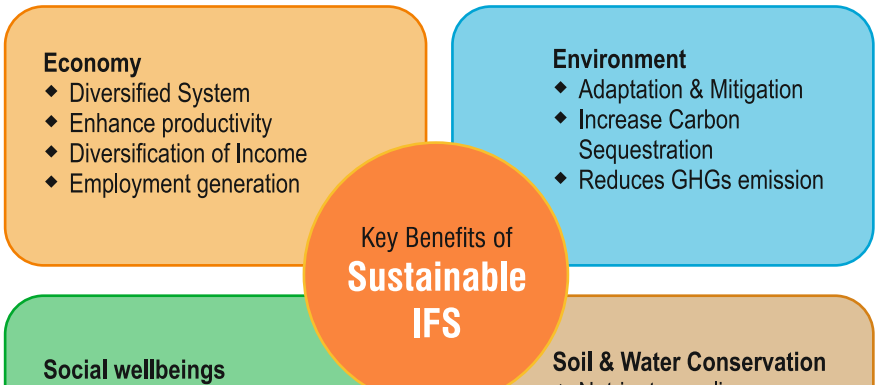

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NRRI Technology Bulletin - 162

Editing : BB Panda and P Panneerselvam

Laser typeset at the National Rice Research Institute, Indian Council of Agricultural Research, Cuttack (Odisha) 753 006, India and printed at Printech offset, BBSR. Published by The Director, for the National Rice Research Institute, Cuttack (Odisha) 753 006.

Crop-Livestock-Agroforestry based Integrated Farming System for Higher Productivity in Lowland Rice Ecologies

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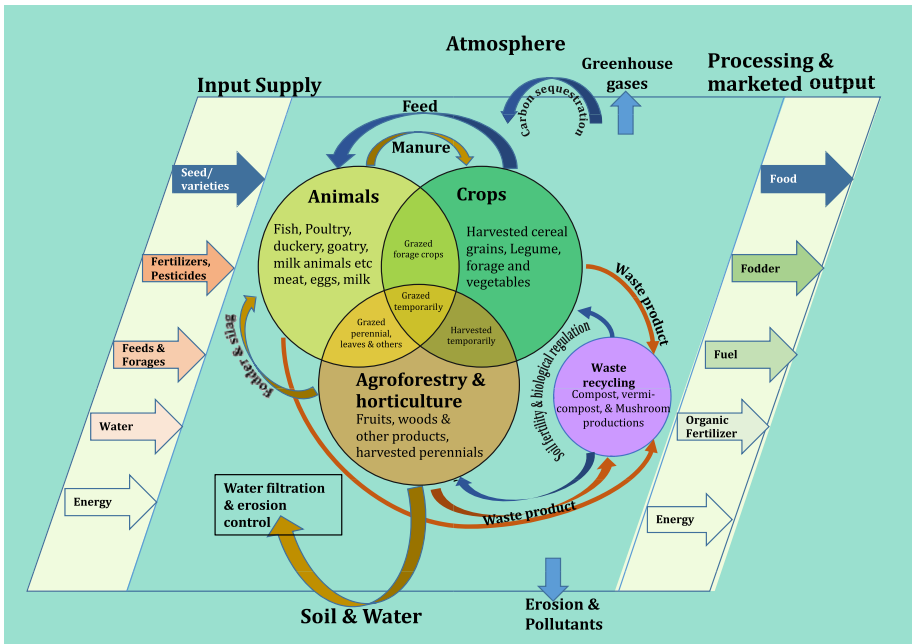

Fig 1. Integration of material flows and eco-system processes in Crop-Livestock-Agroforestry based IFS

Rice is grown in about 44 million hectares (Mha) in India, out of which 40% areas are rainfed lowlands, mostly located in eastern India. Productivity of rice in these rainfed lowland areas are quite low (around 1.5 t ha^{-1}) as it is subjected to a number of biotic, abiotic and socio-economic constraints. ICAR-National Rice Research Institute, Cuttack has developed a crop-livestock- agroforestry based integrated farming system (CLAIFS), which ensures sustainability in production while providing nutritional, economic, employment and environmental security to the farmers. The system integrates three major agricultural enterprises i.e. crop, livestock and agroforestry system. The crop component includes cultivation of rice in main field with improved high yield

potential and submergence tolerant varieties and dry season crops like pulses (greengram and blackgram), vegetables and flowering plants. The livestock component includes fish and prawn farming in pond/water refuge areas and rearing of poultry, duckery and goatry on bunds. The agroforestry component integrates the fruit trees, beneficial forestry trees, root crops and forage/fodder crops in bunds (Fig.1). The system also includes apiary and recycling of organic waste through composting.

Farm site selection, field design and construction

- Medium deep or deep water low lands free from heavy flooding and prolonged water stagnation with clayey soil are preferable.
- Land area of one acre or more with rectangular or square shaped fields are desirable.
- Field design includes wide bunds (20% area) around the field (dykes 2-4 m wide), pond or water refuge connected with trench on two sides (15% of area) and rice fields (65% of the total area) with suitable provision of guarded water inlet and outlet (Fig. 2).
- The duck, poultry and goat shelter houses are constructed with locally available materials (i.e. bamboo, wood and wire net with straw thatching or asbestos top) on the side of the bund projected towards water refuge area for direct droppings.

Production methodologies

- In CLAIFS, the components *i.e.* improved rice varieties, fish, prawn, dry crops after rice, vegetables, fruit crops, agroforestry trees, forage and fodder crops, floriculture, apiculture, and livestocks such as poultry, duckery, goatery etc. are integrated depending upon the farmer needs and suitability/feasibility.
- The wastes generated from the system are optimally recycled using mushroom production, vermicomposting, and other composting (Pit and NADEP) methods.
- The production methodologies, specific managements and suitability of crops/varieties etc. need to be better understood for wider adoptability by the small and marginal farmers and agri-entrepreneurs.

Rice

- Improved high yielding, semi-tall, long duration photo-sensitive rice varieties with in-built tolerance to pest and diseases are mostly suitable. Rice varieties such as Gayatri, Sarala, Durga, Varshadhan and CR Dhan 506 are recommended in wet season. If irrigation facilities are available, farmer can opt for *rabi* season rice (rice varieties such as Naveen, CR Dhan 303, CR Dhan 304, CR Dhan 305 and CR Dhan 306 etc.), instead of other dry season crops (mung bean or vegetables in the main fields). Farmer can select the rice varieties depending upon the agro climatic situation and local needs.

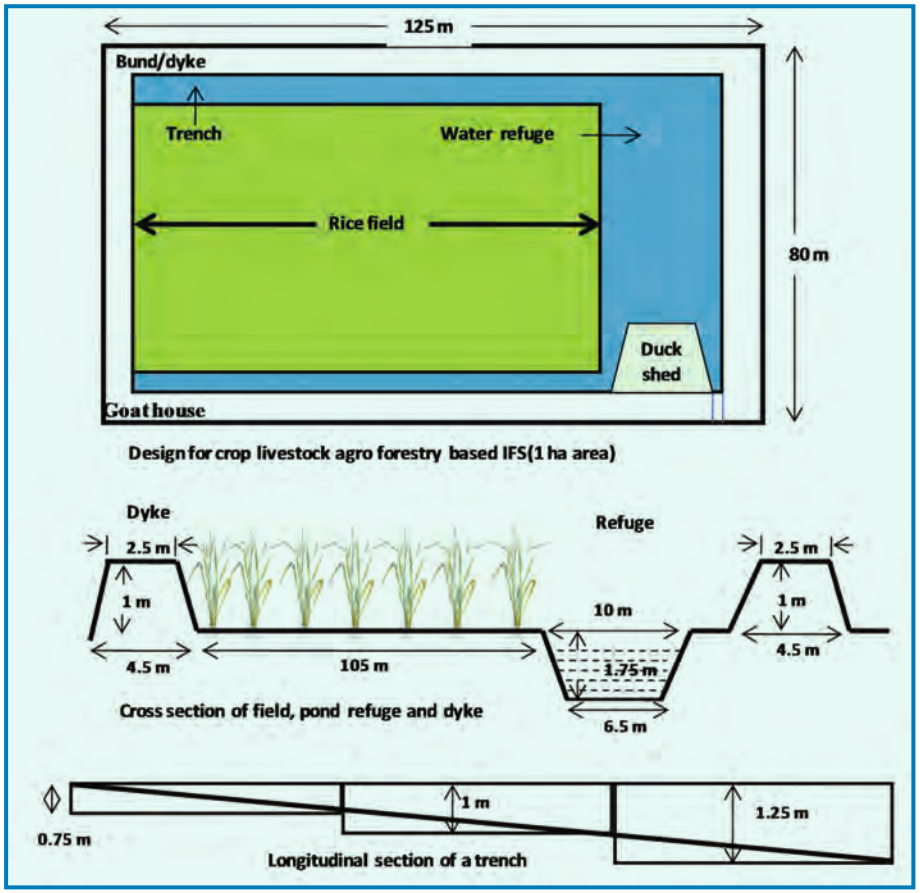

Fig 2. Schematic representation of layout of low land rice-livestock-agroforestry based integrated farming system

Management Practices

Wet season

- Apply FYM @ 5 t ha^{-1} at the time of land preparation.
- In irrigated lands, transplant healthy rice seedling with spacing of 20 cm x 15 cm.
- In rainfed lowlands, do dry seeding with line sowing before the monsoon (@ 75-80 kg seed ha^{-1} with a spacing of 20 cm between the rows).
- Apply fertilizer NPK @ 60:30:30 kg ha^{-1} with N in the three splits (50 % as basal dose, and rest in two equal splits during active tillering and panicle initiation stages) and entire P and K as basal dosages in transplanted rice. In rainfed conditions, apply fertilizer NPK @ 40:20;20 kg ha^{-1} as basal dose only. However, the requirements of fertilizers are substantially reduced in integrated farming system (rice with fish and livestocks).

- Use finger weeder in dry condition and cono-weeder in standing waters (5 cm to 10 cm) for weeding. Avoid using insecticides and herbicides in integrated systems. Use of sex pheromone trap (control yellow stem borer), and neem based botanicals (Nethrin or Nembecidine @ 1%) for controlling stem borer.

Dry season

- Prepare the land with application of FYM @ 5 t ha^{-1} and do puddling for rice transplanting.
- Apply, NPK @ 80:40: 40 kg ha^{-1} with N in three splits (50 % during planting and the remaining in two equal splits during active tillering and panicle initiation stages) and entire P and K as basal doses.
- Avoid using insecticides and herbicides and do manual weeding.
- In the absence of irrigation facilities, *rabi* rice is not recommended, and farmer should practice alternate farming like water melon, groundnut, sunflower, mung bean, okra and pumpkin with limited irrigation from stored rain water in the micro-watershed.

Fish and Prawn culture

- Successful integration of rice with fish farming equally depends upon the pre and post stocking management of fish in rice-fish system.

Pre-stocking managements

- The weeds should be removed manually while unwanted and predatory fishes and other animals like frog, snake, crab and water insects etc. should be eradicated by repeated netting in water refuge area. In absence of proper drainage, application of herbicides i.e. 2, 4-dichlorophenoxy acetic acid, paraquat, aqueous ammonia or diruon etc. may be useful for weed control.
- Prior to release of fish fingerlings and juveniles of prawn, eradicate the predatory and weed fishes using bleaching powder (150-200 kg ha^{-1}, limited water refuge area) or sun drying or application of mahua oil cake (@ 2500 kg ha^{-1}, limited to water refuge area) and prepare the pond with application of lime (@ 200-250 kg ha^{-1}). However, rate of application of lime depends on soil pH (if pH 5.1-6.5 @ 1000 kg ha^{-1}, 6.6-7.5 @ 500 kg ha^{-1}, 7.6-8.5 @ 200 kg ha^{-1} and if soil pH is 8.6-9.5 then no need for application of lime). Apply cow dung slurry @ 5000 kg ha^{-1}, and inorganic fertilizers (30:15:15 kg ha^{-1} of Urea, Triple super phosphate and Muriate potash).
- After 15-20 days of transplanting in July depending on water availability in water refuge area, stocking of fish fingerlings (4-6 inch size, stunted fingerlings) @ 6,000 - 7,000 nos. ha^{-1} with the ratio of 30:30:40 as surface feeder, column feeder and bottom feeder and prawn juveniles @ 2-4 nos./m^2 should be maintained.

- In rice-fish system, a combination of six fish species are ideal (*viz.*, surface feeder - catla (*Catla catla*) and silver carp (*Hypopthalmichthys molitrix*), column feeder - rohu (*Labeo rohita*), bottom feeder - mrigal (*Cirrhinus mrigala*) and common carp (*Cyprinus carpio*), and vegetation feeder (*Puntius javonicus)*, however, addition of compatible prawn juveniles (*Microbrachium rosenbergii* and *M. malcomsonii)* species are also recommended.

Post-stocking managements

- After release of fish fingerlings, supplementary feeds to be provided for 10-15 days within the water refuge area at a rate of 4-5% of their total biomass (total weight of fish fingerlings), and then allowed to roam inside the paddy field. At this stage there must be at least 6-10" water in the field. After that, the supplementary feed should be given at the rate of 1-2% of total fish biomass.
- In rice-fish system, fishes mostly depend on natural feeds (phytoplankton, zooplankton, benthos and detritus) and decomposed organic matters, insect larvae etc. available in the rice fields. However, addition of supplementary feeds (combination of rice bran, oil cake and fish meal; 1:1: 0.5 ratio) @ 2 % of body weight is recommended for achieving better growth of fishes. Integration of rice-fish with poultry, duckery and/or goatery etc. reduces requirement of supplementary fish feed.
- After water recedes from the paddy field, fishes take shelter in water refuge area and can be harvested in the month of November/December. In case of irrigated field, if farmer decides to cultivate *rabi* rice, fish culture can be continued without harvesting the crop or again initiated by releasing newer fingerlings.
- The average fish body weight achieved during wet season (July-December) under rice-fish system depends on period of water retention, introduction of suitable species and their composition in a mixed culture (Table 1).

Duck Husbandry Practice

- Ducks breeds *i.e.* Indian Runner, Khaki campbell (egg layer) or their cross with indigenous local ducks and White pekin (meat type) are preferred, however, selection of duck breeds depends on local availability and farmer's needs.
- In CLAIFS, rearing of 70-80 numbers of ducks (Khaki campbell or White pekin) per hectare is recommended where poultry birds and goats are reared in the same fields. Maintaining sex ratio of 1:10 male and female is ideal for obtaining fertilized eggs.
- Construct night shelter either on embankment projecting towards the water refuge area or in the form of floating duck house, with floor space of 0.5 m^2 per bird, using locally available materials (bamboo, rice straw, wire mesh

Table 1. Growth performance of fishes in rice-fish system with provisioning of supplementary feeds during wet season
(July-December, total 170 days of culture periods)

Fish Species	Weight of fingerlings at release (g)	Weight of fish at harvest (g)	Growth rate (g/day)
Catla (*Catla catla*)	50-75	500-650	3.01
Rohu (*Labeo rohita*)	40-60	330-380	2.08
Mrigale (*Cirrhinus mrigala*)	35-60	300-350	1.62
Cyprinus (*Cyprinus carpio*)	35-60	450-650	2.95
Silver carp (*Hypophthalmichthys molitrix*)	50- 75	500-700	3.15
Punti (*Puntius javanicus*)	15- 20	150-300	1.21
Prawn (*Microbrachium rosenbergii and M. malcomsonii* species	1.5-3.0	50-60	0.31

and asbestos on top cover. Fencing around the rice field peripheries using fish net and bamboo poles (1.5-meter height) may be done to prevent ducks foraging in the fields.

- Allow ducks to forage during day times in the rice fields (as 50 - 75% of their total feed requirement meets from the water refuge and rice fields areas), and feed on duck weeds (*Lemna, Wolfia, Azolla* etc.), aquatic weeds, insects, tadpoles, juvenile frogs, dragon fly larvae and various other organic decomposed materials available in the rice environments.
- Provide supplementary feed (consisting of standard poultry feed or mixture of rice bran and choked etc. @ 2% body weight) daily during evening hour. Moist chaff rice, vegetable waste, horticultural waste and kitchen waste etc. are also used for feeding ducks.
- Ducks lays eggs after attaining age of 24 - 28 weeks and continued laying until 360 - 380 days old. With provisioning of balanced nutrient supplementary feeds, Khaki campbell attain 2.2 - 2.8 kg body weight and lays average 300 eggs per year with eggs weight ranging from 60- 70 grams. Meat varieties (White pekin) attain 3.0 - 3.5 kg after one year.
- Each duck voided about 130 - 150 g excreta per day. The duck excreta that contains 81% moisture, 0.91% nitrogen, 0.54%phosphorus and 0.38% potassium, act as an organic fertilizer for rice. It also stimulates plankton growth which act as fish food and helps in reducing the cost of productions.

Poultry husbandry

- The breeds/type of poultry bird to be reared depends on farmer choice (i.e. broiler or layer birds or both mixed types. The breeds of Rhode Island, Leghorn, Black rock and Vanraja are suitable for rearing in rice based system.
- The poultry shed should be constructed using local available materials (bamboo, wood and thatched roofs with floor space of 0.2 0.3 m^2 $bird^{-1}$) adjoining to the bund area. Rearing of 50 - 75 nos. poultry birds ha^{-1} rice fields is ideal when combined with other enterprises (duckery and goatery) in a farming system.
- Procure one day old chicks from hatching farm and do brooding for 3 - 4 weeks (with a desirable temperature, adequate feed, drinking water and space), and then reared in rice based farming system with provisioning of supplementary feeds (poultry feed, waste rice, chaff rice including vegetable wastes etc).
- Layer birds are reared up to 18 months and each bird lays approx. 210 - 250 eggs per year. The broiler type bird after 2 - 3 months of rearing attains 2.5 - 3.5 kg of weight and sold in the market. The farmer may continue 2 - 3 cycles in a year.

Goat husbandry

- Goatery is another important livestock enterprise that can be taken up in CLAIFS for enhancing the profitability of the system.
- About 20 numbers of Black Bengal Goat (20 females: 1 male ratio) is ideal for rearing in rice based farming system. However, indigenous local goat breeds i.e. Malkangiri goat, Koraput Hill goat, Ganjam Hill goat, Raighar goat, Narayanapatnam goat, Phulbani goat and Dorangi goat etc. can be reared in the farming system depending on their availability and ecological conditions of the system.
- Construct goat shed using local materials in the bund area (space requirements for female goat: 1.0 - 1.2 m^2, male buck: 1.8 - 3.2 m^2 and kids 1.5 m^2). However, while raising goat shed, wooden plank should be fixed one and half feet above the ground for easier collection of droppings and maintenance of dry environment during night shelter for goats.
- Do stall feed daily with 3 - 4 kg of green fodder, 1 - 2 kg of dry fodder and 200 - 250 grams of ready-made seeds as concentrates. In case of partial stall-feeding, at least 50 percent of the above quantities should be fed to goat.
- The concentrate feed ingredients include: groundnut cake, maize, sorghum, broken rice and wheat grains.
- In addition to the grains, goat required green cereal fodders (hybrid napier, guineagrass, sorghum, bajra, etc.) and legume fodders (stylo, barseem, hedge lucerne, cowpea, Desmanthus) and some tree fodders (velvel, seemaikaruvel, arasu, subabul, agathi, glyricidia, vagai, karuvel and kodukapuli etc.) for achieving better growth.

- Goats are prolific breeders and produce 2-3 young ones in 6-9 months' intervals.
- Under proper management, goats can improve and maintain grazing land and reduce bush encroachment and weeds.
- Female goat attain 12 - 14 kg and castrated male attain 16 - 17 kg in a year. Normally, goat attains 5 kg within 3 months, 7 kg in 6 month and 12 kg in 12 months. Goat provides good quality manure (12 kg animal^{-1}) with a daily load of 0.7 kg of dropping day^{-1} with nutrient contents of 3.0% N, 1.0 % P and 2.0 % K.

Components on bund

Vegetables: Location specific seasonal vegetables such as okra, gourd, radish, brinjal and leafy vegetable is proffered. During winter tomato, french bean, radish, pumpkin and leafy vegetables can be grown.

Fruits: Dwarf papaya (Pusa dwarf, Pusa majesty, Pusa nanha, CO-2, Coorg and Honey Dew), banana (Cavendish, Robusta or tissue cultured, Poovan, Bonthal), coconut (TxD), arecanuts, guava and improved mango are found suitable for the system.

Fig 3. Fruit trees as a component in Integrated Farming System

Agroforestry : *Acacia mangium*, *A. auriculiformis*, *Eucalyptus globulus* are ideal for lowland system and planted 2 - 3 meter apart east to west on northern and north to south on western side of the bunds. Prune the tree every year and leaves are used as fodder or composting. In shaded areas, turmeric, ginger, amorphophallus, yam, colocasia and pine apple can be grown.

Gourds : Creeper vegetables such as snake gourd, bitter gourd, ridge gourd, bottle gourd, ash gourd and pumpkin etc. can be grown on the extended platform over the water refuge area or seepage gallery.

Mushroom : Straw mushroom (*Volvariella* spp) - 30 days after sprouting yields 2.0 - 2.5 kg per bed) during March to September and Oyster mushroom (*Pleurotus* spp.) yields 2.0 - 2.5 kg per bed during October to February in thatched house.

Apiculture : Two to three bee boxes can be kept inside the farm and honey can be harvested at regular intervals.

Floriculture : Marigold and tuberose can be grown bunds.

Fodder grass : Fodder like Napier, Gunia grass, Legume fodder Cowpea/ lobia can be taken up on bund areas.

Waste recycling : Organic wastes generated from farming systems are converted into high quality manure through vermicomposting or peat composting.

Productivity and Economics

The system requires initial investment of Rs. 2.0 lakhs and annually produces 18 - 20 t of food crops, 0.6 t of fish and prawn, 0.6 - 0.9 t of meat and 10,000 numbers of eggs. The system productivity is around 28.5 t rice equivalent yields (REY) per hectare, which is 3.9 times higher compared to traditional rice-rice farming system (7.3 t REY ha^{-1}). The benefit - cost ratio varied from 2.9 - 3.4 depending upon the extent and type of integration. It also generates 400 - 500 man days ha^{-1} yr^{-1}. The proportionate area and income generation by the individual enterprises are presented in Table 2. Thus, the system could sustain the production, while providing nutritional, economic, employment and environmental security to the farmers.

Table 2. Percentage share of area and income from crop-livestock agroforestry IFS

Enterprises	Area share (%)	Income share (%)
Cropping system	65	49
Livestocks	8	20
Others	27	31

Water budgeting and water use efficiency

The rainwater stored in the water refuge area are utilized for life saving irrigation to dry season crops taken up both in fields and bund areas, fish culture and animal rearing purpose. The total harvested water in the pond refuge area of 1500 m^2 (average depth of 150 cm) was 2250 m$^{3.}$ Irrigation requirements for dry season crops in the field was around 25%, and the other components on bund was 17% including 5% water use in livestock rearing. The water loss due to percolation and evaporation was around 38%. Thus, the total water saving was around 20% in crop livestock agroforestry system under shallow water table conditions of Mahanadi delta region. The CLAIFS improved water use efficiency and gross water productivity (GWP) Rs. 13.31/m^3.

Salient features and benefits of technology

- The crop-livestock agroforestry integrated farming system increases farm productivity by 15 - 20 times and net income up to 20 folds over the traditional system of rice farming.

- This system is an eco-efficient and eco-friendly synergistic one which promotes the recycling of wastes within the system.
- CLAIFS enhances productivity, sustainability and climate resilience. The positive interaction among various components improved soil health, soil nutrient status and bio-control of weeds and insect pests, substantially reduced the inorganic chemicals in agriculture and mitigate the impact of climate change.
- The integrated farming system generates additional farm employment round the year for farm families.

Impacts : The impact analysis of IFS indicated the system is productive, energy and water use efficient with bio-control prospecting of weeds and pests (Table 3). Additionally, the system also 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

Table 3. Eco-efficiency rating and ecosystem service functionalities in crop-livestock-agroforestry based Integrated Farming System

Sl. No.	Components of ecosystem functions	Rating	Comments
1	Biodiversity	+++++	Use of improved variety, crops, animals, agro forestry, horticultural plant, fodder
2	Soil quality & nutrient management.	+++	Use of less inorganic manure, increase of SOM, residue recycling.
3	Water conservation & water productivity	++	Rain water harvest and storage for reuse
4	Addition of organic manure & residue management.	+++	Animal components added organic manure continuously to the system, Farm residues composted for use
5	Bio control of weed	++	Fish, duck and poultry controlled the weed population substantially
6	Bio control of pest	++	Fish, duck & poultry controlled the pest population substantially
7	Carbon sequestration	++++	Org. manure & agroforestry enhances carbon sequestration
8	Energy-use efficiency	++++	Higher efficiency as compared to conventional system farming
9	Reduction in Green house Gas potential	++++	Higher in RFD and agroforestry system
10	Resilient to climate change	+++	Higher resilient, biodiversity, water conservation etc.
11	Crop Pollination	+++	Higher with inclusion of apiary unit
12	Crop productivity	++++	Higher REY as compared to Conventional system

RFD = Rice-fish-duck, REY = Rice equivalent yield, (+ denotes ecosystem service rating in rice mono-cropping; ++ to ++++ denotes comparative enhancement of ecosystem service in IFS as compared to rice mono-cropping)

greenhouse gases (GHG) and global warming potentials. 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 the reasonable time frame.

Up scaling

In India, various type of region-specific farming systems with varied enterprise combinations in respect to topography and agro-climatic conditionare available. Rice-based IFS including crop-livestock-agroforestrybased IFS (CLA-IFS) models developed by ICAR-NRRI for enhancing productivity and profitability for small and marginal farmers has been validated and implemented in commercial enterprising modes. At present, Govt. of India operationalized various innovative schemes, like Rastriya Krishi Vikash Yojana (RKVY), National Horticulture Mission (NAM) and other various scheme at State Govt. levels, which provides an opportunity for promotion and development of Integrated farming systems. Additionally, National Mission for Sustainable Agriculture (NMSA) is expected to transform Indian agriculture into a climate resilient production system through suitable climate adaptation and mitigation measures in the domains of crop, livestock's husbandry and agroforestry with rational use of natural resources (conservation and sustainable use) through adoption of integrated farming systems.

Conclusion

Integrated crop-livestock-agroforestry systems (CLAIFS) could foster crop diversity, synergy and mutual benefits between enterprising components with profitability and sustainability. These systems are climate-resilient, eco-efficient and less labour intensive which relies on waste recycling with lesser dependence of non-renewable resource, and enhances the farm productivity, ensures livelihood security, diversify and enhances farm income and maintain overall sustainability. The CLAIFS is having potentials for climate change resilience and mitigation options and thus enables the farmer's participation in climate risk management for building a climate resilient production system.