneswar, has recently started further intervention in form of deep-water high-density rice-fish integration system by developing 1.2 ha of the adjacent waterlogged field (Figure 14). Under this system, WTCER's

Fig. 13. Visit of Dr. J.S. Sarma, DDG (NRM), ICAR along with director and scientists of WTCER to the project site.

Fig. 14. Interaction with farmer at the excavated site of deep water rice-fish integration system.

already proven technology of rice-fish integration will be carried out, where high density rearing of fry to fingerling stage of IMCs @ 1.0 lakh ha^{-1} will be continued for 3-3½ months. After that, 75% of the stock will be harvested and sold as fingerlings (Rs. 2.00 per fingerling) to the nearby farmers and rest will be allowed to grow further upto 6-7th month even after the harvest of rice in the specially designed refuge. Under this system the expected net return would be around Rs. 1.5-1.6 lakh per ha per year including 0.3 lakh by cultivating low duty crops such as green gram and black gram after harvest of rice and fish. These new interventions would also increase the area of this existing system by nearly two folds. Revival of poultry component and introduction of milch cattle is being argued with the farmer.

5.1. The Principles of Integrated Rice-fish Farming Technology

Principles pertaining to various aspects of the culture technology and fish production in integrated rice-fish farming are:

- Paddy fields are complex ecosystems than the conventional separate aquaculture system, in which rice is the dominant population under human control. There are many primary producers and consumers at different levels in the paddy field culture, most of which cannot be utilized by humans. These producers and consumers compete with rice by consuming materials and energy.
- In the biotic part, rice is autotroph while fish are heterotrophs. One has to know what their feeds are and how many trophic levels are involved in feeding fish. Fish production in integrated deep-water rice-fish systems is more complex requiring more knowledge and better management inputs.
- As higher density and adverse hydro-biological conditions may often lead to severe consequences resulting in poor growth and survival, an understanding of the complex interactions continuously taking place between the ecosystem and stocked organism is essential to enhance the survival and yield.
- Integrated deep water rice-fish farming systems may vary in the degree of intensification from extensive, semi-intensive to intensive sub-systems. Extensive sub-systems utilize natural feed produced without external fertilization; semi-

intensive subsystems require fertilization to produce natural food with or without supplementary feed but with a significant component of diet supplied by natural feed; and in intensive subsystems, all the nutritional requirements are provided by artificial feed given to fishes with natural feed contributing little or no nutrition.

- The strategy for rice cultivation under rice-fish system, is low planting density (10-20%, lower than the density used in regular fields), less fertilizer, a small population and strong individuals. Improved ecological conditions (ventilation and illumination) prevent lodging and help produce heavier grains and high and stable yields.
- Fish in an integrated deep-water rice-fish farming system utilize the pelagic algal-based food web, which develops in the pond due to the fertilization by organic manures.
- In a manure-fed deep-water rice-fish farming system, fish nutrition may also be derived from direct consumption of the manure. However, a detritus food web has a secondary role in fish biomass production as compared with the algal-based food web.
- Over-fertilization with manure may lead to poor water quality of fish refuge, particularly leading to depletion of dissolved oxygen and fish mortality.
- Management of water quality is needed to overcome fish mortality due to oxygen depletion and extreme fluctuation of dissolved oxygen levels. The strategy is to promote a growing biomass of phytoplankton, which will generate sufficient oxygen to maintain relatively high dissolved oxygen, and it is essential to maintain a positive net photosynthesis.
- The criteria for selection of fish species for stocking into manure-fed deep water rice-fish farming system should be based on the ability of fish species to filter and feed on plankton (bacteria, phytoplankton and zooplankton) and to tolerate low levels of dissolved oxygen.
- An optimal stocking density of fish/ prawn species is critical in attaining high cumulative fish yields and in reaching the upper carrying capacity of the system.
- Ways to intensify fish production from integrated rice-fish farming system involve management strategies like high-density stocking (stocking with a higher initial fish biomass) followed by phased/ selective harvesting, when the growth curve of stocked fish/ prawn starts to slow down.
- Integrated rice-fish farming not only enhance productivity, but also generate employment opportunity, increase income and provide nutritional security to resource poor farming community but also distribute the risk (both biological and

economical), since two subsystems are involved instead of a single-commodity farming system.

5.1.1. Species suitability

Fish species should be adaptable, compatible, resistant to environmental changes, high-yielding and be able to tolerate heavy doses of fertilizer. Since the water column in the refuge, perimeter canal and the paddy field in the renovated system is suitable for rearing of carps, three Indian major carps, i.e., *Catla catla, Labeo rohita and Cirrhinus mrigala,* prawn (*Macrobrachium rosenbergii* and *M. malcolmsonii*) and exotic carps like silver carp and common carp may be stocked for culture in the integrated system. Improved high-yielding, tall, long-duration, submergence and pest resistant variety of rice with in-built characteristics of photoperiod-sensitivity, strong seedling vigor such as *Durga, Gayatri, Tulasi,* (for Orissa), *Sabita* (for Assam and West Bengal), *Sudha* (for Bihar) and *Jalapriya* (for eastern UP) can be tried.

5.1.2. Rice cultivation

Sowing can be carried out in dry condition, well before monsoon, using 80-100 kg seed per ha, with a spacing of 20 cm between rows. Transplanting, if required can be done early by using aged and healthy seedlings. Fertilizer @ 40:20:20 kg N:P:K per ha at seeding should be applied (apply 50% N at seeding and rest 50% after weeding). FYM @ 5 t ha^{-1} at the time of land preparation is also essential. Avoid insecticide and herbicides and use of bio-agents and sex pheromone trap to monitor and control yellow stem borer, neem extract based composition such as Nethrin or Nimbecidine @ 1% for control of stem borer. To ensure better productivity, higher planting density must be avoided to provide greater ventilation and illumination, that helps in enhancing both plant and plankton growth which ultimately helps fish growth and yield. In fact, the yield of rice for a specific variety correlates positively with planting density.

5.1.3. Application of fertilizer and chemicals

The growth and development of paddy and the fish is greatly influenced by the kind and quantity of fertilizers applied and the method of application. Nitrogen, phosphorous and potassium needed by the paddy are also nutrients required by the planktonic and benthic organisms, which are in turn, the natural food of fish. But too much inorganic fertilizer is also toxic to fish. The improved technique of fertilization is to use organic manures (Table 5) as much as possible and inorganic fertilizer as little as possible. Organic manure should be applied after its decomposition. Seventy percent of the total manure should be applied as basal and rest as supplementary manure, which should be applied in small amounts frequently.

Table 5. Nutrient composition of different organic manures used for aquaculture.

Manure	*Nutrient composition (%)*			*Manure*	*Nutrient composition (%)*		
	N	P_2O_5	K_2O		N	P_2O_5	K_2O
Animal Origin				**Plant Origin**			
Cattle dung	0.5	0.4	0.2	Groundnut cake	6.5	1.0	1.0
Pig dung	0.6	0.6	0.4	Mustard cake	4.5	1.5	1.6
Poultry dropping	1.7	0.9	0.7	Mahua cake	2.5	0.8	1.9
Duck dropping	0.9	0.5	0.6	Neem cake	5.2	1.1	1.5
Farm Yard Manure	0.6	0.5	0.1				

Although fish in rice fields can eat some of the pests and play a role in the biological control, they can not totally replace insecticides, so chemical control is needed. However, chemical plant protection should be avoided to prevent fish/ prawn mortality. In fact, in waterlogged situation, insecticide hardly works, as high standing water dilutes the concentration. But in emergency, chemicals that have low toxicity, low residue, high effectiveness and a broad spectrum can be applied. Chemicals in powder form should be applied in the early morning hours, while there is still dew around, and application of sprays should be delayed until after the due fades. Nowadays, the splashing method is adopted with good results especially when the rice grows tall. It is always economical and advisable to reduce the water level before application of fertilizer and chemicals.

5.1.4. Fish culture

After proper refuge preparation, liming @ 500-750 kg ha^{-1}, manuring with raw cattle dung @ 7000 kg ha^{-1} as basal dose should be carried out at the onset of monsoon during June. Before fish fry are released in the rice field refuge, it is essential to clear it from aquatic vegetation and predatory fishes. The floating and emergent weeds may be removed manually instead of using chemical/ weedicide. It is better to use MOC (*mahua* oil cake) @ 250 ppm at the onset of monsoon during June when rainwater starts accumulating in the perimeter canal. MOC not only helps in eradicating predatory/ unwanted species such as catfish *sp., Channa punctatus, C. Orientalis, Glossogobius giuris, Puntius ticto, Esomus danricus, Ambasis* spp. and *Barilius* spp., but also acts as a manuring substance. During the month of July-August, when the rainwater starts accumulating in the refuge and paddy field, advanced fry/ early fingerlings of *Catla, Rohu, Mrigal, Silver carp, Common carp* and prawn juveniles may be stocked with a composition of 30:25:45 (surface feeder: column feeder: bottom feeder). *Labeo bata* can also form a stocking component in this system. As the culture duration is short, fingerlings (10-15 g size) should be stocked at a higher density of 15,000 to 20,000 per ha for continuous rearing for a duration of 4-5 months or early fingerlings (2-3 g size) at a higher density of 75,000 to 1,00,000 per ha for advanced fingerling production, based on the principle of phased/ selective harvesting.

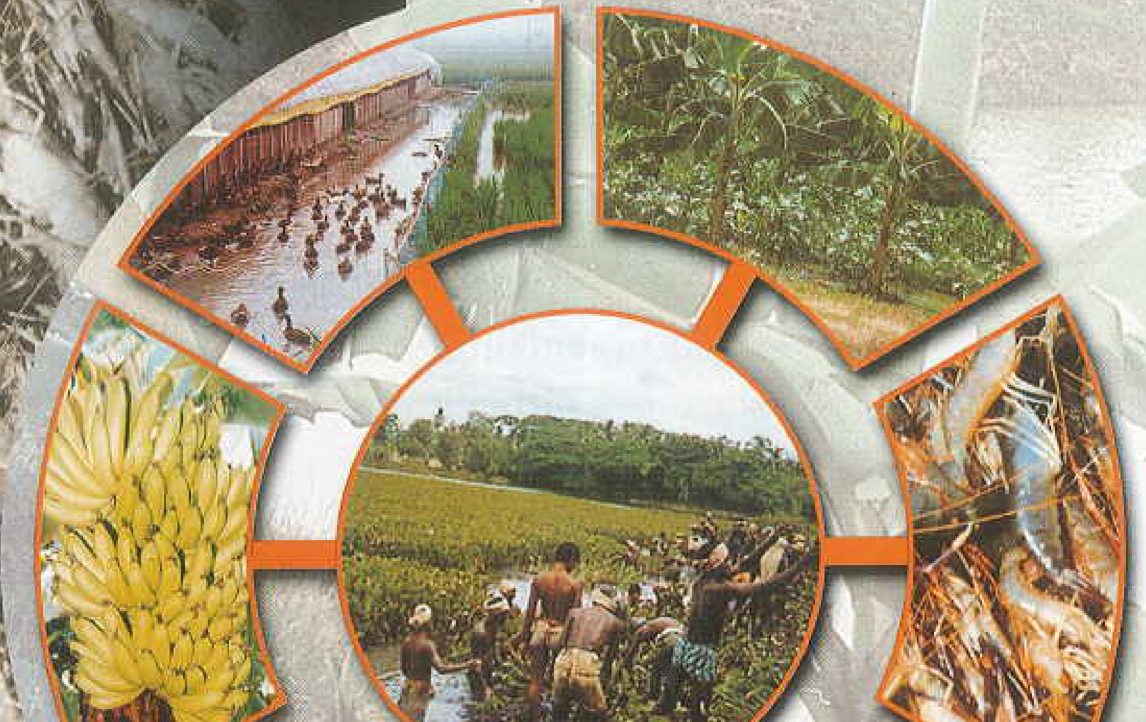
5.1.5. On-dyke horticulture

The dykes to be constructed for preventing escape of fish from the integrated system may be used for growing vegetables and other fruit trees like papaya and banana to make the system more economically viable. Vegetables such as gourd, radish, brinjal, leafy vegetables during pre and *kharif* season and vegetables such as tomato, french beans, radish, bitter gourd, cucumber, cauliflower, cabbage, brinjal, pumpkin and leafy vegetables (coriander, amaranthus and Indian spinach) can be grown during winter. Vegetables such as snakegourd, bittergourd, ridgegourd, bottlegourd or ashgourd can be grown throughout the year on raised platforms.

6.0. Impact of the System

Recently, two such systems have been developed in that locality by two other farmers seeing the success of Mr. Radhakanta Sahoo. The farmer has advised his eldest son, a law graduate to devote most of his time in this farming system rather than practising in the court. In farmer's version his son will earn many times more than that of his law practice. The farmer is however skeptical about the proliferation of the technology as he believes if more number of farmers will go for pisciculture, the price of the products will go down in that area. However farmer's view is not justified because of the growing demand of fish in the domestic market. More over, proper cold-chain marketing facility should be developed in the rural interior areas for smooth running of aquaculture business.

Despite the devastating effect of super cyclone in 1999 the project, without any compensatory financial assistance from other sources, remained viable as evident from Table 4. Though there was a huge loss in the same year, but considering the net profit from other years, the project is still viable and highly remunerative. This has not only enhanced the social and financial status of the farmer but also maintained the sustainability of the system, gradually over a period of time. It thus has served as an example of a successful agricultural enterprise though integrated farming system approach with right kind of scientific approach driven by market demand. In post world trade organization (WTO) scenario in agriculture where production by masses (about 70% of Indians are farmers) has to compete with mass production technologies of developed world. Such IFS approach in small units may provide answer to enterprising farmers in competitive agri-business environment in future.



Diversified integrated farming system