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Integrated rice based farming system for enhancing productivity & climate resilience

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INTRODUCTION

India is a country of about 1.30 billion people. More than 70 per cent of India's population lives in rural areas where the main occupation is agriculture. Indian agriculture is characterized by small farm holdings and the average farm size is only 1.57 ha. Around 93 per cent of farmers have land holdings smaller than 4 ha and they cultivate nearly 55 per cent of the arable land. On the other hand, only 1.6 per cent of the farmers have operational land holdings above 10 ha and they utilize 17.4 per cent of the total cultivated land.

Major farming systems in India are classified into eight broad categories *viz.,* irrigated, wetland, rainfed farming (in arid, semi arid, sub humid and per humid areas), coastal, mixed and urban based farming systems. India, being the country of rich agricultural diversity, almost all the farming systems are under practice across various agro-ecosystems.

India has one half of buffalo and one sixth of cattle population of the world and ranks first in goat and sixth in sheep population. It has a vast potential of fishing resources comprising 2.02 m. sq. km of Exclusive Economic Zone (EEZ), 7,517 km of coastline, 29,000 km of rivers, 1.7 mha of reservoirs, 0.90 mha of brackish water areas and 0.75 mha of tanks and ponds. These environments provide opportunities for multiple farming systems in diverse agro ecosystems.

Traditional farming systems practice in different agro climatic zones of India

High Altitude Cold Deserts: Pastures with forestry, goats, angora rabbits and limited settled agricultural crops like millets, wheat, barley, and fodder crops.

Arid and Desert Region: Centering mainly in animal husbandry with the camels, sheep and goat and with moderate cropping components involving bajra, wheat, pulses, gram and fodder crops.

Western and Central Himalayas: Horticultural crops as a major component and have a less intensive agriculture mainly on the hill terraces and slopes with maize, rice, wheat, pulses and fodder crops.

Eastern Himalayas: Primitive crop husbandry with rice, millets, pulses, etc. Agro-forestry systems are also common. Piggery and poultry are the chief livestock activity.

Indo-Gangetic Plains: Intensive crop husbandry, involving rice-wheat-maize-mustard-pulses and livestock inclusive of dairy cattle and buffaloes.

Central and Southern Highlands: Cropping pattern with cotton- sorghum-millets-pulses with dairy cattle, sheep and goats and poultry are the secondary animal husbandry enterprises.

Western Ghats: Major activity on plantation crops, cultivation of rice and pulses are the secondary agricultural activity. Cattle, sheep and goats are the livestock components, which in most parts are maintained as large herds and allowed to range.

Delta and Coastal Plains: Rice cultivation along with fish culture, poultry and piggery enterprises. Capture fisheries of the marine ecosystem is a specialized enterprise and does not mix with cropping activity.

Integrated farming system

Integrated farming system meets spread out demand for food, income and diverse requirements of food grains, vegetables, milk, egg, meat etc., thereby improving the nutrition of small - scale farmers with limited resources. Integration of different agriculturally

related enterprises with crops provides ways to recycle the products and by products of one component as input to another and reduce the cost of production and increase the total income of the farm.

Research studies carried out in wetlands of different agro climatic zones have demonstrated the technical feasibility and economic viability of the integrated farming systems. Besides facilitating cash income, these farming system models generated additional employment for family labor and minimize the risk associated with conventional cropping system. This paper throws insights on the technologies to improve productivity and profitability of rice based farming systems.

Promising integrated farming systems for climate resilient irrigated agriculture

i. Western Zone of Tamil Nadu

Crop + poultry/ pigeon + fish + mushroom

In this system, the components of integrated farming system involved were crop + fish + mushroom, crop + poultry + fish + mushroom and crop + pigeon + fish + mushroom. The efficiency of the component linkages was evaluated predominantly on the basis of productivity, income, employment generation and resource recycling potential.

Experimental results on enterprise linkage for low land farming systems revealed that rice - soybean - sunflower and rice - gingelly - maize cropping systems each in 0.18 ha with pigeon (40 pairs), fish (400 polyculture fingerlings in 0.04 ha of ponded water) and mushroom (2 kg/day) was best in obtaining higher productivity in the system as a whole than the conventional cropping system being popular with rice-green gram-maize (0.20 ha) and rice - sunhemp - maize (0.20 ha) cropping systems. Cropping + pigeon + fish + mushroom integration earned the highest gross and net returns with better per day returns and benefit cost ratio. Integration of poultry + fish + mushroom + cropping applied with recycled poultry manure sustained the productivity of soil through the additions of bio resource residue with better NPK nutrients supply potential.

To enhance and sustain the productivity, economic returns, employment generation for the family labour round the year and soil fertility with environmental protection, integration of rice-gingelly-maize and rice- soybean -sunflower cropping each in 0.45 ha with recycled poultry manure as fish pond silt to rice and 75 per cent of the recommended NPK to each crop in the system + poultry (50 layers) + fish (1000 polyculture fingerlings in 0.10 ha of ponded water) comprising catla (20 per cent), silver carp (20 per cent), rohu (20 per cent), mrigal (15 per cent), common carp (15 per cent) and grass carp (10 per cent) fed with poultry dropping + oyster mushroom (5kg/ day) for the lowland farmers having one hectare farm (Jayanthi,1995).

Crop + poultry / pigeon / goat + fishery

The study was carried out with cropping, poultry, pigeon, goat and fishery enterprises in all possible combinations during 1998-2001, with a view to recycle the residue and by- products of one component over the other (Fig. 1). In one hectare farm, an area of 0.75 ha was assigned for crop activity, 0.10 ha for growing fodder grass to feed the goat unit (20+1), 0.03 ha allotted to goat shed and the remaining 0.12 ha allotted to 3 fish ponds. Three integrated farming systems *viz.,* crop + fish + poultry (20 Bapkok layer birds), crop + fish + pigeon (40 pairs) and crop + fish + goat (Tellicherry breed of 20 female and 1 male maintained in 0.03 ha deep litter system) were tried for three years. Polyculture fingerlings of 400 numbers (catla, rohu, mirgal/ common carp and grass carp) in the ratio of 40:20:30:10, respectively, reared in 3 ponds of size 0.04 ha (depth of 1.5 m) each.

Fishes were fed with poultry, pigeon (700 kg poultry/pigeon droppings obtained from 20 Bapkok layers/40 productive pairs of pigeon) sheltered over two fish ponds and goat droppings (3 animals - 800 kg droppings) to assess the feasibility of rearing fish by using different manures as feed. Under Integrated Farming System, cropping sequence includes (i) sugarcane (planted) - sugarcane (ratoon) - banana (3 years) (ii) banana - turmeric - rice - banana (3 years) and (iii) maize - rice - sesame - sunhemp (annual) each in 0.25 ha and bajra - napier grass + desmanthus (perennial) in 0.10 ha.

Conventional cropping system comprising (i) rice -rice - black gram (ii) maize - rice - black gram (iii) maize - rice - sunnhemp and (iv) rice - rice - sunnhemp each in 0.25 ha, as practised by the farmers

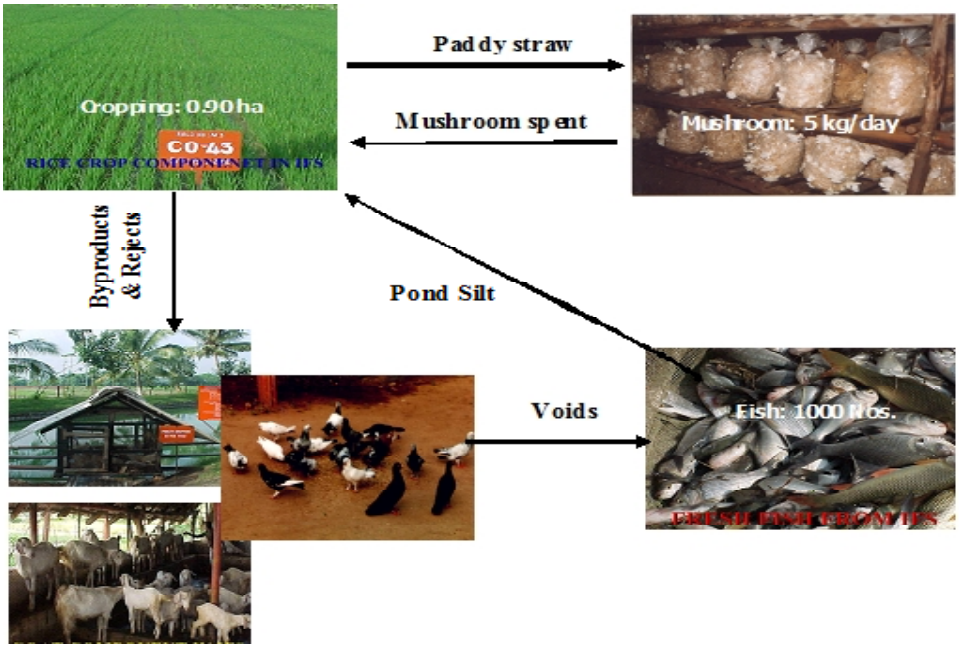

Fig. 1. Component integration and resource recycling in lowland ecosystem

was taken up for comparison. To sustain the productivity of soil through integrated nutrient supply, recycled poultry, pigeon and goat manures and composted crop residue (banana waste and sugarcane trash) as vermicompost each @ 6.25 t/ha were tested along with 100,80 and 60% of the recommended fertilizer for the sequences of cropping.

Integrated farming system provides an opportunity to increase economic yield per unit area per unit time by virtue of intensification of crop and allied enterprises. Research results on integrated farming system revealed that integration of crop with fish, poultry, pigeon and goat resulted in higher productivity than cropping alone under lowland. Crop + fish + goat integration recorded higher rice grain equivalent yield of 39610 kg/ha (mean over three years) than other systems. Similarly, as an individual animal component, the goat unit (20 + 1) gave the highest productivity of 8818 kg (mean over three years). This could also provide 11.0 t of valuable manure apart from supplementing the feed requirement of 400 numbers of fish. While assessing the feasibility of rearing fish by using poultry, pigeon and goat droppings as feed, the fish fed with poultry droppings resulted in higher fish yield (825 kg / 0.04 ha ponded water) than the other two sources of feed.

The highest net return of Rs.131118 and per day return of Rs.511 ha^{-1} were obtained by integrating goat + fish + cropping applied with recycled fishpond silt enriched with goat droppings. Higher net return of Rs. 3.36 for every rupee invested was obtained by integration of pigeon + fish + cropping applied with recycled fishpond silt enriched with pigeon droppings. The poultry, pigeon and goat droppings were utilized as feed initially and at the end of a year after the fish harvest, about 4500 kg of settled silt from each pond were collected. The pond silt was utilized as organic sources to supply sufficient quantity of nutrients to the crops.

Rice - Fish + Azolla Farming system

Field experiment was conducted at Agricultural Research Station, Bhavanisagar to develop an integrated N management practices for rice-fish- azolla farming in wetland. Farming systems consisted of rice - rice + fish and rice - rice + azolla + fish and two levels of N (100 and 75 per cent recommended) with and without green leaf manure (Sesbania rostrata) applications. In the rice - fish system, rice and fish crops were raised together in rice field. Field trenches were provided with 1.0 m depth and 1.5 m width occupying 10 per cent of the rice area, for sheltering the fish. Azolla microphylla was grown in rice field throughout the cropping period.

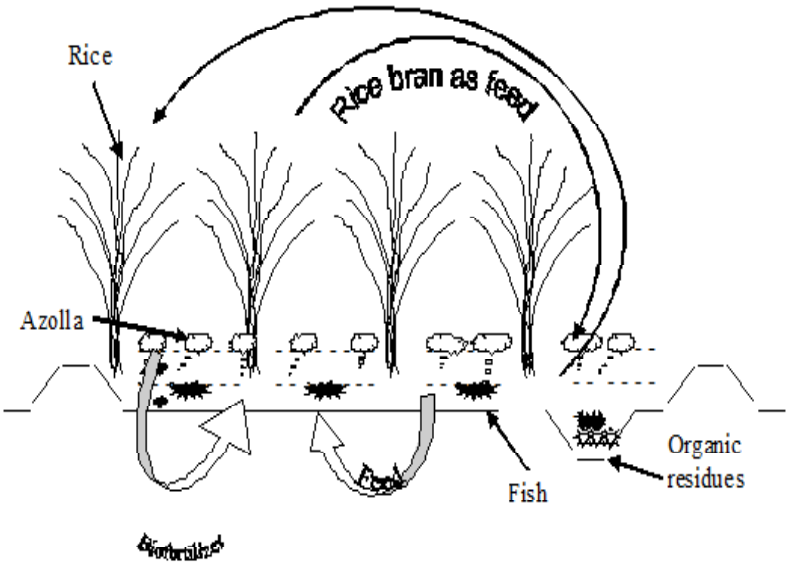

Fig. 2. Fish - Azolla integration in rice field ecosystem

The dual culture method of growing azolla with rice has gained widespread adoptability because standing water is available in rice field from seedling to panicle maturity in lowland rice fields and is effectively used as biofertilizer for rice. Azolla cultivation in rice field can improve the fish food organisms. Fish culture in rice fields loosens the soil as a result of their swimming and thus aerating the soil, enhance the decomposition of organic matter and promotes release of nutrients from soil. The excerta of fish directly fertilize the water in rice fields leading to increase in utlizable source of N to the rice crop. Integration of allied components like azolla + fish with rice in lowland farming could provide wider scope for bioresources recycling (Fig. 2 and 3).

Rice-rice-azolla + fish farming with 75 per cent recommended N as well as incorporation of green leaf manure resulted in higher productivity with increased economic returns and improved the soil fertility through recycling of organic residues. The quantum of organic residue addition and N added through recycling were higher in rice- rice- azolla + fish farming with Sesbania rostrata incorporation. The unutilized fish feed, decayed azolla and fish excreta settled at the fish trench bottom had a higher nutrient value, which can be recycled to enrich the soil (Balusamy,1996).

ii. Cauvery delta zone of Tamil Nadu

The Cauvery Delta Zone comprises of Karur, Trichy, Thanjavur, Tiruvarur, Nagapattinam districts and Aranthagi taluk of Pudukkottai district contributing about 40 per cent of Tamil Nadu rice production. The production of kuruvai (I season) rice is estimated to be 20 lakh tonnes and the productivity during kuruvai is 72 kg grain ha^{-1} day^{-1} and is the highest among other rice seasons. The average rainfall varies from 900 at Grand Anaicut near Trichy to 1200 mm at Nagapattinam. The mean annual rainfall is 940 mm of which 500 mm received from North East monsoon, 350 mm from South West monsoon and 80 mm from summer. The soil is sandy clay loam in texture.

By choosing a viable integrated farming system, it could be possible to sustain the productivity in this deltaic region through recycling of different farm by-products with mixed farming enterprises as a production system in a farm to exploit the complementary economic and ecologic interaction of each enterprise so as to achieve profitability and multiple benefits of the system approach. Research work conducted at the Tamil Nadu Rice Research Institute, Aduthurai during 1987-96 to evaluate different farming system enterprises revealed favorable response to integrated farming systems in the Cauvery delta region. The experiments were

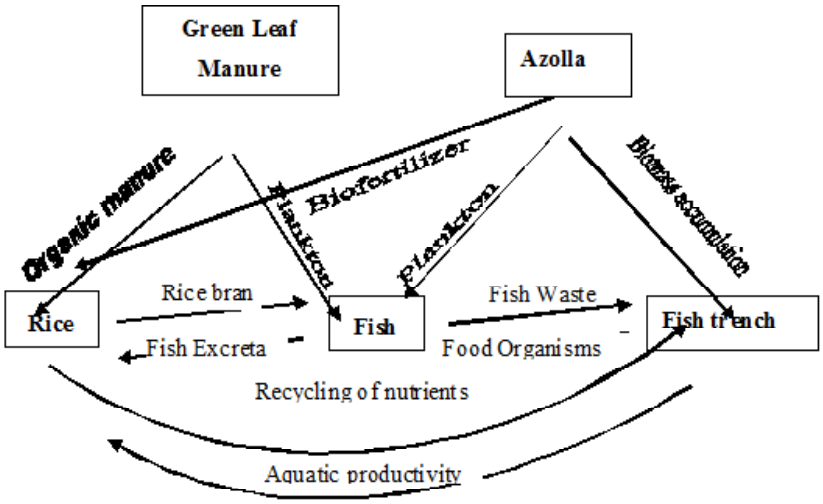

Fig. 3. Bio-resource flow model of Rice-Fish -Azolla integrated farming system

conducted with the objectives to evaluate and identify a biologically feasible and economically viable farming system so as to suit to the deltaic farming situations to augment higher productivity and profitability to the delta farmers. A few feasible integrated farming system (IFS) approaches tested under deltaic condition are discussed below.

Crop + fish + poultry

An experiment was conducted during 1992-1994 in rice based farming system as a demonstration trial at Aduthurai. The components were cropping, fish culture and poultry. An area of 0.40 ha was selected for the farming system study, considering the small and marginal farmers of the state. Conventional cropping as practised by farmers was taken up in an area of 0.96 hectare. In the fish pond with 400 m^2, fingerlings belonging to the species viz., Catla (Catla catla) (200) Rohu (Labeo rohita) (100), Marigal (Cirrbinus mrigala) (100) were stocked. Accordingly the stocking density of fingerlings works to 10,000 ha^{-1} of ponded water without artificial feeding.

A poultry shed was erected over the fish pond at one corner. Bottom of poultry shed was provided with wire mesh (3mm x 3mm) to facilitate free falling of poultry droppings into the pond. Total of 100 Bapkok layer birds were kept in the poultry shed. The birds started laying eggs around 22 weeks and were culled at the age of 72 weeks when the egg productions become uneconomical.

The economics worked out for the system as a whole was Rs.28.983, in which cropping system contributed Rs. 23,709, Poultry and Fisheries contributed additional income of Rs.5,274. Poultry droppings added to the fish pond as feed was 3 tonnes $year^{-1}$ (100g/ birds). Mean number of egg production was 262 $year^{-1}$ $bird^{-1}$. In the case of fish pond (0.04) yield recorded was 234 kg. Of the income obtained from the integrated farming system, 78% was from cropping system and poultry cum fisheries generated additional income and employment (Porpavai et.al., 2000).

Crop + duck + fish culture

Integrated farming system with duck-cum-fish culture as a component was tried during the year 1989. Two farm holdings each with the size of one ha were selected for conducting the study. In one holding, conventional cropping as practiced by farmers was followed. In another one hectare, cropping was practiced in an area of 0.973 ha and an area of 0.027 ha was allotted for duck-cum-fish culture. Economics of IFS was compared with existing cropping systems. Net income of Rs.13790/- was obtained from existing cropping system (Kuruvai-thaladi rice - pulse) and a net income of Rs. 22676/- was obtained from the modified cropping system (Kuruvai - thaladi rice - cotton and maize) with

an area of 0.973 ha allotted for cropping.

The additional profit from modified cropping alone was Rs. 8886/-. From duck-cum-fish culture as a component in mixed farming system, a net profit of Rs.1441/- was obtained from an area of 0.027 ha. Totally an additional income of Rs.10327/- was obtained from the mixed farming system over existing cropping system (Ganesan, 1989).

Crop + milch cows

Another comparative study with rice-rice-pulse as conventional cropping system (CCS) and rice- rice-blackgram/ cotton and NB21 fodder grass and three milch cows as Integrated Farming System were tried. The results revealed that a net return of Rs. 8422/- was obtained form CCS and Rs.10913/- was obtained from IFS. Net return from dairy enterprise was Rs. 8987/-. The additional net income of Rs. 11478/- was obtained from the dairy based mixed farming over the existing farmer's method of cropping (Rajkumar, 1988).

A study by integrating goat (5+1) with crop activity gave a net income of Rs.25, 400 ha^{-1} $year^{-1}$. Additional income over conventional cropping system was Rs. 11, 932 ha^{-1} $year^{-1}$. Similarly in a study, where, sericulture unit was linked with crop activity, the net income was Rs. 22, 426 ha^{-1} $year^{-1}$. Thus, the farmer could get an additional income to the tune of Rs. 9, 951 ha^{-1} $year^{-1}$ (Kuppusamy, 1989). In yet an other study, where, edible mushroom cultivation was linked with crop activity, the net income was Rs. 24,685 ha^{-1} $year^{-1}$. Integration of edible mushroom provided additional income to the tune of Rs.12,977 ha^{-1} $year^{-1}$.

Crop + dairy + goat

Integrated farming system experiment was carried out during 1992-96 with multiple objectives of achieving better utilization of available resources for obtaining maximum returns by integrating crop component with dairy and goat unit, to recycle farm and livestock wastes effectively and providing gainful employment throughout the year and to assure stability in production and return.

An area of one hectare was selected for this integrated farming system (IFS) study. Conventional cropping system (CCS) as practised by the farmers was taken up in an area of 0.2 ha for comparison. Tellicherry goats (5 female + 1 male) at the age of 4 to 5 months were chosen for the study. The goats were fed with 4 kg of green fodder and 1 kg of legume $adult^{-1}$ day^{-1}.

Out of the total income obtained from the IFS, 66 per cent was from crop component and 17 per cent from goat unit. The cost-benefit ratio from crops, dairy and goat units were 2.2, 1.9 and 2.3 respectively. This clearly indicates the feasibility of rearing goats as complimentary enterprise for small farmers of Cauvery delta zone to get additional economic returns. Hence, for the regular flow of income, additional employment generation and also effective recycling of wastes, dairy and goat units would be the ideal complementary enterprises with crop component for the Cauvery delta zone farmers (Sheik Dawood et al., 1996).

Integrated farming system gaining momentum with the farmers of all kinds certainly will reach its peak around 2020 and would help in enhancing the productivity to satisfy the ever-increasing population of the country and creates confidence among the farmers through higher profitability.

CONCLUSION

Indian agriculture is the gift of tropical climate with sufficient sunlight and rains. Inter-governmental Panel on Climate Change (IPCC), in their report mentioned that the mean global temperatures in the next century might increase by 1.4 - 4.0°C over the present century. IPCC Fifth Assessment Report indicated an intensification of the hydrological cycles such that 'wet' areas may receive more precipitation, although the inter annual and intra seasonal variability of rainfall is less certain.

Climate change is likely to have a significant impact on the agriculture, which will vary with intensity of the climate changes. Agriculture, especially crops, displayed a high sensitivity to climate change. Food security is unlikely to be threatened at the global level, but some regions are likely to experience food shortages and hunger. Water resources will be affected as precipitation and evaporation patterns change around the world.Seasonal water scarcity, rising temperatures, and intrusion of sea water would threaten crop yields, jeopardizing the country's food security. Agricultural production must therefore be resilient to rising temperatures, and also to changing rainfall amounts,

patterns, and variability. To sustain food and fibre production, it is important to decrease the vulnerability to climate with appropriate measures. Crop diversification, more efficient water use, improved soil management practices, together with the development of drought-resistant crops can help reduce some of the negative impacts. In this context, Integrated Farming System is a viable option to have climate resilient agriculture.

In view of the untapped agricultural potential, increasing demand for food due to the ever increasing population, differed response of agricultural systems to climate change, the integrated farming system ensure food security and freedom from hunger and malnutrition. IFS transpire agriculture to an era of prosperity, modern and developed India with sustainable climate resilient agriculture.

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