

Rice-based integrated farming systems

for doubling of farm income in Eastern India

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The realisation of low farm income from the farming sector invariably caused agrarian distress among farming communities caused economic and social problems poses detrimental effects on agricultural farming. Suitable integration of rice farming with other crops, fish, livestock and agroforestry components and up scaling with newer varieties of cash crops etc. (i.e. rice-ornamental fish, crop-livestock-agroforestry, multitier farming, rice-fish-duck and rice-fish-azolla-duck integrated farming etc.) can create an opportunity for strengthening the farm productivity and income, which can fulfil the target of doubling the farmer's income. The system provides production sustainability with nutritional, economic, employment and environmental security for Indian small and marginal farmers.

Keywords: Doubling farm income, Rice-based integrated farming systems

INDIAN agriculture basically dependent on monsoon and situational market prices, leading to uncertainties of production and income of farmers, resulting frequent distresses leading to economic and social problems and posing threat and insecurity to farmers' livelihoods and welfare among the farming communities. Additionally, fragmented land holdings (85% small and marginal), limited irrigation facilities (60% rainfed), complexities of insurance and credit facilities, inadequate procurement policies especially for rural farmers, poor implementation of farm mechanization (less than 50%), inadequacies in warehousing and cold storage facilities, issues with APMC *mandis* (transportation, levy on market fee, product quality and gradation etc.), fluctuating price of the commodities, shortage of labour during the peak time of agricultural activities and lack of proper scientific knowledge in respect to modern farming (timing, quantity and precision etc.) further added to the plight of farmers.

Extensive practices of agricultural intensification and monocropping leading to extensive soil mining and environmental degradations (emitting greenhouse gas), causing large scale concerns to the society at large. Moreover, completion after 50 years of the Green Revolution, Indian agriculture is encountering the second generation challenges i.e. declining growth of factor productivity, deterioration soil health and fertility, reduction in soil organic carbon, water scarcity and water pollution, augmented incidence of pests and diseases, amplified cost of inputs, decline in farm profits etc., which needs to be addressed urgently. All these factors lead to declining farm productivity and lower farm income (evident from the incidence of poverty), worsening disparity of income between farmer and non-agricultural worker, consequential to emergence of mass scale agrarian distress, causing detrimental effects on the interest in agrarian farming and farm investments, which is cumulatively forcing more and more cultivators, especially younger age

groups, to leave the farming sectors, which pose serious adverse impact on continuance of the future practice of agriculture in India.

Why Double Farmers' Income?

Enhancing farmer income is crucial and first step for addressing the agrarian distress and subsequent promotion of the welfare of farmer's community. The main concern of farmers in present-day agriculture is one-way increase of agricultural inputs cost and on the other, declining trend of farm income and productivity. The study conducted by National Institute of Agricultural Economics and Policy Research (NIAP) indicated country's 70% of farmers having annual per capita income less than ₹ 15,000 (around USD 250). It is often argued that India's Green Revolution made self-sufficiency in food production, however, has bypassed the majority (almost 86 %) of smallholder farmers having less than 2 ha of lands. Additionally, farmers now are facing emerging problems of the Green Revolution with twin challenges of



Fig. 1. Ornamental fish Culture in rice fields.



Fig. 2. Coloured Cyprinus carpio species.

global climate change and globalization of agriculture.

For making agricultural farming profitable, farmers invariably require newer production technologies with the use of low cost agricultural inputs with higher productivity, a well-designed policy support getting easier lower interest rate credit support, and realize higher returns/income by suitably linking farmers to direct marketing or selling their products. Doubling real income of farmers till 2022-23 (respect to base year of 2015-16), requires 10.41% of annual agricultural growth rate. This perpetually needs adoption of strong strategies and policy frame work, which subsequently requires massive investments in the key areas like agricultural research and development, leading to the adaption of Good Agricultural Practices (GAP), conservation agriculture technology, implementation of farmer's friendly policies, judicious use of available resources and inputs along with improved market and transportation facility, MSP reform, supported by adequate, timely and easier availability of bank credits. Diversification of farming and processes of value chain addition may provide a game changer with the inclusion of higher value crops.

Achieving doubling farmers' income by 2022 is a most challenging task. The economic think-tank at NITI Aayog has put forth four-point action plans i.e. provisioning of remunerative prices, increasing productivity, reforming agriculture policy and provisioning of adequate relief measures. Expert committee

engaged in searching the options recommended Integrated Farming System (IFS) approach adoption as one of the potential farming options for enhancing the productivity and income of small and marginal farmers within a reasonable time frame. With that context, the rice based integrated farming system has become more important especially, in the eve of declining natural resources, increasing water scarcity, increasing energy costs and cost of production with ensuing problems of climate change impacts and their mitigation. Therefore, multi-enterprising integrated rice-based farming system can contribute towards sustainability, enhancing productivity and possibly, doubling the farm income and may improve the livelihood of small and marginal farmers.

Rice-Fish based Integrated Farming Systems: A case study

ICAR-NRRI has developed rice-fish based integrated farming systems (IFS) using ecological engineering concepts of soil, water conservation, nutrient and farm waste recycling (composting, mushroom and vermicomposting) with multi-enterprising components of crops, seasonal vegetables, horticultural plants (banana, papaya, mango, guava, coconut), livestock (fishery, duckery, poultry, goatry), fodder grass and agro forestry etc. The four key agro-ecological strategies (bio-diversification, soil conservation, water harvesting and farm waste recycling) were used in the design and managements in rice-fish based integrated agro-ecosystems for

enhancing the farm productivity, diversified farm income with provisioning of adaptation and mitigation options. Some of these technologies are as follows:

- Rice-Ornamental fish culture
- Crop-livestock-agroforestry based IFS
- Multitier rice-fish horticulture-based IFS
- Rice-fish duck integrated farming system
- Rice -fish -*Azolla*-duck IFS

1. RICE - ORNAMENTAL FISH CULTURE TECHNOLOGY

The waterlogged rice ecology harbours good source of fish food organisms (insect, pest and their larvae), which provides a natural environment for breeding and culture of the ornamental fishes. Irrigated and medium deep-water lowland (30-50 cm) rice ecologies having clay sandy loam soil with prolonged water retention capacity is preferred. A rectangular or square field (area of 500 m² to 1,000 m²) with provisioning of 15% water refuge area having strong dyke are preferred for rice-ornamental fish integration (Fig. 1).

Production methodologies

High yielding, semi-dwarf (in irrigated ecology), semi-tall and long duration rice varieties (in lowlands) such as Naveen, Lalat, IR 36 and IR 64 (irrigated) and Gayatri, Sarala, Durga and Varshadhan (medium deep lowlands) are suitable.

Among the ornamental fishes, Gourami's mostly breeds during June to August and are egg layer and hatchling release from the egg mass

after 20-25 hours depending on the water temperature. Varieties of gourami species with attractive colouration used for culture such as blue gourami (*Trichogaster trichopterus*), gold gourami (mutant of *T. trichopterus*), rainbow (stripped) gourami (*Colisa fasciata*), rainbow dwarf gourami (*Colisa lalia*), pearl gourami (*Tricogaster leeri*), moonlight gourami (*Tricogaster microlepis*) and kissing gourami (*Helostoma temminckii*). Guppies (*Poecilia reticulata*) are live bearer and prolific breeders (breed throughout the year). There are many varieties of guppies like round tail, fin tail, veil tail and cobra guppies etc. Males are identified by the bright coloured tail fins. Guppies naturally breed round the year in waterlogged rice field. Juveniles are reared for two months till attainment of marketable size. Popular live bearer molly (*Mollinesia* spp including sail-fin molly, black molly, moon-tail, round tail, chocolate molly, silver molly, balloone molly), sword tail (*Xiphophorus helleri*) including red sword tail, green sword tail, sunset sword tail, double sword tail) and platy (*Xiphophorus maculatus*) with many varieties such as round tail, veil tail, fringe tail, lyre tail, pin tail) are suitable live bearer species for culture in rice ecologies. Other ornamental fishes like Gold fish (*Carassius auratus*) and Koi carp (*Cyprinus carpio* Var. *Koi*, Fig.2) are found in different colour combinations, barbs like rosy barbs (*Puntius conchonis*) and tiger barbs (*Puntius tetrazona*) and danios such as zebra danio (*Brachydanio rerio*) species are suitable for rice ecology.

Productivity and economics

About 1-2 lakh numbers of



Fig. 3. Crop – livestock – agroforestry based integrated farming system.

ornamental fish and 3-5 t rice grains are produced per ha. The cost-benefit ratio (B:C) was 2.5 depending on extent of integration, varieties and extend of suitable managements. It provides additional benefits of controlling various pests, insect larvae and mosquito larvae in the rice fields.

2. CROP - LIVESTOCK - AGROFORESTRY BASED IFS

The crop-livestock-horticultural and agroforestry-based IFS (CLAIFS) developed with the integration of improved rice varieties, vegetables, fruit crops, agroforestry, floriculture, apiculture, fish, prawn, poultry, duckery, goatry etc., with the provision of greater scope for diversification and climate resilience system for enhancing farm productivity, farmer income and achieving sustainability (Fig.3). Medium deep or deep-water lowlands, free from heavy flooding having clay soil and prolonged water retention capacity are preferred. A rectangular or a square shaped field with an area of half to one hectare or

more is desirable. On the bund provisions of duck, poultry and goat shed are constructed using locally available materials.

Components and production methodologies

Field design: Total area 1 ha, rice cultivation (65% area), water refuge area (15%) and complete bunding on four side of the plot 20% area.

Components in Main Field

- Rice Varieties: Varshadhan, Durga, CR Dhan 505/500
- Fish: Catla, Rohu, Mrigal, Common Carp, Silver Carp, Fresh Water Prawn (*M. rosenbergii*)
- Crop after Rice : Watermelon, Cowpea, Okra, Pumpkin, Sunflower, Poi

Components on bunds

- Vegetables: Summer/Wet/ Winter; seasonal vegetables
- Horticultural crops: Banana, Papaya, Mango, Guava, Coconut
- Agroforestry : *Acacia mangium*, *A. auriculiformis*
- Floriculture: Marigold and



Fig. 4. Multi-tier integrated farming system

Tuberose

- Mushroom: Straw and Oyster mushroom
- In the shade: Amorphophallus, yams, Colocasia, Ginger, Termaric.
- Duckery: 50 duck/ha unit (Khakhi Campbell)
- Poultry: 50 broiler/ Layer or Dual purpose birds (Vanraj, Black rock)
- Goatary: 10 Goats (Black Bengal Breeds)

Productivity and economics

18 to 20 t of food and fodder crop, 0.6 t of fish and prawn, 0.6 t-0.9 t of meat and 10,000 eggs. In addition to 3-5 tonnes of animal feed and 12-15 tonnes of fiber/fuel wood from one ha farm area. The cost-benefit ratio was 2.9-3.4 depending upon the extent and type of integration and generate employment of 400-500 man days/ha/yr.

3. MULTI-TIER FARMING SYSTEM MODEL FOR DEEP WATER ECOLOGY

Design & components:

Farm Area: 1 ha

Upland (15% area) area divided into two tiers,

Tier I- Perennial & seasonal Fruit crops; Mango, Banana, Papaya, Sapota, Guava, Pineapple

Tier II- Tuber crops & seasonal vegetables

Rice field (40% area):

Tier III: Rainfed lowland rice - Sunflower, Groundnut, Sweet Potato, Vegetables

Tier IV: Deepwater rice- Dry Season rice, vegetables

Micro Watershed (refuge): 25% area for aquaculture and irrigation

Bunds:

Agro-forestry, Coconut, Duckery, Poultry

Productivity and economics:

The system produces 14-18 t of food crops, 0.6- 1.0 t of fish and prawn, 0.5-0.7 t of meat, 8-12 thousand eggs in addition to others like straw, fibre and fuel woods. The cost-benefit ratio was 2.0-2.5 and generating 350 man days/ha/year.

4. RICE-FISH -DUCK IFS

The rice-fish duck IFS (RFD-IFS) provides maximum synergy and utilization of available resources benefitting small and marginal farmers, especially, in tribal dominated areas.

Medium deep or deep-water lowland rice ecologies, free from heavy flooding having clay soil and prolonged water retention capacity is preferred. A rectangular or square shaped field with an area of half to one ha and more is desirable. Field design include bund (dykes 0.5-1.0 m wide) all around (5% of the area), pond or water refuge connected with trench on two sides (10% of area) and rice fields (85% of the total area), guarded with water inlets and outlet. Embankments should have a height of 40-50 cm depending upon the depth of the rice fields. The dyke should have sufficient height to prevent fish from jumping over and escaping to the other rice fields. In the outlet, provision of wires and screens can be provided to prevent the escape of

fishes from the rice fields and to prevent the entry of predatory fishes to the field. All around the field in the bund area, a 1.5-meter height of nylon net can be fixed with positioning bamboo poles to prevent foraging of ducks in the adjoining rice fields and to prevent outside predators from entering the rice field area.

Production methodologies

- Rice Varieties: Varshadhan, Durga, CR Dhan 505/500
- Fish: Catla, Rohu, Mrigal, Common Carp, Silver Carp, Fresh Water Prawn (*M. rosenbergii*)
- Ducks: Indian Runner, Khaki Campbell or their cross with indigenous local ducks are preferred for fish duck integration. *Khaki Campbell* (egg layer) and *White pekin* (meat type) are most suitable for integration with rice fields.
- Approximately, 200-250 numbers of ducks reared in 1 ha of rice fields. The male and female duck ratio 1:10 is maintained for obtaining fertilized eggs.



Fig. 5. Duck feeding on azolla in integrated farming system

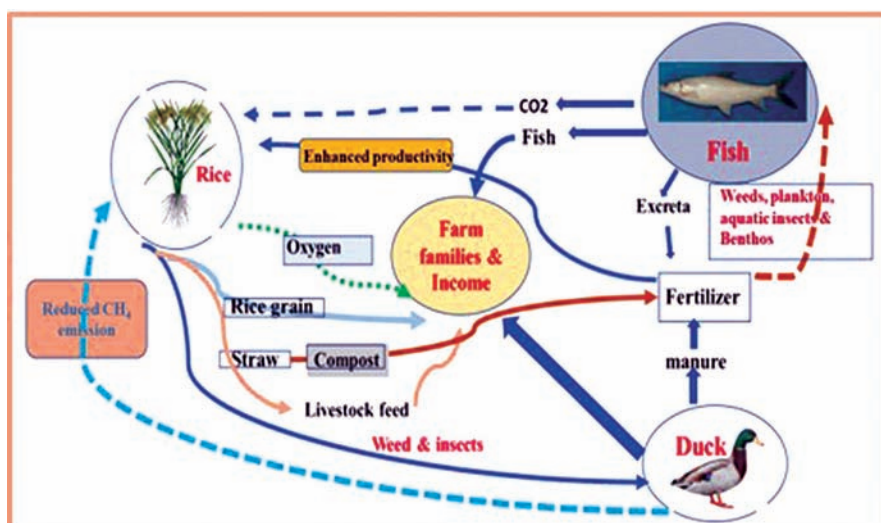


Fig. 6. Recycle and energy flowchart in Rice-Fish-Duck Integrated Farming System.

- Night shelter of ducks can be constructed (locally available materials) either on embankment projecting towards the water refuge area or in the floating duck house having at least 0.5 m² of floor space per bird.
- Duck fed mostly on duck weeds (*Lemna*, *Wolffia*, *Azolla* etc.) and other aquatic weeds available in rice fields. Duck also consume tadpoles, juvenile frogs, dragon fly larvae and various other organic materials available in the rice environments.
- Additionally, supplementary feed consisting of standard poultry feed or mixture of rice bran etc. @ 2-3% of body weight may be provided daily during night shelter. Moist rice chaff, vegetable waste can be used as supplementary feed for ducks.

Productivity and economics:

The RFD IFS in rice-rice farming system annually produced 9-10 t food crops, 0.7 t fish prawn, 0.5 to 0.7 t of meat and 25,000 eggs. The net income will be around ₹ 1,10,000 to 1,30,000 depending upon the integration of the components with benefit-cost ratio varies 2.5–2.8.

Mechanism of function in rice-fish-duck integrated farming (RFDIFS)

In RFDIFS farming technology, ducks and fish in rice field create symbiotic relationship between rice-fish-duck yielding maximum mutual benefits to all the entities. Ducks and fishes control the harmful insects and weeds, dropping utilized as organic manure and mobilization of nutrients, activities (continuous movement, scooping and churning of soil) aerate the rice ecologies which increases the availability of nutrients (like nitrogen, phosphorous and potash) to the rice crops, enhances biodiversity and reduces the global warming potentials. RFD-IFS technology reduced the cost of cultivation, increases productivity, providing sustainability, economic, employment and environmental security to the farm families (Fig. 5-6).

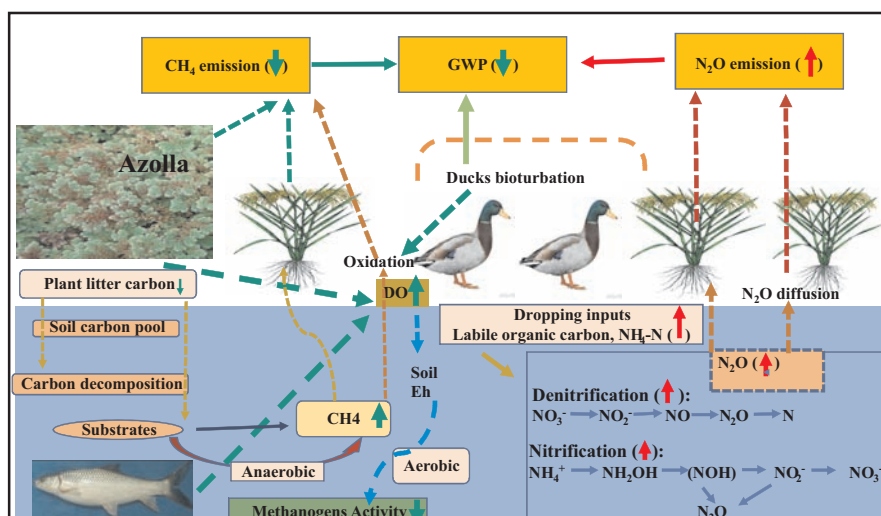


Fig. 7. Mechanism frame work in reduction of Global warming potential (GWP) in rice-fish-duck-azolla Integrated Farming System.

5. RICE-FISH-AZOLLA -DUCK IFS

Since CLA-IFS requires substantial cost involvements towards maintenances (fertilizer, feed for animal and fish etc.), and aiming further reduction of costs, ICAR-NRRI developed a rice-fish-*Azolla*-duck based IFS (RFAD-IFS) models involving minimum operational costs.

Azolla is a free-floating aquatic fern, and naturally available mostly on moist soil, ditches and marshy ponds and widely distributed in tropical India. Nitrogen fixing capabilities of *Azolla* through the symbiotic cyanobionts (around 1,100 kg N/ha/year to plants) are making the plant unique and considered as one of the best bio-fertilizer, feed for livestock and biofuel.

Rice-fish, duck and *azolla* provide symbiotic relationship and mutual benefits to all the entities. The ducks and fish bioturbation (rapid movement) enhances dissolve oxygen concentration in water, helps in fish growth and survival. *Azolla* supplements nitrogen requirements of rice and used as supplementary feed for ducks.

Productivity and Economics

RFAD-IFS in rice-rice system annually produced 9-10 t of food crops, 0.7 t of fish and prawn, 0.6-

0.7 t of duck meat and 25,000 eggs. The cost-benefit ratio was 2.7-3.0 depending on extent of integration.

The impact analysis of IFS indicated higher productivity, energy and water use efficiency with bio-control prospecting of weeds and pests. Additionally, the system having efficient nutrient recycling and waste utilization (composting, mushroom cultivation and vermicomposting, provisioning of enhanced benefit of ecosystem services, improvements in biodiversity, with climate adaptation and mitigation options. The water quality index (WQI) and soil quality index (SQI) has shown enhancement in soil health and soil fertility and substantially reduces the emission of greenhouse gases (GHG) and global warming potentials (Fig. 7). The study indicated IFS are more productive and ecologically efficient agricultural system, accommodating multiple subsystem and multiple enterprises with diversifying the source of income and employments and potentially doubling the farmers' incomes with a reasonable time frame. The system provides production sustainability with nutritional, economic, employment and environmental security for small and marginal farmers.

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