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त्रिलोचन महापात्र, पीएच.डी.
सचिव, एवं महानिदेशक
TRILOCHAN MOHAPATRA, Ph.D.
SECRETARY & DIRECTOR GENERAL

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FOREWORD

Declining land holding, reduced income, threatened nutrition and security, endangered biodiversity and emerging problems of climate change are posing serious challenges to the sustainability and livelihood of large number of marginal and small farmers of India. Shifting from mono-cropping to integrated farming system (IFS) is one of the successful options to address these challenges, especially in the fragile rice ecologies and small farms of eastern India.

ICAR-National Rice Research Institute, Cuttack has taken up the pioneering research on rice-based integrated farming system since late 1980s, in rainfed low land ecology, which occupies 42% of the total area of the country and 82% of rice area in eastern India. The Institute has developed the concept, design and production technology of rice-fish diversified farming system for improvement of farm productivity, income and employment in rainfed lowlands. The technology has been successfully adopted by farmers of Odisha, West Bengal, Eastern Uttar Pradesh and Assam.

This publication on "Rice-Fish Integrated Farming System for Eastern India" presents the various models suitable for different situations under lowland ecology and their potentials, prospects and problems. Interaction studies related to productivity of rice, fish and other components; climate change mitigation potentials of various models; options for recycling of residues; opportunities for reducing the cost of production and enhancing farmers income are also discussed in the bulletin. I hope that the bulletin will serve as a useful reference for the farmers, students, researchers, extension workers and other stakeholders involved in rice-based integrated farming system as an entrepreneurship for increased farm income and employment generation.

(T. MOHAPATRA)

Dated the 15th March, 2019
New Delhi

Executive Summary

Rainfed lowlands in eastern India are highly diverse, complex and fragile in nature with abundance of natural resources. The region experiences several abiotic stresses such as drought, submergence, waterlogging, flash floods, cyclonic disturbances and salinity affecting crop productivity, income and livelihood of farmers. Rice growing farmers in this region mostly has small-holdings and grow rice with low inputs. The lowland and water-logged areas dry up after the rainy season resulting in non-availability of water for growing rabi season crop.

Integrated farming system (IFS) provides an opportunity to increase the economic yield per unit area per unit of time by virtue of intensification and integration of crop and allied enterprises. Though traditionally, farmers have been practicing IFS in their homestead land but is not foolproof in combating climatic vagaries and is mostly non-interactive. The available resources in these areas are not utilized efficiently to reduce the risk related to land sustainability *vis-a–vis* employment problem. Main reason for under utilization of resources is lack of proper understanding of interaction and linkages between the components which help in reducing input cost, increase total productivity, reduce environmental risk and generate employment. Efforts to diversify the rice crop to other compatible allied enterprises accompanied by improved management would enhance land productivity and income; ensure additional employment as well as resource cycling with reduced inputs.

ICAR- National Rice Research Institute, Cuttack has developed three adoptable models: 1) Rice-fish diversified farming system for semi-deep areas (upto 50 cm water depth), 2) Multi-tier rice-fish horticulture crop based farming system for deep water (upto 1 m or more water depth) and 3) Rice-based integrated farming system for irrigated lowlands. These rice-based farming systems models have been validated and upscaled in farmers fields through farmers participatory mode (FPM). These systems with higher land and water productivity ensure food, nutrition and livelihood security for the farming communities, particularly for the small and marginal farmers along with employment generation through engagement of family members in the farming.

Interactions among the rice and non-rice enterprises for increased productivity, bio resource flow, resource recycling and environmental impact

has been assessed. Fish productivity was more when integrated with rice rather than sole fish in the tank. It was further increased with wider spacing of rice over closed spacing or random planting. Continuous addition of fish excreta in the rice fish system increased the organic carbon content of soil. Emission of methane (CH_4) increased with fish in rice field but nitrous oxide (N_2O) emission was relatively low during the entire cropping period except towards maturity when the water recedes leaving the field dry. Fish acts as effective bio-control agent for major rice pests like hoppers, case worm, stem borer, gall midge, leaf folder and snails. Insecticides (phosphamidon, monocrotophos, quinalphos, ethofenprox, carbofuran) though did not kill the reared fishes (common carp, catla, mrigal) instantly, but showed varying degree of deleterious effects on growth, survival and yield. Efficient species of fish are *Ctenopharyngodon idella*, *Puntius gonionotus, Oreochromis mossambicus, Trichogaster pectorals* and *Cyprinus carpio* for controlling weeds directly by feeding or indirectly increasing water turbidity and/or causing mechanical injury under constant flooding.

Sunflower is one of the most promising crops after rice with 2-3 limited irrigations utilizing the water stored in pond. Watermelon was another promising crop in this system when sown during mid January in pits with spot irrigation. Eastern India is having potential to harvest rainwater during peak monsoon period (July-September) that stored in the pond refuge can help to grow several winter vegetables like pumpkin, bitter gourd, lady's finger and chilli either on bunds or in main rice field. Other crops viz., pulses like black gram and green gram or oilseeds viz., sunflower, groundnut and sesamum can be grown during the dry season (January – early April) with limited irrigation by stored water.

Rice-based IFS has immense potentiality in eastern India to emerge out as an effective tool for improvement of rural economy due to low investment and high profitability. However, there is a strong need to monitor the entire rice-based production system in terms of suitability of crop varieties, nutrient dynamics, water table and quality of irrigation water, insect, disease and weed problems, as well as economic feasibility and environmental sustainability to evolve site-specific IFS model. Large scale adoption of IFS model by the farming community depends mostly on socio-economic factors such as labour availability, credit requirement, cost of inputs, processing, marketability and price of produce, risk involved and social acceptability of the new system. Thus while designing a farming system model, the technical, environmental and economic feasibilities should be considered for its successful implementation.

Introduction

Rice, the leading cereal crop, is grown in 114 countries across the world on 160 million hectares (Mha), constituting nearly 11% of the world's cultivated land (Pathak et al., 2018). India is the largest rice producing country in the world and the crop contributes over 40% to the annual food grain production of the country and is grown in varied ecologies from irrigated to upland, rainfed lowland, deep water and tidal wet land ecologies covering more than 43.0 Mha from Kashmir in North to Kanyakumari in South and Gujarat in West to Arunachal Pradesh in East. The cultivation of almost 90% of the world's rice crops in irrigated, rainfed and deep-water systems equivalent to about 134 Mha offers a suitable environment for fish and other aquatic organisms. The integrations of rice and fish farming – either on the same plot, or adjacent plots where by-products of one system are used as inputs for the other, or consecutively – are all variations of production systems that aim to increase the productivity of water, land and associated resources while contributing to increased fish production.

Asia accounted for about 90% of 672 million tons (Mt) of rice produced in the world (FAO, 2012b). Rice farming in Asia used to be characterized by small scale, labour-intensiveness and on-site recycling of green and animal manures. Although rice farming is still labour-intensive in remote areas of Asian developing countries, it has rapidly been mechanized and agrochemicals-intensive. In response to commercialization of agriculture, it is important to shift from routine food grain production system to newer crops; cropping/farming systems to meet the increasing demand of pulses, oilseeds, fodder, vegetables and other commercial crops along with livestock and fishes depending upon the climatic conditions as well as agro-ecosystems and make agriculture an attractive, profitable and sustainable business.

Furuno (2001) formulated the idea of systematically integrating rice with ducks, based on the notion that two products highly complementary to each other can be jointly produced. In the integrated rice–duck farming (IRDF) system, rice paddies provide food (weeds and pests) for ducks, and ducks play a role in fertilizing rice plants. Integrated farming systems (IFS) have traditionally been undertaken by farmers in countries like Indonesia, China, Malaysia, Vietnam, Rwanda and Thailand. However, in many countries these traditional systems have been replaced by the establishment of commercial cash and staple crop production systems that have been promoted by Governments (Ruaysoongnern and Suphanchaimart, 2001). The systems are important in these countries because they provide household food security, reduce the impact of agriculture on the environment, and may be less affected than conventional systems by climate change. Integrated rice-fish production can optimize resource utilization through the complementary use of land and water. This practice also improves diversification, intensification, productivity, profitability, and sustainability of the rice agro-ecosystem.

Since majority of farmers in eastern India are resource poor and have marginal and small economic holdings, it is very difficult to enhance the farm family income unless crop based agriculture is supplemented by some other farm enterprises like livestock production, bee keeping, poultry, fisheries, horticulture, etc. Being inter and multidisciplinary approach, farming system would be highly effective in providing balanced food, regular employment, sustaining soil health, mitigating aberrant weather situation, increased the farm productivity and farm family income, which ultimately increased the purchasing power of the farmer. In this bulletin, important enterprises under integrated farming system and their management under different rice environments have been discussed based on the research works carried out at NRRI source as well as on-farm trials in eastern India.

Importance of IFS in Indian Agriculture

The IFS is a reliable way of obtaining high productivity with substantial nutrient economy in combination with maximum compatibility and replenishment of organic matter by way of effective recycling of organic residues/ wastes etc. obtained through integration of various land based enterprises (Gill et al., 2010, Sanjeev et al., 2011) An experiment on paddy cum fish culture was started in West Bengal in 1945 in an area of 280 hectares adjoining the paddy fields and it was remarkably noted that the growth of tank fishes was slower than those liberated in the paddy fields. The then rice committee of FAO in 1948 strongly advocated the practice of fish culture in the rice field for increased production of rice. The farmers of the Northeastern part of India seven states viz. Assam, Arunachal Pradesh, Nagaland, Meghalaya, Mizoram, Manipur and Tripura cultivate rice as their staple food and a fish crop is traditionally raised only from the paddies of rainfed lowlands (both shallow and deepwater). Traditional rice-fish production systems have an important socio-economic part in the life of the farmers and fishers in the region. Shamim Al Mamun *et al.* (2011) reported that integration of fish with the livestock and crop has helped to improve the fertilizer and feed supplies, plus the high market value of fish as feed and/or food increasing the incomes substantially. Integration of various agricultural enterprises *viz*., cropping, animal husbandry, fishery, forestry etc. not only supplement the income of the farmers but also help in increasing the family labor employment throughout the year(Jayanthi, 2002).

Income from rainfed rice crop and other seasonal field crops on small and marginal farms is hardly sufficient to sustain their family. Integrated farming system (IFS) has been advocated as one of the tool for harmonious use of inputs and their compounded response to make the agriculture in the region profitable and sustainable. The IFS aims at an appropriate combination of farm enterprises like field crops, diary, piggery, poultry, apiculture, goatery, mushroom cultivation etc. for a productive, profitable and sustainable agriculture. IFS interact appropriately with the environment without dislocating the ecological and socio-economic balance on one hand and attempt to meet the farmers need on the other.

Rice-fish diversified farming system developed by ICAR-National Rice Research Institute, Cuttack can be adopted both in rainfed waterlogged, deepwater and irrigated conditions for increasing farm productivity, income, employment, sustainability and household food and nutritional security. This system integrates components such as improved rice varieties, fish, prawn, *azolla*, poultry, goatery and different crops after rice in the field and vegetables, fruit crops, agro-forestry and other components on bunds.

Models of IFS developed at NRRI

Eastern India, in particular with about 5.6 Mha irrigated area and 14.0 Mha rainfed lowlands of the total 26.58 Mha rice area, offers high potential for rice-based diversified integrated farming system, especially in view of the resources, food habits and socio-economic needs of the people. These systems with higher water and land productivity and employment opportunities can ensure food, nutrition and livelihood security for the farming communities, particularly for the largest groups of small and marginal farmers along with employment generation through engagement of family members in the farming. These systems can be mixed or concurrent, sequential or rotational. However, the techniques differ based on the physical, biological and socio-economic profiles of the target agro-ecosystem.

Model I : Rice–fish–livestock-horticulture-based farming system for rainfed lowland areas

In order to improve and stabilize farm productivity and income from rainfed water logged lowland areas, the Institute has developed an adoptable technology of 'Rice-fish diversified farming system'. Farm size may vary from minimum of about one acre to one hectare or more. Field design includes wide bunds (dykes) all around, a pond refuge connected with trenches on two sides (water harvesting come fish refuge system) and guarded outlet. The approximate area allotments will be, 20% for bunds, 13% for pond refuge and trenches and rest 67% for main field. The pond refuge measures 10 m wide and 1.75m deep constructed in the lower end of the field. The two side trenches of 3 m width and average 1 m depth have gentle(0.5%) bed slope towards the towards the pond refuge. Small low cost (Thatched/asbestos top) duck house and poultry unit are constructed on bunds with a floor space of about 1.5 sq.ft. for each duck and 1 sq.ft. for each poultry bird. Poultry unit maybe projected upto 50% over the water in the pond refuge to utilize the dropping as fish food and manure in the system. In such case birds can be housed in cage of made of wire net. A small goat house is made on the bund with floor space of about 2 sq.ft for each animal.

Rice –Fish–Livestock-Horticulture based farming system for rainfed lowland areas

Design and Layout

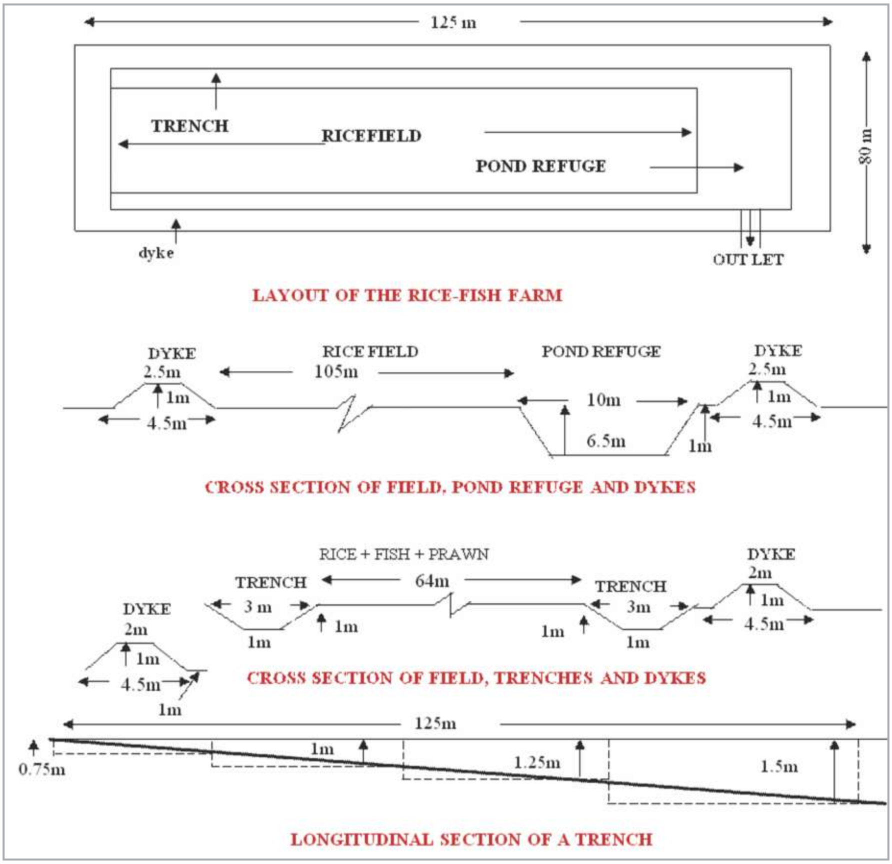


Fig 1. Layout of Rice –fish –Livestock- Horticulture based farming system for rainfed lowland areas

Production Technology: Production Technology broadly involves growing of improved photo-period sensitive semi tall and tall wet season rice varieties tolerant to major insect-pests and diseases. The suitable rice varieties are Gayatri, Sarala, CR Dhan 500, CR Dhan 505, Jalmani, Varshadhan, etc. for Odisha; Sabita, Jogen, Hanseswari, Varshadhanetc. for West Bengal; Sudha for Bihar;Madhukar and Jalpriya for eastern Uttar Pradesh and Ranjit, Mashuri and Sabita for Assam. Management of insect-pests in rice crop is done with the use of sex pheromen traps, light traps and botanicals (Netherin/ Nimbicidin spray at 1%).

Indian major carps i.e., Catla [*Catla catla*(Ham.)]; Rohu [*Labeo rohita*(Ham.)]; Mrigal [*Cirrhinus mrigala*(Ham.)]; exotic carps, common carp [*Cyprinus carpio*(L.)];silver carp [*Ctenopharyn godonidella*(Val.)];silver barb [*Puntius gonionotus*(Bleeker)] and fresh water giant prawn [*Macrobrachium rosenbergii*]fingerlings of 3-4" size and prawn juveniles of 2-3" size are released in a ratio of 75% and 25%, respectively at 10,000 per hectare of water area after sufficient water accumulation in the refuge and in the field. Fish and prawn are regularly fed at 2% of total biomass with mixture containing 95% of oil cake +rice bran (1:1) and 5% of fish meal. After rice, various crops like watermelon, green gram, sunflower, groundnut, sesame and vegetables are grown in the field with limited irrigations from the harvested rainwater. On bunds different seasonal vegetables are cultivated round the year including creepers on the raised platform, spices and pineapples are grown in shades. The fruit crops on bunds include varieties of dwarf papaya, banana T x D coconut and arecanut. Flowers like tuberose, marigold, etc. are also cultivated on the bunds. Both straw and oyster mushroom cultivation are done in the thatched or polythene enclose. Bee rearing is practice in 2-3 bee boxes on bunds. Agro-forestry component on the bund include short term plantation of mainly *Accacia* spp. (*A. mangium, A. auriculiformes).* Animal component constitutes improved breeds of duck, poultry birds and goats. Ducks are allowed in the rice field upto the beginning of flowering stage and later in an enclosure in pond refuge till the harvest of rice crop. Live *Azolla* is released at 0.5 -1.0 tha^{-1} and is maintained to supplement duck feed and also to some extent fish feed, besides nutrition to the rice crop. Fresh water pearl culture is integrated in the system using the host mussel (*Lamellidens marginalis*),which is normally available in the lowland rice ecology. Components can however, be included in the system based on location –specific requirements.

***Productivity and economics*:** The rice fish farming system can annually produce around 16 to 18 t of food crops, 0.6t of fish and prawn, 0.55 t of meat, 8000-12,000 eggs besides flowers, fuel wood and animal feed as rice straw and other crop residues from one hectare of farm. The net income in the system is about Rs. 76,000 in the first year. Subsequently, this increases to around 1,30,000 in the sixth year. This system thus increases farm productivity by about fifteen times and net income by 20 folds over the traditional rice farming in rainfed lowlands (Table 1). It also generates additional farm employment of around 250 – 300 man-days/hectare/year.

Table 1. Cost of raising rice-fish-horticultural model in 1 ha area at NRRI

Sl. No	Particular	Amount (Rs.)
1	Construction of pond refuge and trenches and dykes (2000 m^3x 35)	70,000
2	Constriction of platforms 16 No. @ 200/-	3200
3	Pit digging, planting of fruit and silvicultural plants (125-130 No.)	4000
4	Cost of seeds/seedlings/saplings	8,000
5	Cost of FYM/vermi-compost	5000
6	Cost of fingerlings	8000
7	Cost of fish feed	5000
8	Small farm implements/equipments	5000
9	Labour 400 man days @ Rs. 150	60,000
	Total	**1,68,200**

Model II : Multi-tier rice-fish-horticulture-agro-forestry-based farming system for deep water

With the aim of enhancing farm productivity in deep water areas (50-100 cm water depth), a multi-tier rice-fish–prawn horticulture crops-agro-forestry-based farming system model has also been developed in 0.06 hectares area at Institute Farm.

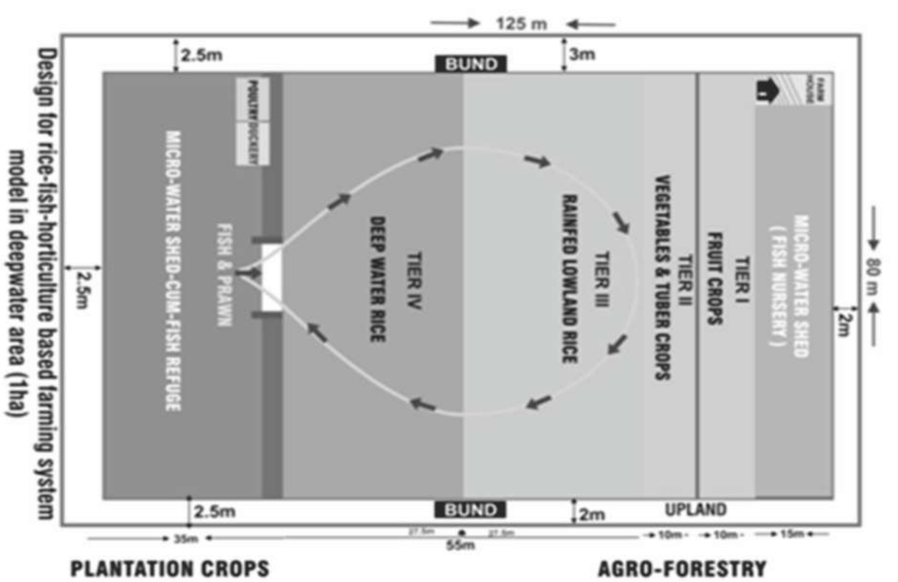


Fig 2. Rice-Fish–Horticulture- based farming system model in deepwater (1 ha area)

Multi-tier rice-fish-prawn-horticulture-agro-forestry based farming system for deep water

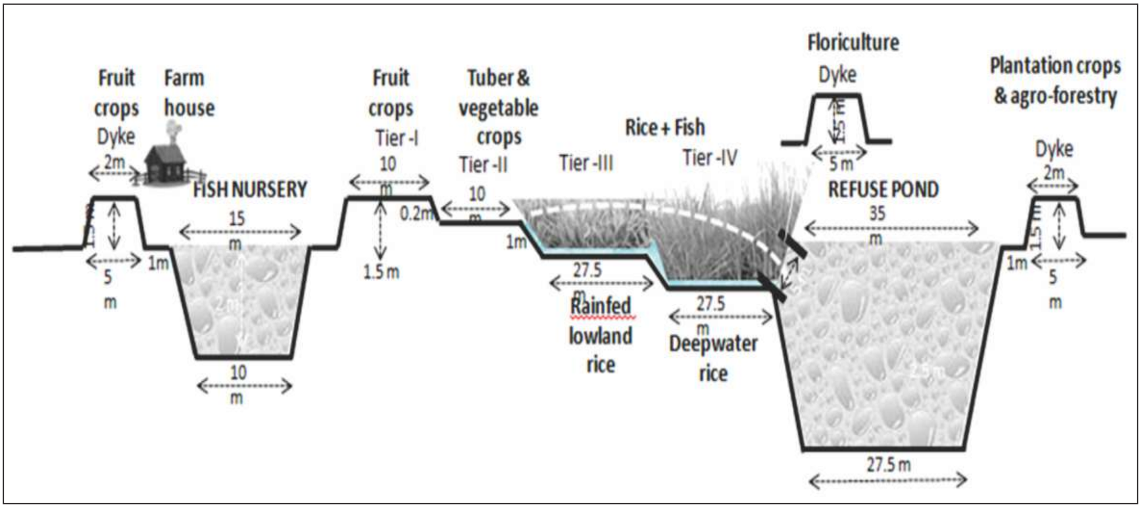


Fig 3. Transverse Section through length of a Deepwater Rice-fish Farm (1 ha area)

Production Methodology **:** The design of the system includes land shaping in the form of uplands(tier I and tier II) covering about 15% of field area followed by rice field area of 40% as *rainfed* lowland (tier III) and deep water (tier IV). This rice field is connected to a micro water shed-cum fish refuge (pond) of 20% area for growing fishes(catla, rohu, mrigal, silver carp, silver barb) and fresh water giant prawn along with the rice crop. Raised and wide bunds are made all around using 25% of the farm area. The production technology includes growing of high yielding varieties of *rainfed* lowland rice (Gayatri, Sarala, Pooja)in tier III and deep water rice (JayantiDhan, CR Dhan 500, CR Dhan 505 CR Dhan 508, Pradhan Dhan and Varshadhan) in tier IV along with the fish and prawn during wet season. Dry season crops like sweet potato, mung, sunflower, groundnut, vegetables are grown after lowland rice in tier III. Dry season rice is cultivated after the deep water rice is harvested in their IV. Harvested rain water in the pond refuge is used for irrigation of the dry season crops. Improved varieties of perennial (mango, guava, sapota) and seasonal fruit crops (papaya, banana, pineapple, etc.) are grown in Tier I. Round the year different seasonal vegetables and tuber crops *viz*., sweet potato, elephant foot yam, yam bean, *colocasia* and greater yam are cultivated in Tier II. Agro-forestry (*Acacia mangium*) and plantation crops (Coconut and areca nut) are planted on the northern side of the bunds. Greater yam is grown with the support of trunk of agro forestry tree. Poultry and duckery components are integrated on bunds of the pond refuge.

Productivity and economics *:* Multi-tier rice-fish-horticulture-based farming system can annually produce about 14-15 t of food crops, 1 t of fish and prawn, 0.5 -0.8 t of meat, 10000-12000 eggs in addition to flowers and 3-5 t of animal feed from 1 hectare farm area. The productivity of food crops further increases to 16-17 t besides, 10-12 t of fiber/fuel wood from eight year onwards due to addition of produce from perennial fruit crops and agro-forestry components. The net income in this system is around Rs. 100000/ha in the first year. This will increase to Rs 1,50,000 or more from the eight year onwards.

Model III : Rice-based farming system under irrigated lowlands

With the objective of improvement of livelihood of small and marginal farmers, rice-based integrated farming system model for irrigated areas has been developed at NRRI, Cuttack.

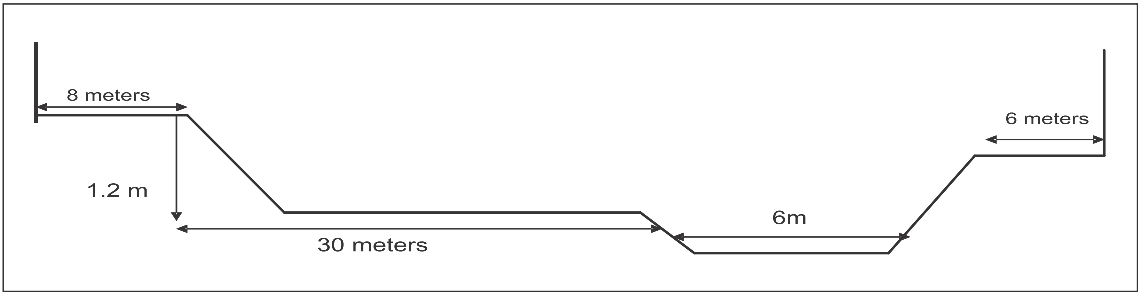


Fig4. Transverse section of the rice based integrated farming system for irrigated area

Rice based integrated farming system model for small and marginal farmers

Production Methodology*:* About an acre of integrated farm area has been reoriented for the farming system of which 30% of the area is converted to two rice-fish fields of 600 sq.m area each with a refuge of 15 % area and another 30 % area is developed into two nursery fish ponds of equal size for fingerlings rearing (Fig.4). The remaining 40% (1500 m^2) area is utilized as bunds for growing vegetables, horticultural crops and agro-forestry. Three rice crops are grown in sequence of *kharif* rice (var.CR Dhan 505/ Varshadhan) followed by *rabi* rice (Naveen/High protein rice) and then summer rice (Vandana/Sidhant). Yellow stem borer is controlled by using pheromone traps or by applying1% Nethrin/Nimbecidine. Fish culture is taken up with catla, rohu and mrigal species. The fish fingerlings are reared in the two nursery ponds and are used for culture with rice crop in the system. The excess fingerlings are sold out. On the bunds agro-forestry plants like teak, *Accacia*, Sisoo, Neem, Aonla and bamboo are planted on the northern andsouthern bunds.

Horticultural crops such as banana, papaya and arecanut are grown on the bunds. Pineapple and spices are cultivated in the shade. Flowers like Marigold, Hibiscus and Jasmine are also cultivated in the western bund in 50m^2 area. Two plants of lemon and each of guava, jackfruit, mango and litchi are also planted on the southern bund near the farm house to meet the household requirement. One poultry and one duckery unit are integrated in the system in which 40 poultry birds are raised during the dry seasons (October to April) and 20 ducks are reared during the wet season (July to December).

Productivity and economics*:* Three crop of rice yields 800 to 1000 kg of grain per year. Entire produce is sufficient to cater the need of the small farm family. The straw is used for the cattle feed, mushroom base and roof of the farm house. Rest of the straw is sold to earn Rs. 500-1000 per year. After two to three months of rearing, fish fry worth of Rs. 4000- 5000 is sold to other farmers. Fish are harvested according to the need after the size becomes 250-300 g after 6 months or 0.5-1.0 kg after a year. The income from fish rearing in the system is Rs. 20,000. Pulses (green gram, blackgram and pigeonpea) taken on the slope and bunds are just enough to meet the protein requirement of the farm family.

Model IV : Rice-fish-horticulture farming system for rainfed lowland rice ecology at *RRLRRS,* Gerua, Assam

Though traditionally rice-fish farming is a common practice in Assam but the productivity of the existing local systems is low due to lack of proper scientific interventions. Rice-fish-horticulture model for rainfed lowland rice ecology developed at NRRI, Cuttack has been modified and validated in the farm of Regional Rainfed Lowland Rice Research Station (NRRI-RRLRRS), Gerua, Assam.

Rice-fish-horticulture farming system for rainfed lowland rice ecology at Gerua, Assam

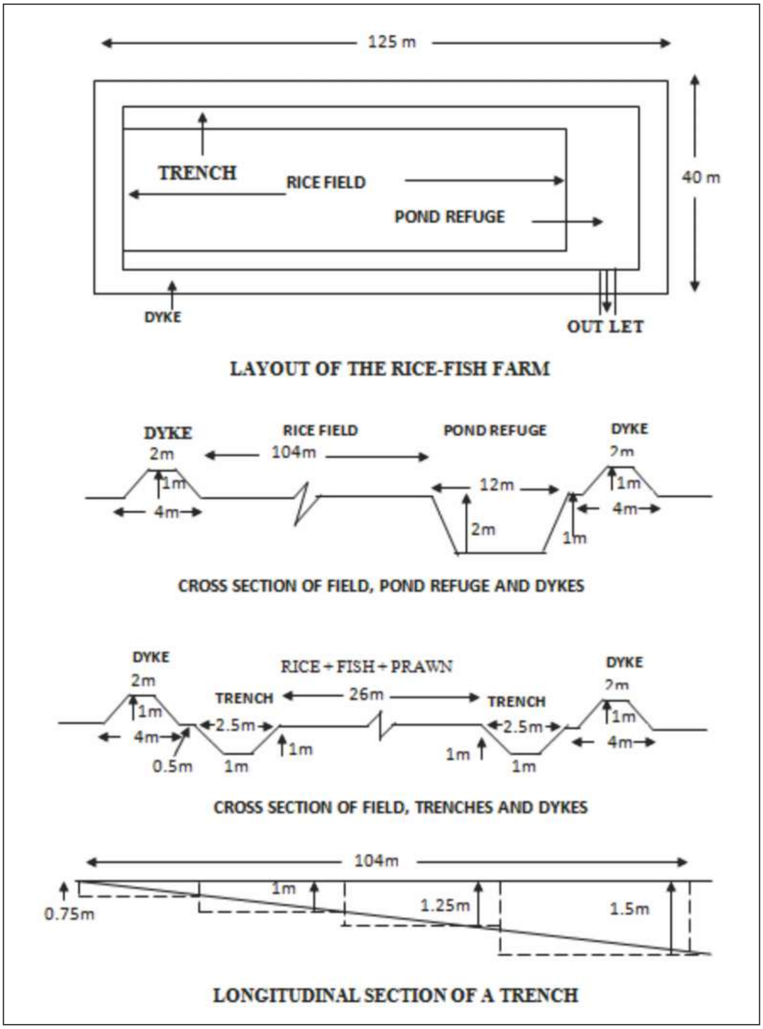


Fig 5. Layout of Rice–Fish–Livestock–Horticulture based farming system for lowland areas at Gerua, Assam

Production Methodology: The field design and components of rice-fish-horticulture model covering 0.5 ha area consists of rice as the major component occupying 60% of the total area followed by horticulture and agro-forestry (23%). The pond refuge (30m x 12 m x 2m) was constructed at the lower end (down slope) of the field occupying 7.2% area. The two trenches of 2.5 m width occupying 10% of the total area were constructed adjacent to the dykes along the longitudinal side of the field and those connected to the pond refuge at one end. The trench bottom had a gentle slope of 0.75% towards the pond refuge. The dug-out soil from the pond refuge and side trenches was used for construction of wide dykes all around with bottom and top width of 4m and 2m, respectively. The average height of the dykes was 1 m, which was 0.4 m higher than the usual maximum water level in the field (Fig 5). Eight platforms of 4mx 3.5m size were constructed from the inner side of the dyke hanging over the trenches for planting the creeper vegetables at the inner side of the dyke and allowing the plants to creep over it.

The cropping systems recommended for rice main field are rice-rice-rice, rice-pulses-rice and rice-vegetables. Several high yielding varieties were tested and found that Ranjeet, Bahadur, Swarna sub-1, CR-Dhan 505 for *sali* and Anjali and Vandana in *ahu* are suitable for growing in rice-fish system. Composite fish cultures like Rohu, Mrigal, Catla, Silver carp and Common carp were found suitable for rice-fish farming. Assam lemon, Coconut, Areca nut, Banana, Papaya, guava were established in pond dyke and vegetables were grown throughout the year in pond dyke with a cropping intensity of 300 or more by using the harvested rain water. Twenty five ducklings of breed Chara-chameli were introduced in to the system for better recycling of the byproducts.

Table 2. Economics of rice-fish-horticulture farming system covering 0.5 ha area (pooled data of 5 years)

Component	GR (Rs.)	COC (Rs.)	NR (Rs.)	B:C ratio	REY-I (t/ha)	MDYs
Rice and other field crops	37190	21820	15370	1.70	-	-
Fish	30180	16220	13960	1.86		
Vegetables	23180	10190	12990	2.27		
Fruits	10700	4120	6580	2.59		
Floriculture	3290	1620	1670	2.03		
Duckery	16700	13890	2810	1.20		
Total	121240	67860	53380	1.79	9.05	206

Productivity and economics: The rice-fish-horticulture system on and average produces 5 to 5.5 and 3.5 to 4 tha^{-1} of rice in *sali* and *ahu* season respectively. The system produce 5-6 quintals of fish, 25-30 quintals of vegetables and besides these it also yielded fruits, flowers, fuel wood, fodder, eggs and meat. After establishment years the system produces REY of 9.05 t/ha and generates average net income of Rs. 52380 per annum from 0.5 ha area. Besides that it also generates employment of 206 man-days /ha/ year (Table 2).

On Station Research

i. Rice and fish growth

Rice-fish interactions in integrated farming creates an environment of mutualism and synergism where both rice and fish benefit from each other and ultimately render the rice field ecosystem more productive, profitable as well as environmentally sustainable. Rice-fish farming in rainfed lowland increases effective tillers by 9-14% and panicle weight by 5-17%

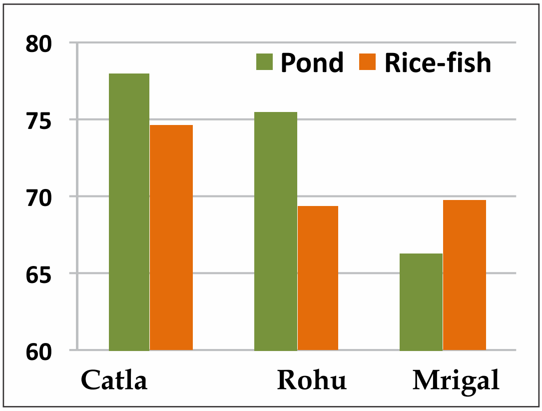


Fig 6. Protein content (%, dry wt. basis) in muscle tissue of fish under rice-fish farming

in rice. This system also enhances Nitrogen (N) uptake by 10-11.8% and Iron (Fe) uptake in straw by two folds over rice alone. Higher concentration and uptake of Phosphorus (P) in rice straw was also observed in this system, but not in the case of other nutrients like K, Ca, Mg and Mn. Increased nitrogen uptake is consistent with higher grain yield of rice in the presence of fish. (Sinhababu et al, 1983, 1992; Panda et al 1987).Rice in this farming system, benefits in terms of increase in grain yield of around 5 to 15% and straw yield of 5 to 9% under rainfed lowland ecologies (Sinhababu, et al, 1998).

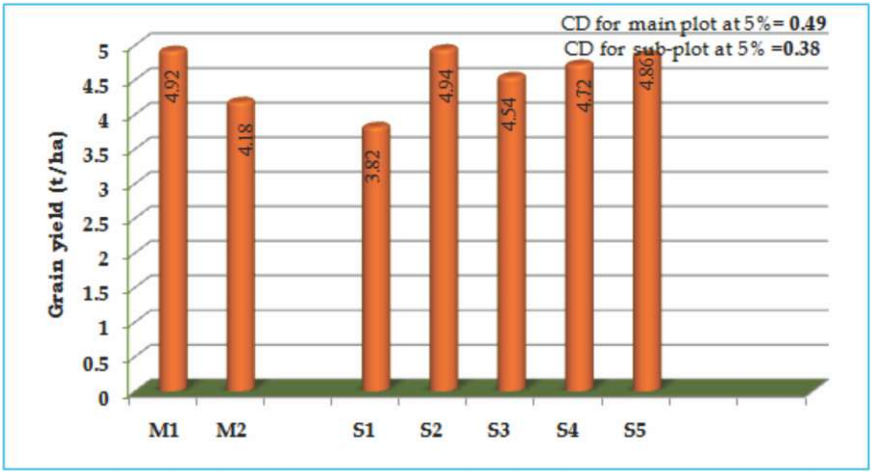
Fish growth in rainfed lowland system (Model I) ranges from 300-500g for catla, 150-450g for rohu, 125-300g for mrigal, 350-600g for common carp, and 250-450 for silver barb. Freshwater giant prawn grows within 30-70g. Sinhababu (1996) reported a growth rate of 150- 400g for fish and 50-70g for prawn in this system, and among fishes, common carp attained maximum growth followed by catla. This growth rate is attained within a season of 5-7 months under a stocking density of 10,000 fingerlings /ha of water area. In the multitier model in deepwater (Model II), fish and prawn register a better growth rate of, 500-800g in catla, 350-500g in rohu,200-400g in mrigal, and 40-75g in prawn with in a season (7- 9 months) under a stocking density of 7,000 /ha (7 fish : 3 prawn).

The protein content (dry weight basis) in the muscle tissue of fish reared in rice field was 74.6% in catla, 69.7% in mrigal and 69.3% in rohu species, respectively (Unpublished data). Use of organics like FYM and fish feed produces higher harvest fish seed and protein(71.57 and 72.50%) in fish flesh under rice-fish seed farming in rainfed lowland (Sinhababu and Sarkar,1998).

Experiment conducted during wet season 2014 with rice + fish and rice alone in the main plot and different spacing in the subplots revealed that grain yield and fish growth was maximum with wider spaced crop. Moreover, grain yield was significantly higher (4.92 t/ha) with the presence of fish (Poonam et al.2016).

Table 3. Fish growth influenced by plant geometry under rice fish system

Treatment	Survival (%)	Specific growth rate (%Body weight/day)	Fish Yield (kg ha^{-1})
S_1- Random Planting	44.1^{d}	1.51^{c}	202.76^{b}
S_2- Skip one Row after every 3rd row with 15 cm x 15 cm	65.8^{a}	1.99^{a}	288.07^{a}
S_3- 15 cm x 15 cm	50.8^{c}	1.60^{c}	209.47^{b}
S_4 - 20 cm x 15 cm	59.2^{b}	1.79^{b}	227.13^{b}
S_5 - 25cm x 15 cm	65.0^{ab}	1.91^{a}	280.96^{a}



Main Plot Treatments: M_1 Rice Fish, M_2 – Rice-Mono **Sub Plot Treatments**: S_1- Random Planting, S_2- Skip one Row after every 3rd row with 15 cm x 15 cm, S_3- 15 cm x 15 cm, S_4 - 20 cm x 15 cm, S_5 - 25cm x 15 cm.

Fig 7. Grain yield (t/ha-^{1}) as influenced by plant geometry under rice-fish system

ii. Rice–fish environment

Rice-fish interactions in integrated farming creates an environment of mutualism and synergism where both rice and fish benefit from each other and ultimately render the rice field ecosystem more productive, profitable as well as environmentally sustainable.

Nutrient change in soil under rice fish system

Rice-fish farming in rainfed lowland increases organic carbon content of soil by 7% and exchangeable ammonium by 25%, besides 6% increase in the available P_2O_5(Sinhababu et al. 1998).Continuous addition of fish excreta in this system may have some role in enriching the soil nutrients.

Physio-chemical parameters under rice fish system

Available information on soil-water environment of rainfed low land rice-fish farming indicates compatibility of this system. In shallow and intermediate deep water rice-fish ecologies, the pH, temperature and dissolved oxygen (DO) content in water remain favourable. The pH of soil is near neutral(6.5-7.1) comparing well with the most productive pond soil. DO content in water in the range of 3.5-5.3 ppm under rice–fish culturecompared to 3.6- 6.7ppm in rice alone during the period of August to Novemberinrainfed lowland. DO content in water increases in the afternoon, and is comparatively higher in ricefield without fish.The water temperature during the same period, ranged in between 25.8 – 35^0 C in rice –fish field compared to 26.2-34.5^{0}C in rice alone (Sinhababuet al. 1983).However, the natural fish food organisms (plankton) status (72 to 282 unit/littre) is low in shallow lowland ecology, requiring enrichment through manuring and supplemental feeding to the fish

(Sinhababu*et al,* 1992). In medium deep and semi-deepwater (up to 70 cm water depth) condition, the zooplankton population averages 689 units/litre. Among the zooplankters, copepods are dominant (65%), followed by cladocera (28%) and rotifers (6%). *Diaptomus,* among copepods, *Moina* and *Daphnia* among cladocerans, and *Brachionus* among rotifers are dominant genera in rice-fish system (Das and Sinhababu 1999).

Methane and nitrous oxide emissions

Datta et al. (2009)reportedthatmethane (CH_4) emission from field plots sown with two rice cultivars, with or without fish, varied considerably. The CH_4 emission was low in all the plots up to 30 days after sowing (DAS). Presence of fish resulted in an increase in CH_4 emission from both the rice cultivars with two sharp peaks recorded at flowering and maturity stages of the rice crop. The mean CH_4 emission (mg CH_4 m^{-2} h^{-1}) from sowing till harvest followed the order: Varshadhan + fish (2.52) >Durga + fish (2.48) >Durga (1.47) >Varshadhan (1.17). Cumulative CH_4 emission was highest in the treatment Varshadhan + fish (96.33 kg ha^{-1})while the lowest emission was recorded in field plots planted to cv. Varshadhan without fish (45.38 kg ha_1). Thus, percentage increase in CH_4 emission as a result of fish rearing was 112 in case of cv. Varshadhan and 74 in case of cv. Durga. CH_4 emission from the refuge pond followed a similar pattern as that from rice fields.

On the contrary, unlike CH_4, nitrous oxide (N_2O) flux from rice fields exhibited a peak almost immediately after germination and stand establishment, at 30–36 DAS and declined thereafter. In general, N_2O fluxes were relatively low during the entire cropping period increasing only towards maturity of the rice crop when the floodwater receded and the field started drying. N_2OPercentage decrease in N_2O emission as a result of fish rearing was 29 in case of Varshadhan and 22 in Durga. Among the four fish species (catla, rohu, mrigal, common carp) grown along with rainfed lowland rice (Varshadhan), the maximum emission of CH_4 (36% higher) was found under rice +common carp, followed by rice +catla, rice +rohu and rice + mrigal farming. On contrary, the emission of N_2O was significantly lower by 9% under rice- fish compared to rice alone (Table4).

Table 4. Cumulative CH_4, N_2O and yield in rainfed shallow rice-fish farming system (2011 wet season).

Treatment	CH_4 emission (kg ha^{-1})	N_2O-N emission (kg ha^{-1})	Rice yield (t ha^{-1})	Fish yield (kg ha^{-1})	Rice straw yield (t ha^{-1})
R	109.3[a]	0.89[c]	4.1[a]	0.0[a]	7.7[a]
RF-A	125.6[b]	0.78[a]	4.6[ab]	195.1[b]	9.3[b]
RF-B	136.0[bc]	0.79[a]	4.1[a]	207.3[bc]	9.3[b]
RF-C	148.5[d]	0.82[b]	5.1[b]	238.4[d]	8.3[a]
RF-D	141.5[cd]	0.81[b]	4.3[a]	226.3[cd]	8.4[a]
CD 5%	10.9	0.01	0.62	29.6	0.77

R= Rice only; RF-A= Rice + Fish (mrigal); RF-B= Rice + Fish (rohu); R-F C = Rice + Fish (common carp); RF-D= Rice + Fish (catla), Rice, Varshadhan (transplanted, NPK 50:25:25)

Source: Bhattacharyya et al. (2013)

iii. Bio-control of rice pests

Fish acts as effective bio-control agent for major rice pests like hoppers, caseworm, stem borer, gall midge, leaf folder, besides snails. Laboratory, green house and field studies indicate common carp as an effective bio- control agent for the major leaf feeding insects like plant hoppers (60% control), leaf folders (47% control) and case worm (50% control). Concentration of proteolytic enzyme in the gut of BPH fed fish corroborates natural feeding of the pest (Table 5). This fish is also effective in reducing stem borer incidence in the vegetative stage and also to some extent in heading stage (Sinhababu and Majumdar, 1981; Xiao,1992).

In a study under a simulated rice–fish condition at NRRI during 2007-2010, it was found that among the four potential insectivorous fish species, magur showed highest bio-control efficiency (32.5% reduction in dead hurts) for yellow stem borer(YSB) followed by koi (27.2%) common carp (22.3%) and Colisa (13.7%). Magur was also highly effective in control(53.3%) of brown plant hopper (BPH) pest of rice, followed by koi(41.2%),Colisa(29.8%) and common carp(25.1%). Koi showed maximum bio-control efficiency (60.2%) in the case of case worm pest of rice, followed by magur (21.9%) under similar situations.

Sinhababu and Rajamani (2000) studied the feasibility and efficacy of different recommended insecticides for use in rainfed lowland rice-fish seed system. The insecticides (phosphamidon, monocrotophos, quinalphos, ethofenprox, carbofuran) though did not kill the reared fishes(common carp, catla, mrigal), instantly, but showed varying degree of deleterious effects on growth, survival and yield. Among the insecticides, carbofuran though was found most effective against yellow stem borer, but was most toxic to fishes. Ethofenprox (an improved synthetic pyrethroid) was found comparatively safer for use in rice–fish field. However, two botanicals namely neem (*Azadirachta indica*) oil and the leaf extract of *Polygonum hydropiper* can be used at their recommended dose levels for control of rice insect pests in the rice-fish eco-system avoiding any mortality in the cultured fish species (Das et al ,2005)

Table 5. Feeding intensity and proteolytic activity in the gut of common carp fed on brown plant hopper (BPH).

Reps	No of BPH Offered	No. of BPH Consumed	Proteolytic enzyme ml/g of wet tissue	
			Control	Treated
1.	215	129	0.50	0.74
2.	252	145	0.52	0.75
3.	276	172	0.50	0.74
4.	204	120	0.51	0.75
5.	298	186	0.52	0.77
Mean			0.51	0.75

Source: Sinhababu and Majumdar, 1981

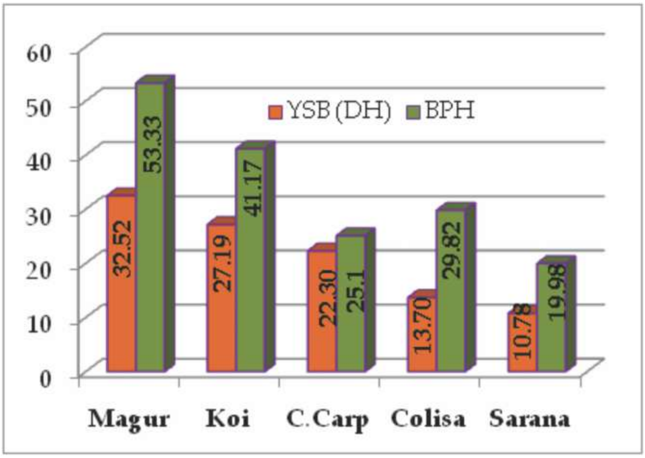
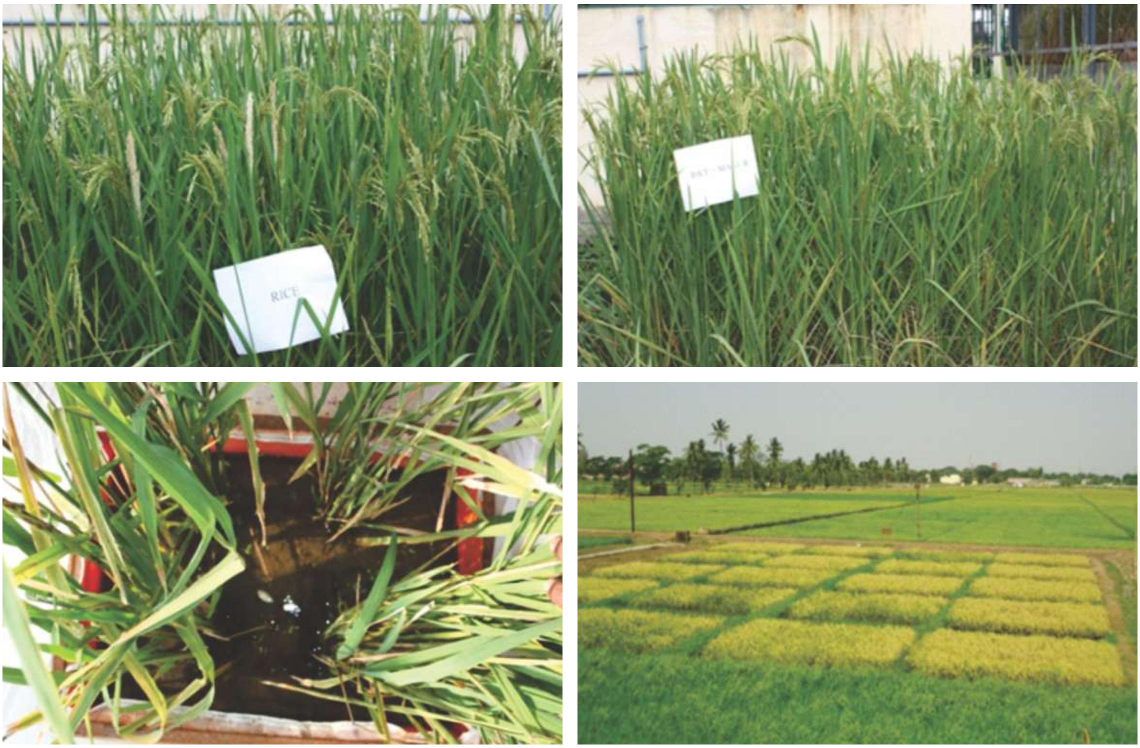


Fig 8. Control (%) of YSB (DH) and BPH by fish fingerlings under controlled condition



Net house and field trials on pest control

iv. Lowland weeds and their bio-control

Fish farming controls weed in rice field both directly by feeding and indirectly by increasing water turbidity, doing mechanical injury and constant flooding. Among the fishes, most useful species are, *Ctenopharyngodon idella*, *Puntius gonionotus, Oreochromis mossambicus, Trichogaster pectoralis* and *Cyprinus carpio.*

Weed flora of different rainfed lowland ecosystems was studied with special reference to rice-fish system at the farm of NRRI, Cuttack revealed that the weed flora decreased with increase of water depth. There was reduction in weeds by 39% under rice –fish system indicating fish as a potential bio-control agent for aquatic weeds (Patra and Sinhababu,1995). Sinhababu et al. (2013) indicated that exotic carps (grass carp, silver barb and common carp in order) were more effective than Indian carps for controlof weed in rainfed lowland rice fields and among the Indian carps, rohu showed potential for weed control. A total of 13 major weeds under the categories of grassy, sedges, broadleaf and aquatic weeds were observed in the rice fields. Grass carp reduced maximum weed biomass (weed control efficiency (WCE) 63% at 60 days after transplanting (DAT) and 62% at 100 DAT followed by silver barb and common carp. Among the Indian carps, only Rohu was effective in control of weeds (WCE, 23% at 60 DAT).

Table 6. Weed flora and fauna under rice-fish system

Grassy weeds	***Sedges:***	***Broadleaf weeds:***	***Aquatic weeds***
Echinochloacolona (L.) Leersiahexandra (Sw.)	Cyperusiria (L.) Schoenoplectus articulatus (L.)	Ludwigiaadscendens (L.) Ludwigiaoctovalvis (Jacq.), Sphenocleazeylanica (Gaern)	Marsileaquadrifolia (L.), Ipomoea aquatica (Forsk.) Otelliaalismoides (L.) Vallisneriaspiralis (L.) Limnophilaindica (L)

Table 7. Weed biomass and weed control efficiency (WCE) in rice alone and rice-fish fields.

Treatments	Weed biomass (g/sqm) 60DAT	WCE (%) 60DAT	Weed biomass (g/sqm)100DAT	WCE (%) 100DAT
Rice + grass carp	0.28[d]	63.34[a]	13.87[d]	62.31[a]
Rice + silver barb	0.32[cd]	60.54[a]	15.62[cd]	56.55[ab]
Rice + common carp	0.43[c]	46.89[a]	21.72[c]	41.81[b]
Rice + rohu	0.61[b]	23.10[b]	28.40[b]	23.22[c]
Rice + catla	0.77[a]	4.99[c]	32.86[ab]	8.49[c]
Rice + mrigal	0.76[a]	3.44[c]	31.75[ab]	11.23[c]
Rice	0.80[a]	–	36.42[a]	–

Source; Sinhababu et al. (2013)

v. Varieties for Rice Fish System

Rice is the major component in this system as it occupies 60-65% of the transformed farm area and water depth remains high (20-70 cm) in the main rice field during rainy season, selection of suitable high yielding, non-lodging and water stagnation tolerant variety is needed for enhancing productivity and profitability of the systems.

Table 8. Grain yield and economics of rice varieties under rice-fish-horticulture system at Gerua, Assam.

Varieties	*Grain yield (t ha^{-1})	Net Return (Rs. ha^{-1})	B:C Ratio	Lodging Behaviour
Ranjit	5.35	24,739	1.82	Non Lodging
Sabita	4.60	14,887	1.52	Lodging at maturity
Pooja	4.24	10,745	1.38	Non Lodging
Jalpriya	3.72	3965	1.14	Susceptible to Lodging
Mahsuri	4.12	13,109	1.18	Susceptible to Lodging
Swarna	5.50	26,073	1.83	Non Lodging
Swarna Sub1	5.22	22,793	1.75	Non Lodging

*Data are means for 3 years

Among the rice varieties evaluated under high level of water (>20 cm at transplanting) Swarna performed better when water level was low during tillering stage. The submergence tolerant variety *Swarna sub-1*was not superior to existing Swarna when mean water depth remained below 40 cm. Ranjit, the popular high yielding variety for shallow lowland performed consistently better under rice-fish system at Assam. During the wet season tall varieties Varshadhan, CR Dhan 505, CR Dhan 500, Jalmani, Durga, Pooja performed better under rice fish system with the water depth varying between 20-50 cm under the coastal ecosystem of Odisha. Variety Jalmani resulted in low yield due to its lodging behavior during the ripening stage. While, varieties Naveen, CR Dhan 305, CR Dhan 205, Pyari proved to be better over CR Dhan 205, CR Dhan 202 with limited irrigation from watershed during dry season at NRRI.

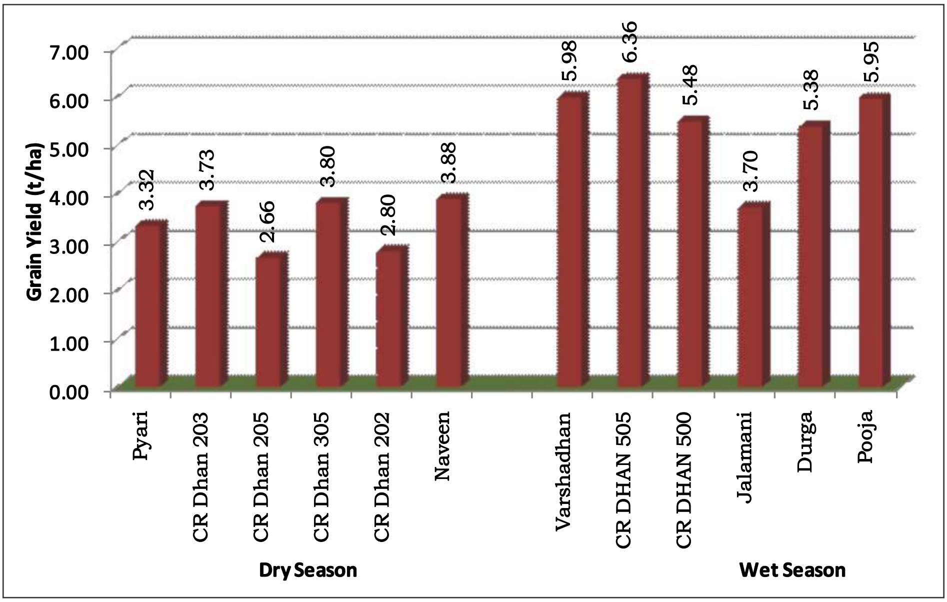


Fig 9. Performance of rice varieties under rice fish system during the dry and wet season

Suitable varieties under to be grown under rice –fish system

vi. Important crops in main field after rice

With proper water management by utilizing the harvested rain water stored in pond refuge, together with soil reclamation and crop management strategies, it is possible to grow certain pulses, oilseeds and vegetables in rice fields during winter/summer seasons. Crops like chilli, sunflower, groundnut, lady's finger, watermelon, *Basella* can be grown after rice during dry season. These crops must be carefully selected based on their suitability to local agro-climatic conditions, soil salinity, profitability and farmers' preferences (Saha *et.al.*, 2007). The tropical tuber crops such as sweet potato, yams are well adapted to these coastal agro-ecosystems. This can ensure food, nutrition, economic, employment and also environmental security. Nedunchzhiyan et al,(2013) reported that sweet potato can be grown in lowland rice fallow in deepwater rice–fish system with the variety Kishan under conventional tillage and Sourin under minimum tillage condition realizing root yield of 20.98 and 13.95 t/ha , respectively.

Eastern India is having potential to harvest rainwater during peak monsoon period (July-September) that stored in the pond refuge can help to grow several winter vegetables like pumpkin, bittergourd, lady's finger, chilli etc. either on bunds or in main rice field. Other crops viz., pulses like blackgram, greengram etc. or oilseeds viz., sunflower, groundnut, sesamum etc. can be grown during the dry season (January – early April) with limited irrigation by stored water (Saha and Biswal, 2004).

From earlier study, it was found that sunflower is one of the most promising crops after rice with 2-3 limited irrigations by utilizing the water stored in pond. It has been found that the sunflower hybrids like KBSH 1, BSH 1, PAC 36, PAC 308, ICI 308, TNAU SUF 7 etc. performed very well with an average seed yield of 12.8 to 27.1 q ha^{-1}. The yield increase of these cultivars over standard check variety Morden ranged from 54 to 75%. All these hybrids matured within 90-102 days (Saha *et. al.,* 2006).However, consistently stable yield was recorded with hybrid, KBSH 1. The highest seed yield (23.7 q ha^{-1}) was recorded by sowing during second fortnight of January at a spacing of 45 X 30 cm with a fertilizer dose of 80:40:40 kg N, P_2O_5 and K_2O ha^{-1}(Saha and Moorthy 2001).

Watermelon was found another promising crop in this system when sown during middle of January in pits with spot irrigation. It produced the highest rice equivalent yield (18.0 t ha^{-1}), net return (Rs. 63423 ha^{-1}) and B:C ratio (8.5). The water productivity (kg rice equivalent yield m^3 water applied) was also the highest for watermelon (83.2). Chilli, another important cash crop, performed well with rice equivalent yield (8.7 t ha^{-1}) and net return (Rs. 29272 ha^{-1}) followed by sunflower (6.4 t ha^{-1} ; Rs 17936 ha^{-1}) in sandy loam soil, where as in other location with clay loam soil rice equivalent yield and net return was the highest for watermelon (13.0 t ha^{-1}, Rs. 49865 ha^{-1}). It was found that there was wide location-wise variability in performance of some crops owing to soil type and availability for irrigation water in pond refuge. Based on the research work carried out under different on-farm IFS models in coastal saline areas of Jagatsinghpur, watermelon, chilli and sunflower are probably the most promising crops for both medium and high salinity areas, while lady's finger is suitable and the most remunerative under low to medium salinity conditions (Singh *et. al.,* 2006).

vii. Rainwater budgeting and productivity

Sinhababu and Mahata (2007) reported the amount of rainwater harvest, its utilization and water productivity in rainfed lowland rice-fish farming system. The water harvested in the pond refuge of 1300 m^2 area is 1820 m^3 equivalent to 140 cm average depth of water. The irrigation water requirement for dry season crops in the field is 21.4% and that for other components on bunds is 10% of the stored water. The water loss due to evaporation and percolation is 40%. Thus, saving of excess water to the extent of 28.6% is possible in rainfed rice–fish system under shallow ground water table and lowland condition in Mahanadi delta areas of Odisha. The net water productivity of rainfed rice- fish system is Rs13.8 $m^{3,}$ of which wet season rice contributes Rs 1.2m^3compared to Rs 2.2 m^3in the case of fish and prawn.

viii. Rice-ornamental fish culture

In order to utilize the rice ecology for value added aquaculture, the technique of breeding and culture of ornamental fishes in irrigated lowland rice field has been developed at NRRI, Cuttack. The rice field has been renovated to make a pond refuge and raise bunds all around. Ornamental fishes like Blue gourami, Red gourami, Pearl gourami, Guppies are bred and cultured with rice (lowland varieties) crop during wet season. During the dry season, rice (Naveen) crop was grown along with ornamental fishes with irrigation. About 25,000 - 6,00000 ornamental fish/ha was produced in the system, in addition to 3.5 t and 5.0 t of rice grain during wet and dry season, respectively (Nayak et al 2008).

Ornamental fish in the rice field

Adoption of rice-fish farming system in eastern India

The rainfed rice-fish system model was also developed in ICAR-NRRI Regional Rainfed Lowland Rice Research Station (RRLRRS), Gerua farm in Assam to facilitate extension in the State of Assam and other States of North Eastern region.

A) Success story in coastal Odisha

KunjoMullick of village Gadkujang, Jagasinghpur district belongs to small farmers category.His rice field was prone to flash flood and submergence during wet season due to poor drainage, back water and remain waterlogged for nearly 4-5 months. Rise in salinity level was another problem during March onwards to till monsoon season. The farmer mostly grew local rice varieties with low inputs and could get very low rice produce (0.8 - 1.0 $t\ ha^{-1}$) and hence could not sustain his livelihood.

Rice based integrated farming system model developed and validated at farmers field in the coastal Saline soil

The NRRI scientist did some basic survey in the Jagatsinghpur district and selected the farmer based on his available resources. The farmer lack vision to utilize his land and water for crop diversification and inability to generate his livelihood from his land. Kunjo Mullick was advised to reshape his rice area and was trained for crop diversification by visiting NRRI farming system models. With the initial investment of Rs 72,000 was done by the farmer for establishment and shaping of his rice area (4 acres) into watershed/pond area of about 1 acre where he was advised to put the Indian major carps and the dug out soil was transformed into raised dykes where the farmer grew banana, coconut and vegetable crops like cowpea, pumpkin, leafy greens, drum stick etc. Poultry and duckery was taken in the house made with locally available materials. At the end of the year he gotnet income of Rs. 150000/- with the cost benefit ratio of 1: 2.1.

B) *Multi-location demonstration of rice- fish system models*

Both the 'Integrated rice-fish farming system models' (rainfed lowland and multitier deepwater models) of ICAR-NRRI, Cuttack were successfully demonstrated and popularised in the farmers' fields of the states of Odisha and West Bengal through Externally Aided Projects (EAPs)and collaboration with NGOs, and by providing technical support to farmers, NGOs and other organizations . A brief account of some of the developed rice–fish farms is given below;

I. Rice- fish farms developed through EAPs of ICAR-NRRI

Rice-fish-horticulture based farming system was developed in different villages under Ersama block of Jagatsinghpur and Astarang block of Puri districts of Odisha with the support of following projects.

S. No.	Projects	Name of farmer	Farm area (Acre)	Village/District
1.	NWDPRA ProjectGovt of Odisha, (1997-2000)	AshokeParida	2.2	Kimilo, Jagatsinghpur
2.	ICDP-Rice Project, Ministry of Agriculture, Govt. of India (1998-99)	UttamPadaNaik	2.3	Oraisal, Jagatsinghpur
3.	NATP Coastal Project, ICAR (2001-05)	Sukumar Jena	1.4	Kiada, Jagatsinghpur
4.	NATP Project, ICAR (2001-05)	Purna Chandra Jena	1.5	Chaulia, Jagatsinghpur
5.	NATP Coastal Project, ICAR (2001-05)	Rupan Das	1.3	Hiradeipur, Puri
6.	NATP Coastal Project, ICAR (2001-05)	Lakhsman Swain	1.2	Sundar, Puri
7.	Adoption by farmers	15 farmersin a cluster	15 farms with av. area of 1.5 acre	Padampur Panchayat, Jagatsinghpur

A cluster of rice-fish farms in rainfed water logged lowlands along with some farmers in Ersama, Jagatsinghpur district in Odisha

II. Rice – fish farms developed through collaboration/MoUs with NGOs

No.	Farmers Name & Village	Farm Area (Acre)	Components
A. Regional Centre for Development Cooperation(RCDC), Bhubaneswar, in Rajnagar block of Kendrapara and Balikuda block of Jagatsinghpur district of Odisha during 2012-2013 (both rainfed lowland and multitier deepwater models)			
1	Sri PunyabrataMandal Vill: Gopaljee Patna	1.1	Rice, Fish, Horticulture-Vegetables
2	Sri BhiguramMandal Vill: Udyan	0.75	Rice-Fish-Horticulture-Duckery-vemi-compost
3	Sri Gopal Ch. Giri Vill: Birabhanjpur	0.40	Rice-Fish-Horticulture-Duckery-vemi-compost
4	Sri Ramakanta Pradhan Vill: Natchhipada	2.0	Rice-fish-Horticulture-Vegetables
5	Sri Ashok Das Vill: Junapangara	0.80	Rice-fish-Horticulture-Vegetables
6	Sarbeswar Pradhan Vill: Baurnipala	2.0	Rice-Fish-Horticulture-Duckery-vemi-compost
7	Sri NandadulalMandal Vill: Dekni	1.30	Rice-Fish-Horticulture-Duckery-vemi-compost
8	PatitpabanKhanda Vill: Naupala	0.90	Rice-Fish-Horticulture-Duckery-vemi-compost
B. Vivekananda Institute of Biotechnology (VIB), Sri Ramkrishna Ashram, Nimpith, West Bengal, in Coastal villages of South 24, Parganas district, West Bengal during 2012. Total 13 rice-fish farms, mostly multitier model (rice, fish, vegetables, tuber crops, banana) of 0.3 -1.7acre area developed			

III. Rice- fish farms developed under technical guidance of ICAR- NRRI Scientist

S. No.	NGOs /organizations	Name of farmer	Farm area (Acre)	Village / District
1.	Bikramananda Institute of Rural Development (BIRD), Puri under NABARD financial support of NABARD during 2011-12	Sarbeswar Paikray	4.0 (rainfed lowland model)	Apithi, Puri
2.	do	Sudam Pradhan	2.0 (multitier deepwater model)	Bhikaripara, Puri
3.	Paradeep Phosphate Ltd(PPL), Bhubaneswar, 2009-10	Subhas Panda	0.5 (rainfed lowland model)	Barakumari, Khurda

4.	Vivekananda Regional Rural Development Organization (VRRDO), West Bengal funded by DST Project during 2010-11,	15 farmers in 8 villages	15 small farms (multitier model)	Patharpratima and Mathurapur blocks, South 24 Parganas district
5.	KVK, Lohit, ICAR-NRC on Yak, Arunachal Pradesh funded by NABARD in 2012.Rainfed lowland model (rice, fish, pigs, fruit crops, arecanut, Tocopata tree)		1.5	Lohit, Arunachal Pradesh

Sinhababu et al (2006) reported that the rainfed rice–fish diversified farming system technology not only increased net farm income by around fifteen times (Rs 44,500 /ha/yr) over traditional rice farming, but also generated additional employment of 110 man-days in the Super-cyclone affected coastal villages in Odisha under NATP Project.

Adoption of Rice based integrated Farming system in Eastern India


Rice-fish farms in South 24Parganas W.B through collaboration with VIB, SRK, Nimpith, 2012


Rice–fish–farm at Lohit, KVK NRC Yak, Arunachal Pradesh, 2012

On-farm validation of the MDW rice-fish farming system during 2010-12

Constraints

The rice –fish systems involves a considerable amount of initial capital cost for land shaping and other infrastructures like small houses for birds and animals etc. This condition impedes large scale adoption of the rice –fish technologies, since most of the target farmers in eastern India are small and marginal with poor economic condition. Linkages with the relevant various Central and State Government on-going schemes for cost of land shaping will ease the problem. Fragmentation and multi ownership of land, and small holdings also stand in way of adoption of this system. Land consolidation and suitable modification /down scaling of technologies for small holdings are needed in these situations. Timely availability of required inputs for this system, like seed and planting materials of different crops, fish and prawn seed, and offspring of birds and animals, are to be ensured in the locality. Marketing of various produces from the system is very important. Rice –fish farm development in cluster and linkages with the market chain will facilitate proper marketing. Rice –fish –horticulture-livestock farming is a specialized system, which requires necessary skill development. Awareness development and capacity building of the farmers are necessary for successful adoption of this system.

Challenges and policy issues

Rice-fish based integrated farming system could be a viable option for crop diversification and reducing the risk over rice mono cropping. This should be encouraged in the large scale to fully exploit the potential areas. Necessary initiatives and public and private sector investments are needed to realize the potential growth of this system. A much greater benefit could be obtained if government policies encourage the promotion of integrated rice-fish farming, as well as the implementation of a workable strategy for large scale adoption in different agro-climatic regions of the eastern India. It is also necessary to provide institutional and organizational support, especially soft bank loan for success of this farming system.

Future perspective

The need for diversification of farming practice is needed as the income of farmers who depend solely on the produce of their traditional mono crop of rice pattern is decreasing due to limited profit margin and changed food habits. To meet the continuous rise in demand for food, stability of income and diverse requirements of food grains, vegetables, milk, egg and meat, integrated farming systems (IFS) seems to be the feasible solution, thereby improving the nutrition of the small and marginal farmers with limited available resources. Integration of different related enterprises with agriculture crops provides ways to recycle products and by-products of one component as input of another linked component which lessen the cost of production and thus raises the total income of the farm. The expenditure on inorganic fertilizers may also decline due to availability of a good amount of manure, which resulted into a saving up to 50% as compared to arable farming. Multiple land use through integration of crops, minor livestock with aquaculture can result in the best and optimum production from unit land area. The rural youths can take up 'Integrated farming system' as micro business through entrepreneurship for achieving income at regular interval and self-employment. This model should be validated in different agro-climatic zones of the country for location specific refinement and finally wide-scale adoption with low invest capital for small and marginal farmers as well as agro-entrepreneurs.

Conclusion

There is a strong need to monitor the entire rice-based production system in terms of crop varieties, nutrient dynamics, water table and quality of irrigation water, insect, disease and weed problems to evolve site specific appropriate management techniques. Economic feasibility is another important criterion for acceptance of any cropping system by the farming community. The large scale adoption of any improved cropping and farming system by the farming community depends mostly on socio-economic factors such as labour availability, credit requirement, cost of inputs, processing, marketability and price of produce, risk involved and social acceptability of the new system. Thus before designing a particular farming system model, care should be given on its technical and economic feasibility.

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