NRRI Research Bulletin No. 24
February 2020

Rice based Integrated Farming Systems in Eastern India

A Viable Technology for Productivity and Ecological Security

Prafulla K. Nayak
A.K. Nayak
Anjani Kumar
Upendra Kumar
B.B. Panda
B.S. Satapathy
Annie Poonam
S.D. Mohapatra
Rahul Tripathi
M. Shahid
Dibyendu Chatterjee
P. Panneerselvam
Sangita Mohanty
Sunil K. Das
H. Pathak

माकृअनुप ICAR
ICAR-NATIONAL RICE RESEARCH INSTITUTE
CUTTACK, ODISHA, 753006, INDIA

NRRI Research Bulletin No. 24

Rice based Integrated Farming Systems in Eastern India: A Viable Technology for Productivity and Ecological Security

Prafulla K. Nayak, A.K. Nayak, Anjani Kumar, Upendra Kumar, B.B. Panda, B.S. Satapathy, Annie Poonam, S.D. Mohapatra, Rahul Tripathi, M. Shahid, Dibyendu Chatterjee, P. Panneerselvam, Sangita Mohanty, Sunil K. Das and H. Pathak

भाकृअनुप
ICAR

ICAR-NATIONAL RICE RESEARCH INSTITUTE
CUTTACK, ODISHA, 753006, INDIA

February 2020

Correct Citation

Nayak Prafulla K, Nayak AK, Kumar Anjani, Kumar Upendra, Panda BB, Satapathy BS, Poonam Annie, Mohapatra SD, Tripathi Rahul, Shahid M, Chatterjee Dibyendu, Panneerselvam P, Mohanty Sangita, Sunil K. Das, Pathak H (2020). Rice Based Integrated Farming Systems in Eastern India: A Viable Technology for Productivity and Ecological Security. NRRI Research Bulletin No. 24, ICAR-National Rice Research Institute, Cuttack-753006, Odisha, India. pp 44.

Published by

Director
ICAR-National Rice Research Institute
Cuttack-753006, Odisha, India

February 2020

Editing, layout and photography
Sandhya Dalal, S.K. Sinha and B. Behera

Printed in India at Print-Tech Offset Pvt. Ltd.,
Bhubaneswar, Odisha 751 024.

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

भारत सरकार
कृषि अनुसंधान और शिक्षा विभाग एवं
भारतीय कृषि अनुसंधान परिषद
कृषि एवं किसान कल्याण मंत्रालय, कृषि भवन, नई दिल्ली 110 001
GOVERNMENT OF INDIA
DEPARTMENT OF AGRICULTURAL RESEARCH & EDUCATION
AND
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
MINISTRY OF AGRICULTURE AND FARMERS WELFARE
KRISHI BHAVAN, NEW DELHI 110 001
Tel.: 23382629; 23386711 Fax: 91-11-23384773
E-mail: dg.icar@nic.in

FOREWORD

Food and nutritional security in the present context of increased demand of growing population is a crucial challenge. Due to gradual shrinking of land holding, there is limited scope for horizontal expansion of land for increasing food production. Rice mono-cropping system has become non-remunerative besides its associated disadvantage. Rice based multi enterprise system has been developed for its productivity enhancement, income generation and long-term sustainability. This needs to be validated and up scaled in the regions of eastern India through innovative extension and policy back up.

ICAR-National Rice Research Institute, Cuttack has developed adoptable technologies of rice based integrated farming system for enhancement of farm productivity, income and employment in different rice ecologies. This institute has developed field design and production technology of different farming system models which has been successfully demonstrated to increase the productivity, enhance livelihood security and profitability.

This publication on "**Rice based Integrated Farming Systems in Eastern India: A Viable Technology for Productivity and Ecological Security**" published by ICAR-National Rice Research Institute, Cuttack, Odisha highlights case studies of different rice-based farming system models. Impact analysis in terms of energy footprint, water use efficiency, global warming potential and ecosystem services are also discussed in this bulletin. I hope that the bulletin will help in understanding the ecosystem functioning of different rice based Integrated Farming Systems with enhanced productivity and sustainability. I appreciate the authors for their efforts in bringing out this useful publication that would serve as a reference material for different stakeholders.

(T. MOHAPATRA)

Dated the 17th February, 2020
New Delhi

PREFACE

In the scenario of declining trend of availability of land for agriculture and size of land holding, one of the serious threats to our national food security is providing food and nutritional security to our growing population. Diversion of agricultural land to cater the need of rapid industrialization limits land resources for agriculture and restricts further horizontal expansion. Thus vertical integration of land-based enterprises within the socio-economic environment of small and marginal farmers is the only option. Integrated farming systems (IFS) are viewed as a sustainable alternative for enhancing livelihood security of small and marginal farmers with the objective of reversing resource degradation and stabilizing farm incomes with efficient soil management, recycling of farm wastes and nutrients with minimization of adverse environmental impacts.

ICAR-National Rice Research Institute has developed need based IFS technologies which has immense potential for improvement of rural economy due to intensification and integration of crop and allied enterprises. Adoption of modern rice based farming system approach helps the farmers to understand the interaction and linkage of different farm resources which helps in resource recycling and ultimately leads to reduction of input cost and enhancement of productivity and profitability of the system. Synergistic interactions among the different farm resources leads to bio resource recycling which ultimately reduces the ecological footprint of the farming systems. Integrated farming system provides sustainability in production along with economic, employment, nutritional and environmental security to small and marginal farmers. However, the adoption of farming system models depends on different social (labour availability, risk involved, social acceptability etc.) and economic factors (credit flow, cost of input, marketability and price of produce etc.).

This research bulletin highlights various rice based farming systems developed and their possible impact on sustainability in term of efficient use of energy, water, nutrient and ecosystem services towards the benefit of small and marginal farmers. This bulletin can also serve as a useful reference material for farmers, researchers, extension workers and policy planners, who are interested to take up or implement rice based farming system as a tool for improving productivity, profitability, employment generation and livelihood security of farming community. This can also show the pathway for achieving an evergreen revolution leading to an increase in productivity in perpetuity without associated ecological harm in future.

Authors

CONTENTS


DURGA

1. Introduction

The declining trend in size of land holding and diversion of agricultural lands for other uses poses a serious challenge to Indian Agriculture in terms of food and livelihood. With this continued trend the average size of holdings is expected to further decline to 0.32 ha by 2030 (Agriculture Census, 2010-11). With the limited scope for horizontal expansion, only vertical expansion of agriculture is the possible way for ensuring food and livelihood security.

Rice (*Oryza sativa* L.) is one of the major cereal crops, cultivated in 114 countries across the world (150 million hectares, 11% of total area) (Pathak et al., 2018). About 90% of the world's rice is produced and consumed in Asian countries and is mostly cultivated by small and marginal land holders for their livelihood security. It is evident that intensification of mono-culture of rice production system leads to anthropogenic alterations that negatively impact the soil physico-chemical and biochemical indicators resulting in loss of biodiversity and degradation of natural resource base, making farming unsustainable in the long run. The Integrated Farming Systems (IFS) therefore assumes greater importance for poor small and marginal farmers for sustaining their production system. Farming system represents the integration of agricultural enterprises such as cropping systems, livestock, aquaculture, agro-forestry, agri-horticulture and apiary in an optimum combination. This bulletin is an attempt to compile information on system productivity, profitability, livelihood security, environmental integrity and sustainability of different farming systems having different enterprises suitable for different ecologies and farmers' socio-economic needs.

2. Principles of Integrated Farming System

Integrated Farming Systems is based on commodity-based production system combined with compatible components essentially functioning under three principles (i) It is cyclic in nature

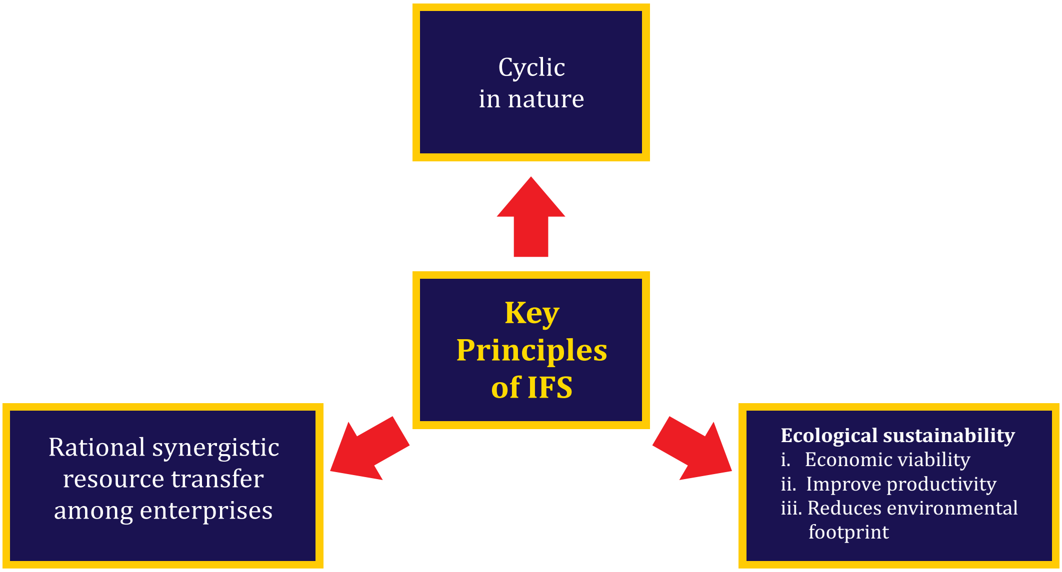


Fig. 1. Principles of Integrated Farming System

(ii) It exploits synergy among the enterprises and (iii) It ensures sustainability (Fig. 1).

3. Objectives of Integrated Farming System

The objectives of IFS is to ensure rational utilization of land, water, biodiversity, genotypes along with social and human resources combined with best available technologies and ecological management practices for sustaining farming for improving livelihood security of small and marginal farmers.

4. Challenges of Integrated Farming System

The successful adoption of IFS is facing challenges of declining land holding size. Developing IFS model for small holders with enterprise optimisation needs proper system design, development and validation. Vast diversity of social and cultural environment in India is one of the factors required to be considered while framing IFS models. Integrated Farming System design and implementation needs some initial and regular investments hence, requires proper credit availability. It involves various enterprises, which needs to be suitably integrated and managed. Therefore, farmers/entrepreneurs need to be technically empowered through the provisioning of suitable training and demonstration. Small and marginal farmers cannot move to market very often to sell their produce because of low value of produce, cost of transport and labor input in marketing. Hence, establishing market chain for round the year marketing of farm product at farm gate is an important issue which needs to be addressed. Some IFS requires security from wild animals and theft. If the farm family is not staying in the system then security remains a major challenge.

5. Evolution of Integrated Farming Systems in India

The rice farming is one of the most evolved sustainable agriculture in Southeast Asian continents over 6000 years ago. Subsequently, different rice-based integrated farming system evolved in India (Table 1).

Table 1. Evolution of rice-based Integrated Farming Systems in India

Sl No.	Indigenous system	Characteristics of the system	Prevalent area in India
1.	Shifting Cultivation	Shifting cultivation or Jhum cultivations are the primitive practice in tribal population in hill region of India. The method involves cutting and clearing of vegetative/forest trees cover on land/slopes, drying and burning before the monsoon and used for cultivation of arable crops for few years. After crop harvest, lands are left fallow and regeneration of vegetation allowed till the plot reusable for the same crop cycle. After few years of cultivation the area is abandoned and again practiced in some other areas. This leads to destruction of forest cover in the hill slope and causes severe soil erosion and ecological degradation.	Hilly areas of north east region.
2.	Taungya cultivation	"Taungya cultivation" is a word originated from Myanmar ('taunga', means hill and 'ya' means cultivation i.e hill cultivation). It involves raising and establishing forest crops temporarily associated with raising other arable crops in the same lands. This was later introduced in Chittagong hills, Bangladesh and also practiced in Asia, Africa and Latin America. The system provide temporary produce from the land and generates employment along with scope to participate in diversified and sustainable agro-ecosystem. This form of agro-forestry system provides short term gain of generating early income, control weeds and reduces establishments of the woody forest plants.	Myanmar, Bangladesh, Asia, Africa and Latin America
3.	Zabo cultivation	The term Zabo (impounding runoff water) in hill region and considered as a most efficient method for water and soil conservation and prevalent mostly in Nagaland area. The rain water is collected from catchment areas and stored in the slope of hill by creating a pond, and later used for irrigation. This system combines various components of agriculture (Fishery, horticulture and animal husbandry). It has an inbuilt water harvesting and recycling systems with provision of soil, water conservation principles and ecological balances.	Nagaland area
4.	Apatani pani Kheti	Apatani farming system, practiced mostly by women farmers also called as water farming (Pani Kheti) - a rice cum fish culture. The fish mostly include common carp, *Cyprinus carpio* released to the rice fields, cultured and harvested depending on water availability.	Arunachal Pradesh

5.	Bheries or Bhasabandha system	The systems involve impounding of adjacent creek/ canal having natural brackish water for fish and prawn along with the traditional wet season rice farming. Productivity of rice is around 1.0 t/ha and fish and prawn approx. 100-200 Kg/ha (Jhingran and Ghosh, 1987).	Sundarbans area, West Bengal
6.	Pokkali system	In Pokkali farming, rice (salt tolerant rice) is cultivated from June to early November (when water salinity level is low) and prawn farming from mid-November to mid-April (when the salinity is high). The prawn seedlings enter through the flow of the backwaters after the rice harvest, feed on the leftovers of the harvested crop. Water flow from the field control through installing sluice gate. For rice crops, no fertilizer or manure is added, and the nutrients are met from the rice straw and the prawns excreta left from the previous cycle. The productivity of rice (0.7 to 1.0 t/ha), fish and prawn (0.5 -2.0 t/ha) which provides good returns with less investments (Dehadrai, 1988).	Kerala State

6. Modern Farming Systems

Modern farming systems are based on integration of more than one crop or different enterprising components aiming for promoting higher productivity and farm income and provisioning of ecological sustainability with risk minimization. It combines the activities of crops and horticulture, animal husbandry, fishery, forestry and other components. Broadly, the rice-based integrated farming systems (RB-IFS) grouped under four categories: *i.e* intercropping system, livestock based cropping system, Silvipastoral - livestock system (agro-silvipasture) and rice-fish-livestock-agroforestry based IFS (Table 2).

Table 2. Different rice-based farming systems in India

Sl No.	Modern farming system	Characteristics of the system	Reference
1	Intercropping system	Intercropping is the multiple cropping with more than one crop at a time utilizes inputs more efficiently and more profitably and reduces risk of crop failure.	Ahmed et al. 2007; Nimbolkar et al., 2016; Xu et al. 2017.
2	Livestock- crop based system	Livestock-crop based farming system is a predominant farming system in India. Both crop-livestock enterprise complement each other through mutual benefits, the animal component often raised on byproduct and agricultural wastes, while animal provides manure to be used as manure and fuel. Animal manure increases soil organic carbon thus, enhances soil fertility and water holding capacity which supports plant growth.	Kochiwad et al., 2017; Jayanti et al. 2000.

3	Silvi-pastoral based system	Silvi pastoral based farming system with improved pasture species or mixture of grasses are grown along with perennial trees on same piece of land. It involves grazing of animals and looping of tree leaves for fodder.	Ramasamy et al., 2007.
4	Rice-fish-livestock integrated farming system	Integrated Rice-Livestock-Fish farming aims at enhancing farm productivity from a limited area and reducing risk by diversifying crops and provisioning of water harvesting through the pond and seepage area etc.	Mahajan et al., 2012; Korikantimath et al., 2008.

7. Case Studies: Rice-Fish based Integrated Farming Systems

Production of fish in rice fields is almost a primitive practice in India. Indian farmers mainly depend on rainfed farming having high risk of weather uncertainty. Over the years, farmers evolved the techniques of rice fish integration mostly in lowlands. The aquatic environment available in rice fields are suitably utilized for fish culture providing additional income along with production of rice. The rice-fish technology is practiced in many rice-growing belts of the world including China, Bangladesh, Malaysia, Korea, Indonesia, Philippines, Thailand and India. Among the various farming system options in rice ecologies, rice-fish farming having a great potential in eastern India considering its ecology, available resources, food habits, socio-economic and livelihood conditions of small and marginal farmers.

ICAR-National Rice Research Institute, Cuttack has developed following adoptable rice based Integrated Farming System by integrating various enterprises to ensure sustainability in production, nutritional, economic, employment and environmental security for farmers.

(i) Rice- ornamental fish culture

(ii) Crop-livestock-agroforestry based IFS for lowland rice ecologies

(iii) Rice-fish-duck IFS

(iv) Rice –fish –*azolla* –duck IFS

(v) Multitier rice-fish horticulture based IFS

(vi) Rice based IFS under irrigated condition

7.1. Rice- Ornamental Fish Culture Technology

Ornamental fish, having an aesthetic value provides a lucrative business in India due to its export-oriented opportunities. At present, aquarium fish production is far behind the actual demand in domestic and international markets, which provides an ample opportunity for boosting trade and especially empowering women farmers. Lack of awareness and suitable production technologies are the major constraint. The waterlogged rice ecology harbors good source of food organisms (insect, pest and their larvae), which provides a natural environment for breeding and culture of the ornamental fishes. ICAR-NRRI has developed a breeding and culture technology for ornamental fishes in rainfed waterlogged and irrigated rice ecologies.

7.1.1. Site Selection, field design and construction

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 shaped field with an area of 500 m^2 to 1000 m^2 is desirable. A water refuge area (10 x 8 x1.5 m depth) is constructed on one side of the rice field using about 15% of the total area of the rice field. The dug-out soil is spread to make a strong dyke with a height of about 30-50 cm or more depending on highest flooding level. Soil compaction and grass pitching should be made on the side of the bund to avoid soil erosion.

7.1.2. Production methodologies

High yielding, semi-dwarf (in irrigated ecology), semi-tall and long duration rice varieties (in lowlands) with in-built tolerance to pest and diseases are grown with ornamental fishes. Rice varieties such as Naveen, Lalat, IR 36 and IR 64 are suitable for irrigated areas. Varieties like, Gayatri, Sarala, Durga and Varsha Dhan are grown in medium deep lowlands in wet season. In both the seasons, crop management practices are practiced as same as rice-fish culture system. Before starting culture, the water refuge area is fertilized with cow dung slurry and NPK @ 100:50: 25 kg ha^{-1} periodically to stimulate the plankton growth. The healthy specimen of ornamental fishes @ 1:1 ratio of male and female are reared in the rice fields with at least 15 cm of water depth (Nayak et al., 2008). The stock feeding daily @ 4% body weight with a pallet feed comprising of a mixture of rice bran (25%), groundnut oil cake (40%), wheat flour (4.4%), fish meal (30%), mineral mix and vitamins (0.1%) and plain butter (0.5%). The ornamental fish species used in this technology are as follows:

a) *Gouramies*

Gouramis are egg layer species that lay greenish colored eggs in bubble nest in water during breeding season. After the eggs are laid, male gourami sprays milt and fertilize it. After hatching, larvae comes out and later swim freely after some time. Gouramies 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 temmincki*) have been introduced and successfully reared in the rice field. The gourami breeds during month of June to August. The hatchling release from the egg mass after 20-25 hours depending on the water temperature. The fry are recovered after two months. The juveniles are reared in the rice field using the same management practices as followed for adults, and grow to adult size within four to six months.

b) *Fish Guppies*

Guppies are live bearer and are 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 colored tail fins. Guppies naturally breed round the year in waterlogged rice field. Juveniles are reared for two months till attainment of marketable size.

c) *Other Ornamental Fishes*

Some of the ornamental fishes that have potential for culture in rice fields includes the Gold fish (*Carassius auratus*) and Koi carp (*Cyprinus carpio Var. Koi*) in different colour combinations, barbs like rosy barbs (*Puntius conchonis*) and tiger barbs (*Puntius tetrazona*) and danios such as zebra danio (*Brachydanio rerio*) that is indigenous to the rice ecology. Popular live bearer molly (*Mollinesia* sps 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 maculates* 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.

7.1.3. Productivity

About 1 to 2 lakh numbers of ornamental fish and approximately 3 t to 5 t rice grain yield can be produced per ha of land. The total profit from this system ranges from 1.5 to 2.5 lakhs/ha depending upon the kind of ornamental fish species and extent of management. The benefit cost ratio (B:C) was 2.5 in rice cum ornamental fish culture. The ornamental fish controls various pests and insect larvae including mosquito larvae in the rice fields as an additional benefit.

7.2. Crop-Livestock-Agroforestry Integrated System for Lowland Rice Ecologies

ICAR-NRRI has developed crop-livestock-horticultural and agroforestry-based IFS (CLAIFS). The system integrates improved rice varieties, vegetables, fruit crops, agroforestry, floriculture, apiculture, fish, prawn, poultry, duckery, goatry. This system provides greater scope for diversification and climate resilience along with increase in farm productivity, income and sustainability (Kumar et al., 2018; Nayak et al., 2018a).

7.2.1. Farm site Selection, field design and construction

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 ha and more is desirable. Field design includes wide bund (dykes 2-4 m wide) all around (20% area), pond or water refuge connected with trench on two sides (15% of area) and rice fields (65% of the total area) and are guarded with water outlet. The duck and poultry houses are constructed on the bund having projection to facilitate dropping fall directly in the pond water (Fig. 3). The goat house is constructed on the bund using bamboo, wood and wire net with straw thatching or asbestos top.

Fig. 2. Crop-livestock-agroforestry based farming system for lowland rice ecologies

7.2.2. Production methodologies

High yielding, semi-tall, long duration photoperiod-sensitive rice varieties such as Gayatri, Sarala, Durga,Varsha Dhan and CR Dhan 506 in wet season (*Kharif*) and Naveen, CR Dhan 303, CR Dhan 304, CR Dhan 305 and CR Dhan 306 during dry season (*Rabi*) are recommended. The farmer can select the rice varieties depending upon the suitability to the agro climatic situation and local needs.

In the absence of irrigation facilities, carry out *rabi* season rice operation are difficult and the farmer should take up alternate farming like watermelon, groundnut, sunflower, mung bean, okra and pumpkin with limited irrigation from stored rain water in the micro-watershed. A combination of fish species, *viz*. surface feeder - catla (*Catla catla*), silver carp (*Hypopthalmichthys molitrix*), column feeder-rohu (*Labeo rohita*), bottom feeder - mrigal (*Cirrhinus mrigala*) and common carp (*Cyprinus carpio*), vegetation feeder

(*Puntius javonicus)* and prawn juveniles of *Microbrachium rosenbergii* and *M. malcomsonii* are ideal for culture. The field is eradicated from predatory fishes, weeds and applied with cow dung slurry and NPK fertilizers. Fish fingerlings @ 6,000 -7,000 numbers/ha are stocked with the ratio of 30:30:40 as surface feeder, column feeder and bottom feeder. Prawn juveniles @ 2-4 numbers/m^2 are desirable. Supplementary feeds consisting of rice bran, oil cake and fish meal (1:1:1 ratio) @ 2.2% body weight are provided. However, rice fields are integrated with poultry, duckery and goatry that decreases the requirements of supplementary feeds for fishes. In CLAIFS integrated system 70-80 numbers ducks (Khaki Campbell or White pekin) (with ratio of 10 female : 1 male) can be raised along with poultry and goats.Ducks may be allowed to forage in the rice fields during the day time and shelter in duck shed during night time (for detail duck management see section 7.3).

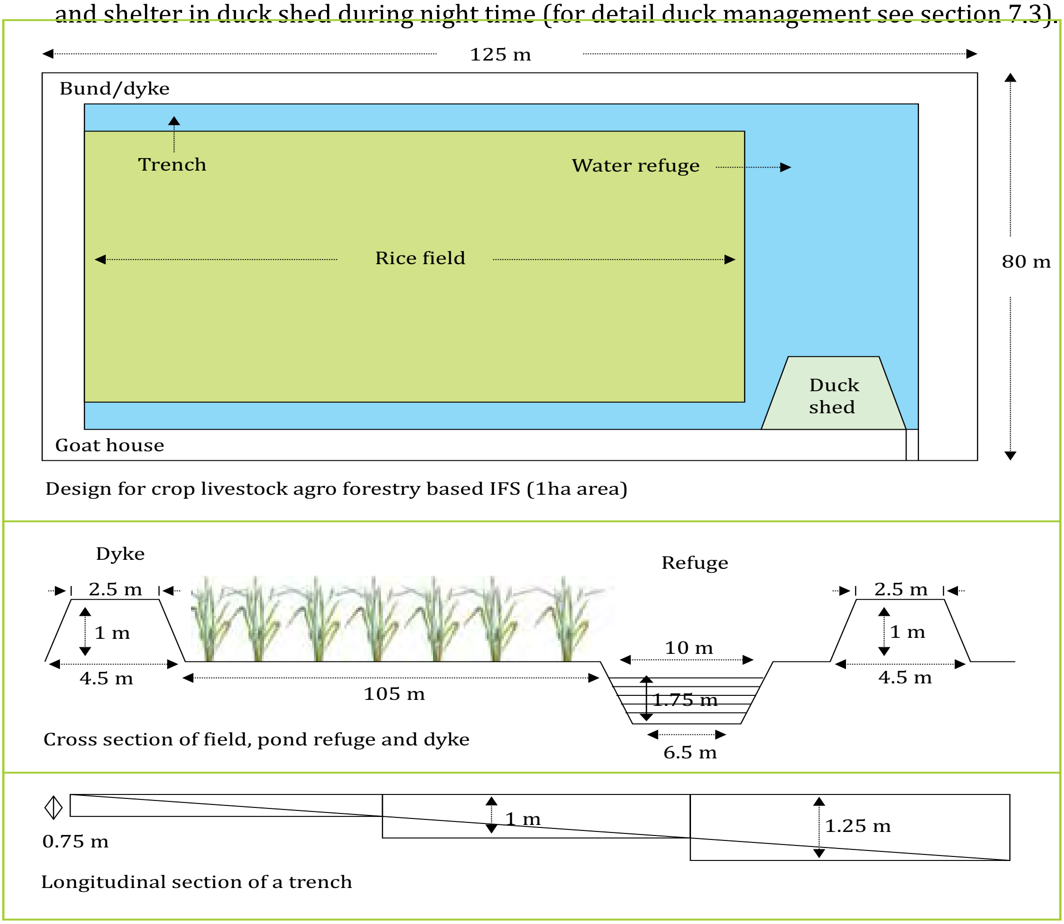


Fig. 3. Schematic representation of layout of Lowland Rice-Livestock-Agroforestry based IFS

7.2.3. Poultry husbandry practices

- The chick varieties either meat type (broiler), egg type (layer) or both mixed types depends on farmer choice. The breeds of Rhode Island, Leghorn, Black rock and Van raja are suitable.

Fig. 4. Poultry species integrated in farming system

- One-day old chicks are procured from the chick hatching farms and brooding up to 3–4 weeks with a desirable temperature, feed, drinking water and space, after which they are reared in rice based farming system by providing supplementary poultry feed, waste rice, chaff rice including other vegetable wastes etc. Poultry shelter can be prepared using bamboo, wood and thatched roofs with floor area of 0.2-0.3 m^2 /bird. 50-75 numbers birds/ ha rice fields is desirable taking into consideration of other enterprises and feed availability and management point of views.

- Layer birds are reared up to 18 months and each bird lays approx. 210-250 eggs/year. The broiler type bird after 2-3 months of rearing attains 2.5-3.5 kg of weight and can be disposed for meat purposes and the operation system is continued in a cyclic phase

7.2.4. Goat husbandry practices

- Goat is a multi-functional animal and plays a significant role in the economy and nutrition of landless, small and marginal farmers in the country. Goat rearing is an enterprise which has been practiced by a large section of population in rural areas. Goats can efficiently survive on available shrubs and trees in adverse harsh environment in low fertility lands where no other crop can be grown.

- In rainfed rice-based farming system (1 ha area) 10-20 number of goats (20 females: 1 male) are suitable.

- The Black Bengal Goat breed is suitable for rice based lowland farming system because they can adopt themselves with almost all types of climate easily. Goats are prolific breeders and breed in 6-9 months intervals and produces 2-3 young ones.

Fig. 5. Goat species integrated in farming system

- Under proper management, goats can improve and maintain grazing land and reduce bush encroachment and weeds.

- Providing stall feeding can ideally fit into the intensive IFS. If the goats are completely stall-fed they should be given around 3-4 kg of green fodder, 1-2 kg of dry fodder and 200-250 grams of readymade feeds as concentrates. If the goats are partly stall-fed and partly free range then 50 per cent of the above quantities should be fed to goats.

- Growing suitable agroforestry species (subabul, babul, shevari etc.) and green fodder (grasses, legume and lobia) with goat rearing will be profitable by providing adequate fodder and saving the concentrated feed cost.

7.2.5. Components on bund

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

b) Horticulture: Dwarf papaya (Pusa dwarf), banana (Cavendish, Robusta or tissue cultured), coconut (TxD), arecanuts, Guava and improved mango are found to be suitable for the system.

Fig. 6. Different horticultural trees as a component in Integrated Farming System

c) Agroforestry: *Acacia mangium*, *A. auriculiformis*, *Eucalyptus globulus* are ideal for lowland system.

In addition to above, periodically grown Moshroom; Apiary; Floriculture; Creeper vegetables; Tuber crops in shade area: (Amorphophallus, Yam, Colocasia, Termaric, Ginger); Fodder: (Napier, Gunia grass, Legume fodder Cowpea/ lobia) can be taken up at bund area.

Fig. 7. Vegetable and flower components in IFS

d) Mushroom cultivation: Mushroom are highly delicious and nutritious and having good market demands. Two types of mushrooms i.e. Oyster mushroom (Pleurotus spp.) and paddy straw mushroom (Volvariella spp.) are suitably grown in bund area in rice-based IFS and provide additional income.

Oyster mushroom cultivation methods includes soaking of chopped straw in water for 12 hours, followed by sterilization, water draining and spreading mushroom spawn in between the straw layers (3-4 layers) in the polythene bag having 10-15 holes in the tops and hanging in a rope. Water sprayed twice daily regularly for maintaining moisture content. In the span of 30 days 2.0 to 2.5 kg of mushroom was harvested.

For cultivation of straw mushroom includes soaking of straw bundle (2 ft length) for 12 hours in water, sterilize, drained completely, making bed on bamboo frame and placing straw and mushroom spawn along with pulse powder (pegion pea/Bengal gram/ horse gram) alternatively for 3-4 layers and covered with transparent plastic polythene sheets (removed after 6-7 days). Water sprayed daily (twice) for maintaining moisture levels in the bed. Within span of 30 days after sprouting yielded 2.0 to 2.5 kg/bed.

Fig. 7a. Mushroom cultivation and Vermi-composting in IFS

e) Vermicompost and compost peats:

Organic wastes generated from IFS converted in to high quality manure through vermicomposting or making composting in a peat. Vermicomposting unit set up in bund tree shaded area using vermibed (purchased from market) or constructing tanks using brick with standard size (12 ft x 4 ft x 2 ft) with adequate provision of drainage facilities. Bottom layer were filled with loamy soil (15 cm) followed by organic waste and cow dung (10 cm each) for 3-4 layer, covered with banana leaves and kept moist with spraying water daily. The vermi worm *Esenia foetida* (epigeic species) inoculated with 2-3 kg worm per bed. After 3-4 months high quality vermicompost have been harvested and use in plant growth.

7.2.6. Productivity and economics

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

7.3. Rice–Fish-Duck Integrated Farming System Technology for Lowland Rice Ecologies

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.

Fig. 8. Integrated rice-fish-duck farming system model at ICAR-NRRI, Cuttack

7.3.1. Farm site selection, field design and construction

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 a 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 escape of fishes from the rice fields and to prevent 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 entering to the rice field area.

7.3.2. Production methodologies

Improved rice varieties, fish and prawn species already discussed in CLAIFS (section 7.2) are followed in RFD IFS. The duck husbandry practices specific to the RFD are discussed here.

Fig. 9. Duck foraging in rice-fish-duck IFS

7.3.3. Duck husbandry practices in rice-fish-duck IFS

- Duck varieties Indian Runner, Khaki campbell,White pekinor indigenous local ducks, stocking density of @ 200- 250 numbers (10:1, female and male) are suitable for rice fish duck integration.

Fig. 10. Duck feeding on a*zolla* in Integrated Farming System

- Night shelter for ducks can be constructed on the dyke projecting towards water refuge area or over the water refuge area having at least 0.5 m2 of floor space per bird using locally available materials (such as bamboo, rice straw and using wire mesh).

- Ducks may be allowed to forage in the rice fields during the day times.

- Duck fed mostly on duck weeds (Lemna, Wolfia, Azollaetc.), 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.

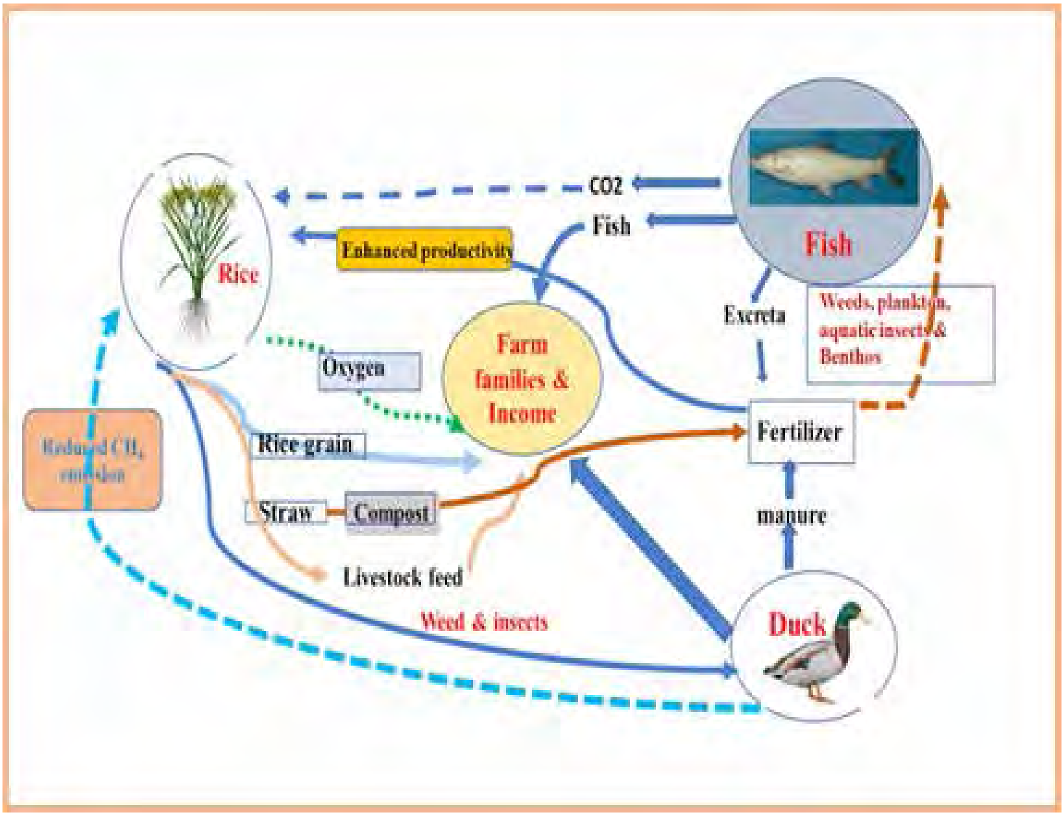


Fig. 11. Recycling of nutrients and energy flow in Rice-Fish-Duck IFS

- Additionally, supplementary feed consisting of standard poultry feed or mixture of rice bran etc. at 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 which reduces cost of other feeds. Care should be taken that wet feed should not be left out and carried for the next day.

- Peripheries of rice fields along with water refuge area should be fenced for proper protection as well as preventing duck to forage in adjoining rice fields.

7.3.4. Mechanism of system function

In RFDIFS farming technology, ducks and fish in rice field creates 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.

7.3.5. 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 25000 eggs. The benefit-cost ratio was 2.5 – 2.8 depending upon the extent of integration and their managements.

7.4. Rice-Fish-*Azolla -d*uck Integrated Farming System

Since CLAIFS requires substantial cost involvements for system maintenances (fertilizer, feed for animals and fish etc.), and aiming further reduction of costs, ICAR-NRRI has developed a rice-fish-*Azolla*-duck based IFS (RFAD-IFS) models involving minimum operational costs. The mutualism and synergies among the enterprises (rice-fish-*Azolla*-duck) are mentioned in Fig. 13.

Fig. 12. Azolla –rice interaction in IFS

7.4.1. *Azolla*

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 1100 kg N/ha /year to the plants) are making plant unique and considered as one of the best bio-fertilizer, feed for livestock and biofuel.

7.4.2. Functional mechanism of RFAD-IFS in rice field

The integration of duck, fish and *azolla* in the rice field creates symbiotic relationship. Rice-fish, duck and *azolla* provides mutual benefits to all the entities. The ducks and fish bioturbation (rapid movement) and presence of *azolla* in the rice ecosystem enhances the concentration of dissolve oxygen in water, resulting aerobic conditions, which decreased methanogens bacterial activity and subsequently decreases the GHG emissions. Azolla used as one the feed components for animals reared (fish, duck, poultry, goat and diary etc.) in the systems. *Azolla* in the rice fields provides substantial amount of nitrogen for rice growth and reduces weed infestations. The integrated system enhances biological diversity leading to augmentation of nutrient mineralization through faster decomposition of organic matters, thereby enhances the release and availability of nutrients to supports better growth and productions. The RFAD-IFS utilizes the maximum ecological niches, increases soil and water nutrient levels and fertility, provides healthy ecosystem services and reduces the GHG emissions, hence, increases the farm productivity and sustainability.

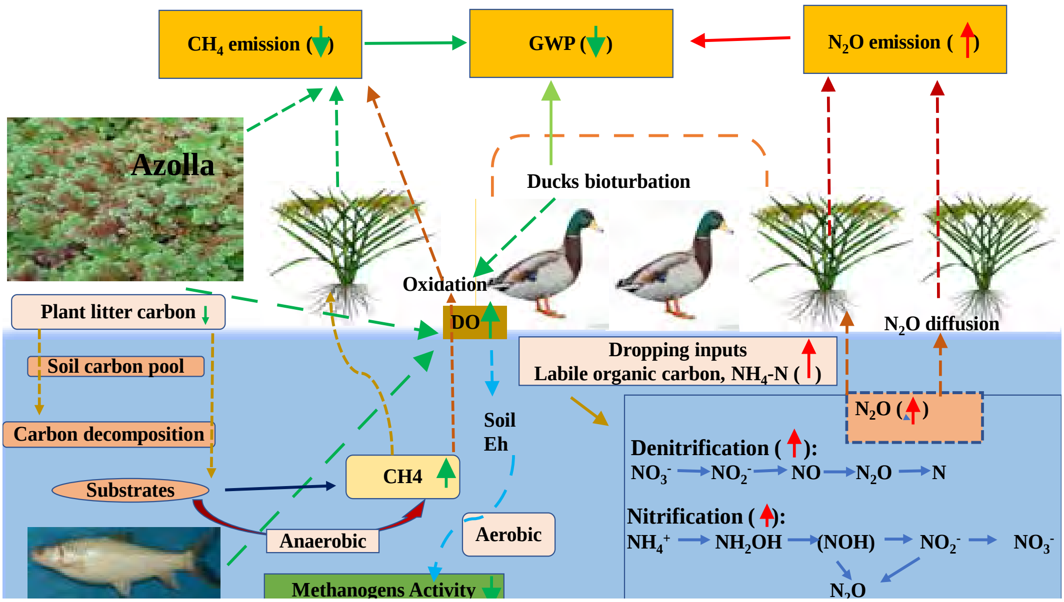


Fig 13. Mechanism frame work in reduction of Global warming potential (GWP) in RFAD-IFS

7.4.3. Economics

RFAD-IFS in rice-rice system annually produced 9-10 t of food crops, 0.7 t of fish & prawn, 0.6-0.7 t of duck meat and 25000 eggs. The benefit-cost ratio was 2.7 – 3.0 depending upon the extent of integration and their managements.

7.5. Multitier Rice-Fish-Horticulture based IFS for Deep Water Areas

Deep water rice is grown in about 4 mha in India and mostly located (3 mha) in eastern regions of the country with very low productivities (0.5- 1.0 t ha^{-1}). To enhances the productivity from these areas (50- 100 cm depth water), a multitier rice-fish –horticultural, agroforestry system has been developed at ICAR-NRRI.

The design includes digging of soil for micro-water shed and shaping the soil to create different tiers (upland, medium lowland and deep-water rice environments) for integrating various components. The land shaping includes in the form of an upland (Tier I and Tier II, 15% of the field area), rainfed lowland (Tier III, 20%, up to 50 cm water depth), deep water (Tier IV, 20%, up to 50 – 100 cm water depth), micro-watershed (20% area) and raised wide bund (25%) surrounding the entire fields area. The watershed includes bigger ponds connected to the rice fields for raising fishes and smaller ponds used for fish seed and fingerling raising.

Improved high yielding varieties of rice are grown depending on ecologies and tier, rainfed lowland rice (Gyatri, Sarala) in tier III and deep-water rice (Durga, Varshadhan, CRDhan 500, Maudamani) in tier IV alongwith fish and prawn during wet season. Dry season crops

Fig. 14. Multitier rice –fish farming system for deep water areas

(sweet patato, mung bean, groundnut, sunflower, watermelon and season specific vegetables) are undertaken in tier III and IV. Harvested rain water stored in micro watershed used for irrigation of crops. Improved horticultural plants (mango, guava, coconuts, arecanuts, sapota), seasonal fruit crops (papaya, banana, pineapples) and seasonal tuber crops (elephant foot yam, sweet patato, colocasia and greater yam) are cultivated in tier I and tier II. In side of the bund area, agroforestry tree (*Acacia mangium*) are planted on northern side of the plot. Different varieties of fish are cultured in the bigger micro watershed pond, however smaller one utilized for fish nursery raising and raising fish fingerlings.

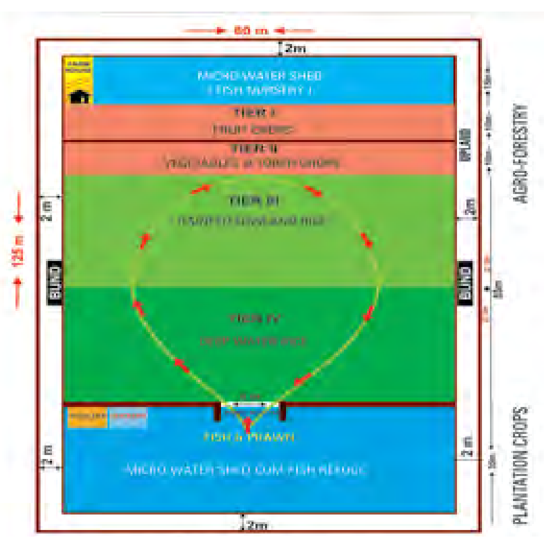


Fig. 15. Design for rice-fish-horticulture based IFS model for deepwater rice ecology

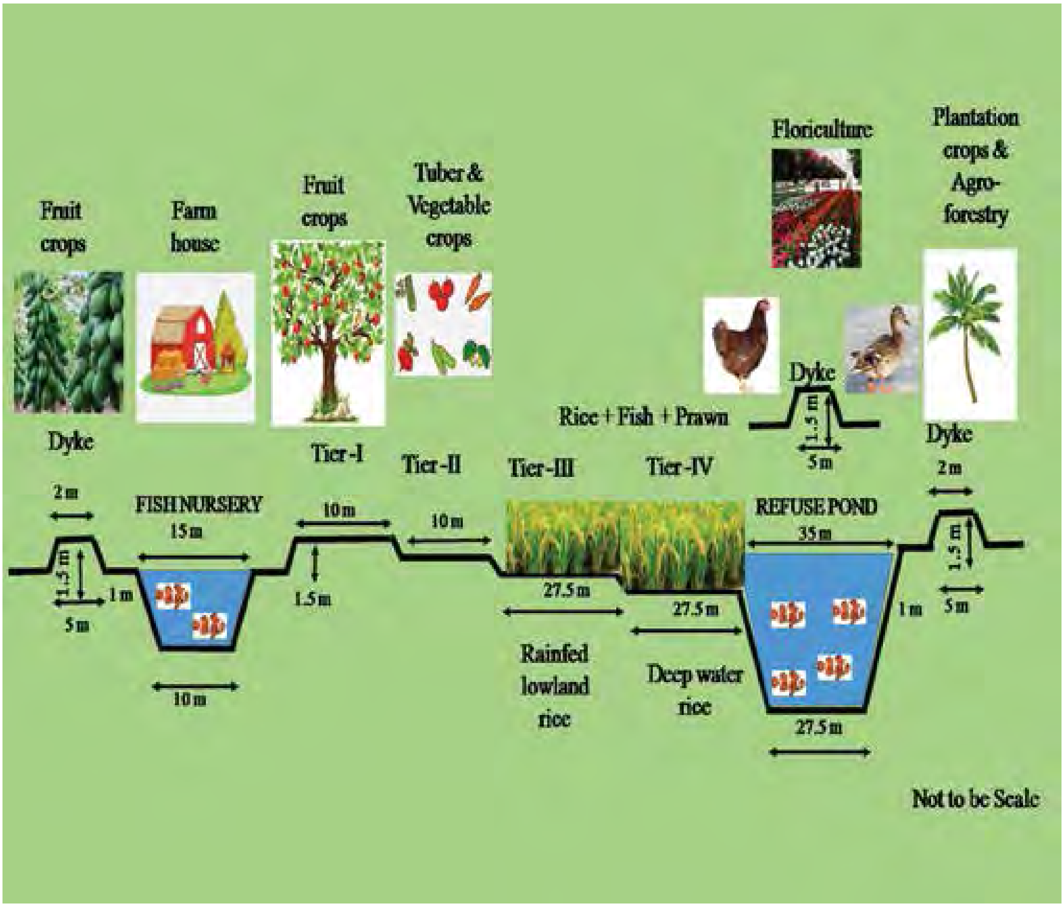


Fig. 16. Cross section of Multitier rice–fish based IFS

7.5.1. Productivity and economics:

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 of eggs in addition to others like straw, fiber and fuel woods. The benefit cost ratio was 2.0-2.5, and generating 350 man days/ha/year.

7.6. Rice based Integrated Farming System under Irrigated Condition

With the development of agriculture, irrigation facilities for agriculture has been increased many folds. Under the irrigated condition, water availability is not a major constraint; hence suitable designing of the land resources might yield better crop intensification and higher productivity. Keeping view of the above, ICAR-NRRI, Cuttack developed rice based integrated farming system in irrigated area for higher productivity and improving livelihoods of farmers.

Fig. 17. Rice based IFS model for irrigated areas

7.6.1. *Production methodologies*

To reorient the farming system in irrigated ecology (1 acre), the 30% area land is converted to two rice plus fish fields (of 600 sq. m area each with a refuge of 15% area), another 30% area is converted into two numbers of fish nursery ponds for fingerling rearing and rest 40% area is utilized as bunds for growing vegetables, horticultural crops and agroforestry. The system utilized for three rice crops in the sequence of *kharif* rice (Sarala/Durga) followed by *rabi* (Naveen/Satabdi) and summer rice (Vandana/Sidhant). Indian major carps (*Catla catla, Labeo rohita and Cirrhinus mrigala*) are reared to fish fingerlings using two fish nursery ponds. Horticultural plants (lemon, guava, mango, jackfruit and litchi and banana, papaya and arecanut) and agroforestry plants (teak, *Accacia*, sisoo, neem, anola and bamboo) are planted on northern and southern side of the farms only to avoid effect of shadings. During the period varied seasonal vegetables are cultivated on bund area. The system is also integrated with bird components having 40 numbers of poultry and 20 numbers of ducks.

7.6.2. *Productivity and economics*

The system produces 8-10 q of rice grains, 1.0 q of fish, 0.5 q of meat, 14 q of vegetables and 0.9 q of fruits besides others straw and fuel woods etc. The benefit-cost ratio was 2.2 and generate approx. 500 man days/ha/year.

8. Impact Analysis of Integrated Farming Systems

In the present scenario it is important to meet the growing demand for food in a manner that is socially equitable and ecologically sustainable over the long run. To achieve this objective, here we analyzed farming systems and their impact on several aspect of sustainability.

8.1 Energy footprint and efficiency

Indiscriminate use of chemical fertilizers and pesticides/herbicides and increasing mechanization for agricultural operations is progressively making the modern agriculture system less energy efficient. The direct energy use in various agricultural operations includes fuels and electricity mostly required for performing various tasks related to land preparation, irrigation, harvest, postharvest processing, transportation of agricultural inputs and outputs etc. and indirect energy is the energy consumed in the manufacture processes, packaging and transport of fertilizers, seeds, machinery production and pesticides etc. The integrated farming system comprising of the rice-fish-duck (RFD) was found to be more energy efficient as compared to conventional mono cropping system of rice farming (RMC). RFD utilized higher renewable energy (52841.3 MJ/ha, 70.62 %) and lesser non renewable energy (21975.6 MJ/ha; 29.37%) as compared to conventional rice mono-cropping system that utilizes less renewable energy (15690 MJ/ha; 44.4 %) and higher non-renewable energy (19938 MJ/ha: 55.96 %) (Nayak et al., 2018c).

Table 3. Energy balance in different Integrated Farming Systems

Items	Unit	RMC	RFD
Energy input	MJ ha^{-1}	35629.4	92448
Energy output	MJ ha^{-1}	105516	347154
Grain yield (REY) (rabi+ kharif)	Kg/ha	7178	16420
Energy efficiency	-	2.96	3.75
Energy productivity	-	0.201	0.177
Specific energy	-	4.96	5.63
Net energy	MJ ha^{-1}	69887	272337
Direct energy	MJ ha^{-1}	6033.1 (16.9%)	5306.2 (7.0%)
Indirect energy	MJ ha^{-1}	29596 (83.1%)	69510.7 (92.9%)
Renewable energy	MJ ha^{-1}	15690.9 (44.40%)	52841.3 70.62%)
Non-renewable energy	MJ ha^{-1}	19938.5 (55.96%)	21975.6 (29.37%)

MJ : Mega Joule per hectare; REY : Rice equivalent yield; RMC : Rice monocropping

The findings of the present study showed that IFS (RFD) is more energy efficient as compared to the conventional rice farming which has also been corroborated by others (Bailey et al., 2003; Deike et al., 2008; Channabasavanna et al., 2010; Alluvione et al., 2011, Reddy et al., 2018).

8.2. Water use efficiency and quality

Rainwater harvesting, conservation and judicious use of existing available water resources can improve the water productivity. The rice-fish based integrated farming system models developed at ICAR - NRRI provides a provision of rain water harvesting, storage and conservation of water that ensures higher water productivity (WP), gross water productivity (GWP) and net water productivity (NWP) as compared to conventional system (Table 4).

Table 4. Water productivity in conventional rice farming and IFS

Treatment	WP (kg m^{-3})	GWP (Rs m^{-3})	NWP (Rs m^{-3})
Conventional farming	0.390	5.854	1.235
Integrated Farming System	0.872 (2.325)	13.310 (2.273)	7.272 (5.888)

Values in bracket indicates times higher in water productivity in Rice-fish- livestock agro forestry based IFS as compared to the rice-mono cropping. WP : Water Poductivity; GWP : Gross water productivity; NWP : Net water productivity

8.3. Bio-control prospecting of Weed and Pests

In the integrated farming system (RFD), inclusion of fish and duck decreases the weed density and enhances weed control efficiency (Fig. 18). Presence of fish and ducks in the IFS enhances the bio-control efficacy in controlling rice insect pests in *rabi* rice. It was observed that the number of rice plant leaf rolled by the rolling insect pests/hills was reduced (Fig.19). Insect pest of Brown plant hopper (*Nephotettix nigropictus)*, Zig zag leaf hopper (*Recilia dorsali)*, rice leaf roller (*Cnaphalcrocis medinalis)*, stem borer (*Scirpophaga incertulas), (Chilo suppressalis*) can be biologically controlled in RDF model and thus, application of pesticides/ herbicides can be avoided.

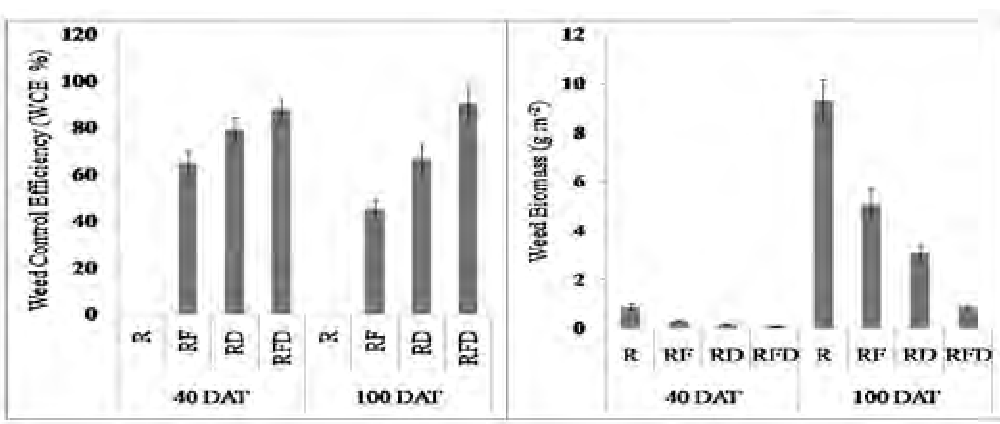


Fig. 18. Weed biomass and weed control efficiency in rice-fish-duck IFS (R : Rice; RF : Rice fish; RD : Rice duck; RFD : Rice fish duck; DAT : Days after transplanting)

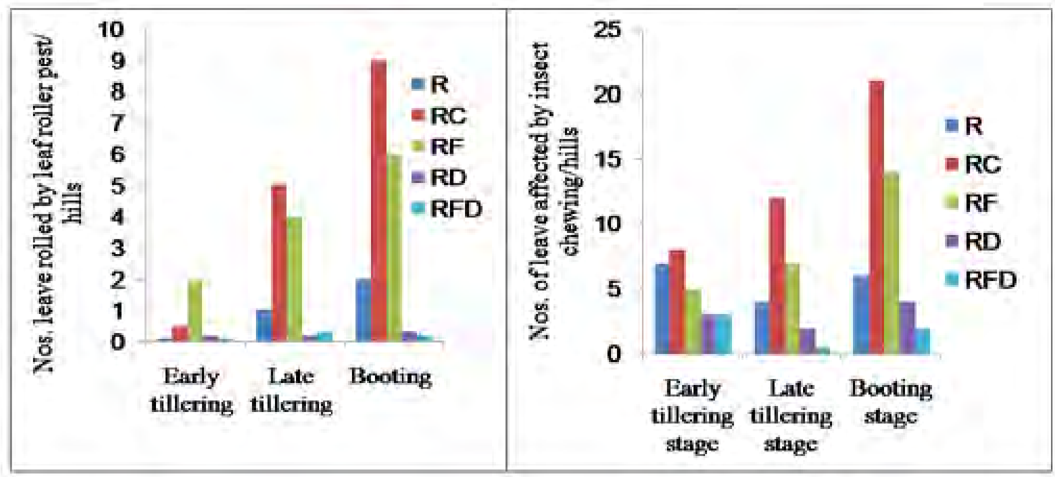


Fig. 19. Bio-control of insect pests under rice fish duck IFS (R : Rice; RF : Rice fish; RD : Rice duck; RFD : Rice fish duck; DAT : Days after transplanting)

8.4. Greenhouse gas emission

Rice-fish integrated systems are helpful for mitigation of emissions of different greenhouse gases. Higher rate of application of fertilizer, pesticide and herbicides in conventional monoculture rice farming is the major source of methane and nitrous oxide emissions (Bhattacharyya et al., 2013; Kumar et al., 2016). Reduced fertilizer rate and the aeration of the soil by the activity of the fish are responsible for the reduced emissions. In rice-rice conventional system, total GWP (6069.13 kg CO_2 equivalent ha^{-1}) was higher as compared to the rice-fish-duck IFS (5333.8 kg CO_2 equivalent ha^{-1}) suggesting substantial reduction of global warming potential (Table 5).

Datta et al. (2009) reported rice-fish integration leads to 12 % increase in methane emissions, while nitrous oxide emissions were reduced by about 10 %. Conversely, 60 % methane emission reduction (from 4.73 to 1.71 mg m^{-2} h^{-1}, monoculture vs rice-fish) was observed (Huang et al. 2001). However, looking to closer spatial resolution, the fish refuge area contributed larger emissions (13.10 mg m^{-2} h^{-1}, 175% increase), but, when entire integrated system taken together the emission of methane from the rice-fish system was 34.6 percent less than that from monoculture rice fields (Lu, 2006).

Improved crop-livestock integration and integrated manure management practices can improve the efficiency of nutrient utilization; reduce the need to import nutrients from outside the farm; and decrease emissions from crop production (Soussana et al. 2015). These practices include improving animal health and herd management, improving animal diets by more digestible feeds with higher feed use-efficiency reduces enteric fermentation per unit of product and is generally lower in integrated systems. Mixed crop-livestock integration reduces methane emission by 30 % in South Asia and 14 % in east Africa through better integration of production components (Mottet et al. 2016). It has been reported that inclusion of agroforestry system (crop-livestock- agroforestry IFS) as additional component, significantly reduces the effects of global warming potential (Carson et al. 2014; Xu et al. 2017).

Table 5. Component wise GHG emission in conventional and rice-fish-duck Integrated Farming System.

Items	Mode of Operation	CO_2 (kg ha^{-1})	N_2O (kg ha^{-1})	CH_4 (kg ha^{-1})	GWP (kg CO_2 equivalent ha^{-1})
Kharif Rice (Conventional)	Dry seeded	1264.13	1.35	55.18	3045.93
Rabi Rice (Conventional)	Transplanted	1093.29	1.17	63.25	3023.20
Total		2357.42	2.52	118.43	6069.13
Kharif Rice (RFD)	Dry seeded	1157.36	1.05	49.24	2701.26
Rabi Rice (RFD)	Transplanted	977.18	0.82	56.44	2632.54
Total		2134.54	1.90	105.68	5333.8

RFD : Rice fish duck

8.5. Ecosystem services in Integrated Farming Systems

Integrated Farming System provides both tangible and non tangible benefits to ecosystems through Provisioning services, Regulatory services and Supporting services. The provisioning services include providing food grains, vegetables, fish, meat, fuel and other harvestable goods.

Supporting services include nutrient supply such as nutrient flow from one system to other. Dropping of animals/birds provide nutrient to crops and vegetables, and thus the resource recycling enriches organic matter and nutrient. Hydrological flow such as water applied to one system is used in other system either through seepage, leaching, run off, capillary rise. The multiple use of water enhances the water productivity.

Regulating ecosystem services or biological pest control is considered as one of the most important aspects in IFS. The protection and multiplication of natural enemies pertaining to specific pests of different guilds e.g., specialist and generalist predators are often have a pervasive negative effect on pest population growth in the agricultural field. In the IFS, understanding of landscape perspective management and determinants of predator community composition along with their biological control services in respect of IFS components such as fishery, duckery, poultry and diversified rotational cropping systems with use of bio-pesticide will enhance future biological control potentialities.

Crop pollination in the IFS is another regulating ecosystem services which enhances the crop yields. Although many staple crops (wheat, maize and rice) are wind pollinated, while vegetables and fruits mainly rely on insect's pollination for generating large economic values (Eilers et al., 2011). Inclusions of apiary unit in IFS remain the most commonly

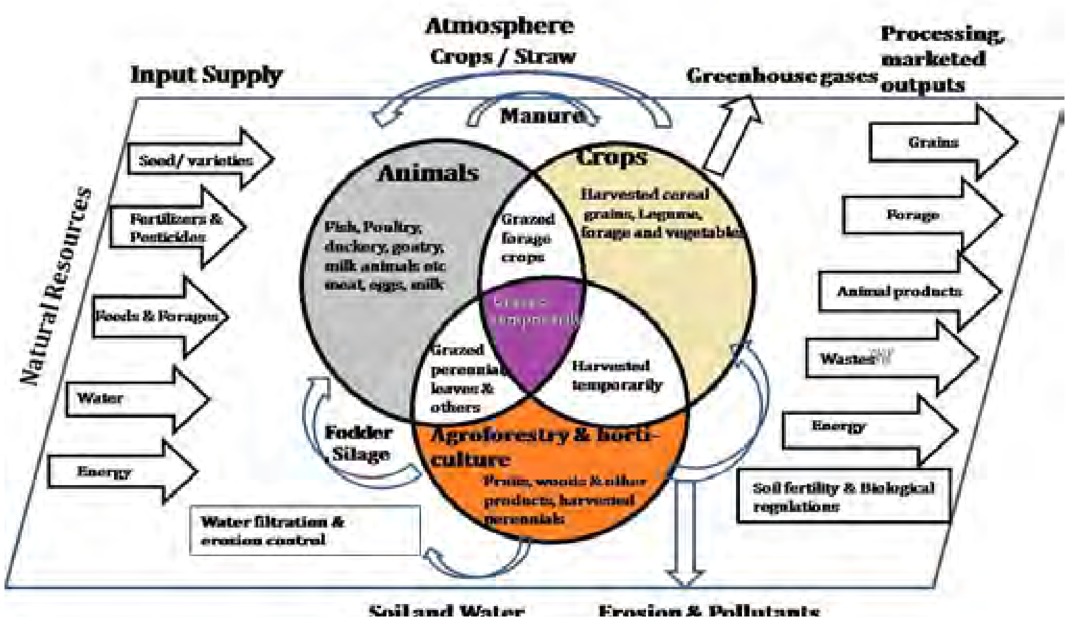
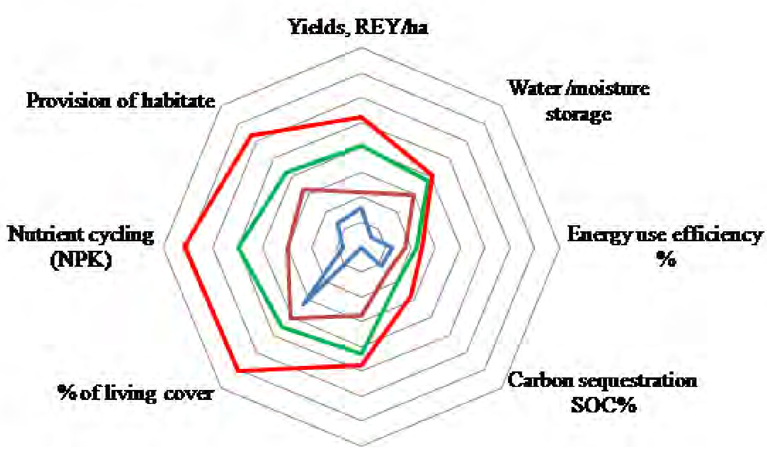


Fig. 20. Biophysical components, key material flow and key ecosystem processes in crop-livestock-agroforestry IFS



RM : Rice monocropping; RF : Rice fish; RFD : Rice fish duck; IFS : Integrated farming system

Fig. 21. Ecosystem service indicators in different rice based farming system

managed pollinators used by farmers and often dominate pollinator communities in crops. Presence of diversified species of wild insect pollinators increases crop yield, quality, and profit, as well as the stability in the IFS with minimization of the yield gaps. Rice-fish farming system is related with the culture of eastern India. Rice, fish, vegetables, ornamental plants and trees grown in the system are used in many functions and rituals round the year. The eco-efficient rating of bio-physical components, material flow in important ecosystem processes in crop- livestock –agroforestry IFS are given in Table 6.

Table 6. Eco-efficient rating and ecosystem functions in crop-livestock-agroforestry IFS

Sl.No.	Components of ecosystem functions	Rating	Impacted and realised in IFS
1	Biodiversity	+ + +++	Use of improved variety of crops, animals, agro forestry, horticultural plants and 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 to the system with farm residues compost, vermi compost and mushroom cultivation
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 and soil organic carbon
8	Energy-use efficiency	++++	Higher efficiency as compared to conventional system farming
9	Reduction in GHG 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

Our study used a quantitative tool to assess the ecosystem services of IFS by ecosystem scoring of various indicators which indicated distinct difference among the ecosystem services and which varies to the extent of integration i.e. IFS > RDF > RF > RM.

8.6. Biodiversity improvements

Modern agriculture causes biodiversity loss as well as ecosystem degradation which is considered to be a costly affair for the society as whole (da Silva and Pontes, 2008). On the contrary, sustainable integrated farming systems reverses trends and enhance the biodiversity (Bengtsson et al. 2005). Biological soil quality index (SQI_{Biol}) indicated higher value in integrated farming system as compared to conventional farming (Kremen et al., 2012; Nayak et al., 2018b). Agro-biodiversity maintenance directly influences the productivity and can perform several ecosystem services to agriculture, thus reducing dependence on environmental externalities as well as off-farm inputs. Therefore, IFS is considered as eco-efficient and environment-friendly agriculture which provides important environmental advantages such as reducing the use of harmful chemicals and their spread in the environment and food chain, reducing water use, as well as reducing carbon and ecological footprints. Integrated farming seems to be capable of producing sufficient yield by maintaining crop-livestock diversities (FAO, 2000) and sustainability, as compared to conventional agriculture (FAO, 2012; Nayak et al., 2018c). Decreasing biodiversity reduces the resiliency in an ecosystem which cost severely higher towards management cost in general. Our study on the integrated farming system (RF, RFD and IFS) indicates higher biodiversity index scoring as compared to rice mono-cropping.

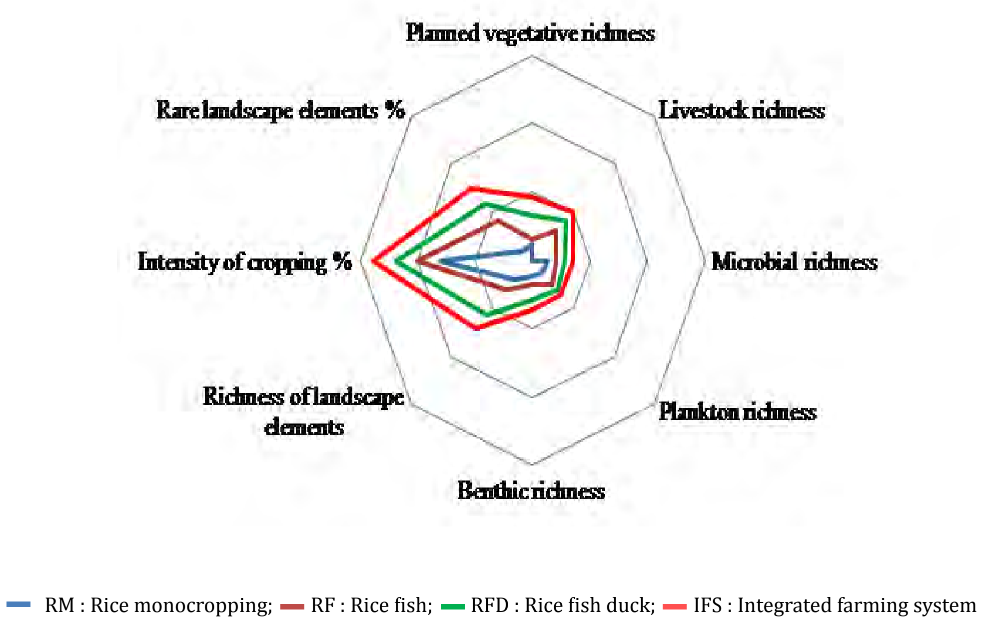


Fig. 22. Biodiversity index scoring in different Integrated Farming System

8.7. Nutrient recycling

Integrated Farming System evidently plays an important role in the production processes by enhancing nutrient content of soil (nitrogen, phosphorus, organic carbon and microbial diversity) and improving soil health and thus, increasing the productivity (Walia and Kaur, 2013; Nayak et al., 2018b). Integration of different enterprises within the farming systems is helpful in recycling of by products and waste products. FYM, ducks and poultry dropping, goat manure, vermicompost and silt in the pond were applied to the system at different times. The quantity of goat and ducks dropping and their nutritive values are given in Table 7. In the crop-livestock system, livestock manure is continuously applied to the system which enhances soil organic matter, and thus improves water holding capacity, water infiltration and increased cation exchange capacity in soil, which maintain the sustainability within the system.

Table 7. Manure and nutrient loading of livestock components in IFS

Animals	Wt of animals in kg	Loading rate kg/day wet. wt	Nos. of animals	Manure added tonnes	Content (%) of N	Content (%) of P	Content (%) of K	TN/yr in kg	TP/yr in kg	TK/yr in kg
Goat	12	0.7	15	3.832	3	1	2	115	38	76
Duck	2.5	0.018	50	0.328	0.95	0.54	0.37	31	18	12

TN : Total nitrogen; TP : Total phosphorus; TK : Total potassium

8.8. Soil and water quality

The physico-chemical properties of water such as dissolved oxygen, nitrate, ammonia, total alkalinity, dissolved organic matter, and total suspended solid) and soil nutrient levels were significantly higher in rice-fish -duck IFS as compared to the conventional system due to the continuous addition of faecal matters, scooping and churning of soil by fish and ducks in the paddy field ecology (Nayak et al., 2018b). The aquatic biological diversity including planktons phyto and zoo, soil benthic fauna and microbial populations were dynamic in integrated rice-based system, provides an indication of enhanced soil fertility, soil organic carbon build up, improvement in soil health and production sustainability (Bihari et al., 2015; Nayak et al., 2018b). Apart from the production enhancement, water quality index (WQI) and soil quality index (SQI) are good indicators of ecological aspects of agro-ecosystem. The water quality, soil quality and soil biological indices (SQI_{Biol}) are improved under IFS which led to productivity enhancement as compared to conventional system (Figs 23, 24 & 25).

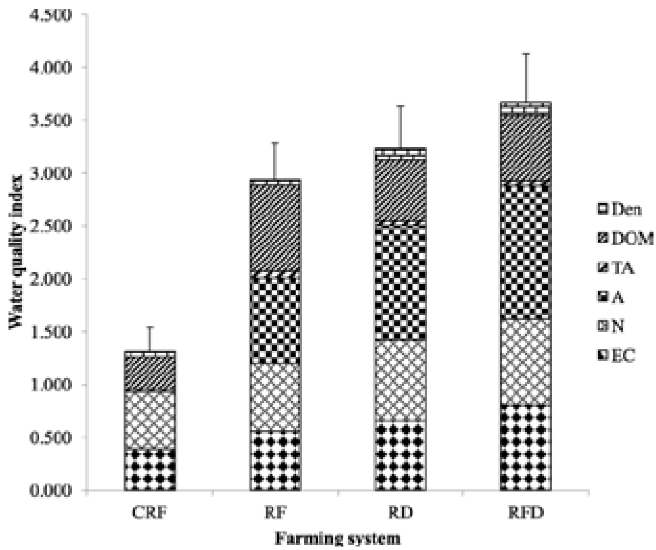


Fig. 23. Water quality indices (WQIs) of different farming systems. (Stacked bars represent the index values for weighted MDS variable scores. Error bars denotes standard deviation of overall index values. CRF : Conventional rice farming; RF : Rice fish; RD : Rice duck; RFD : Rice fish duck)

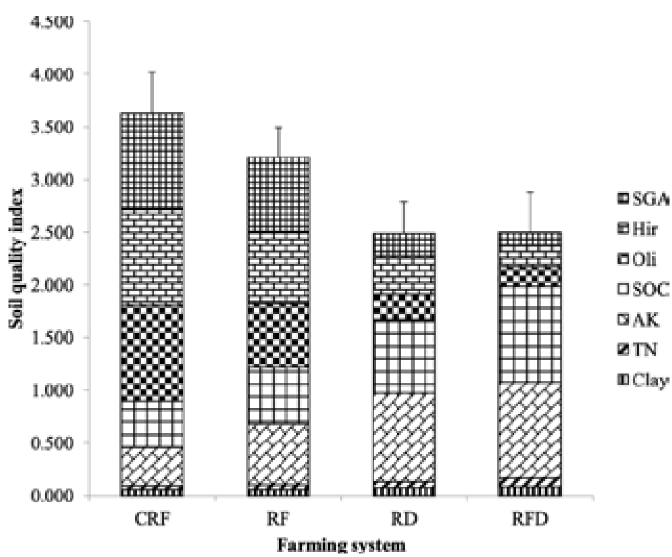


Fig. 24. Soil quality indices (SQIs) of different farming systems. (Stacked bars represent the index values for weighted MDS variable scores. Error bars denotes standard deviation of overall index values. CRF : Conventional rice farming; RF : Rice fish; RD : Rice duck; RFD : Rice fish duck)

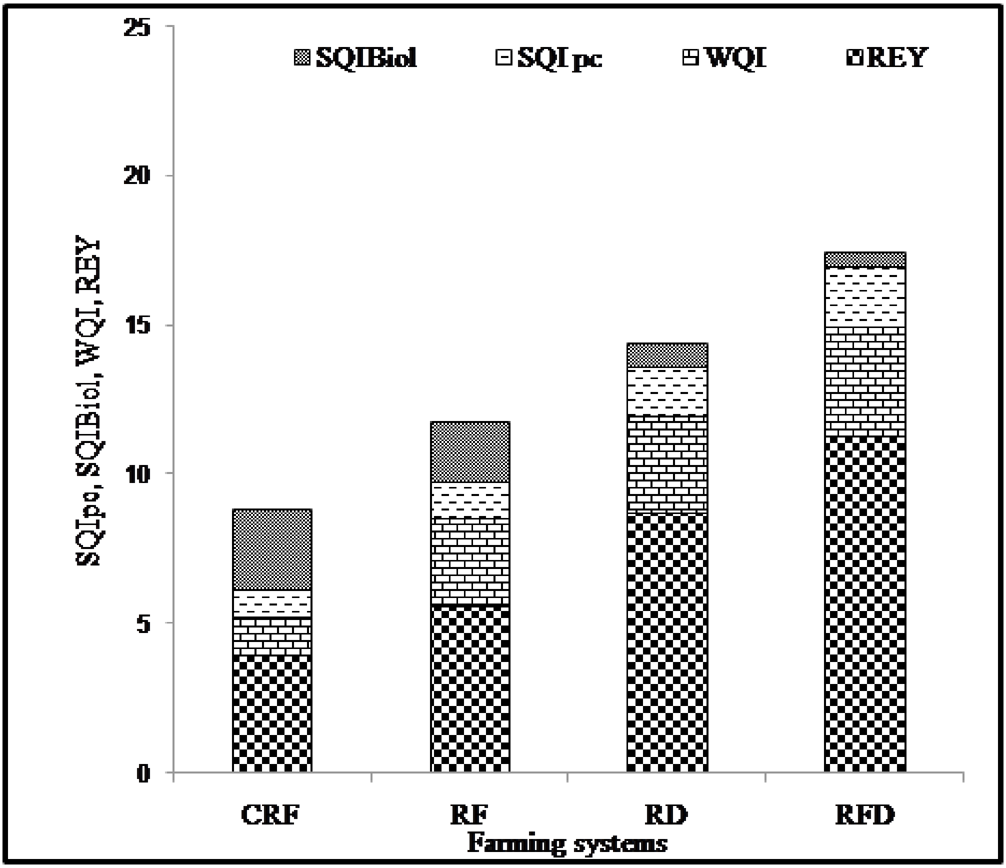


Fig. 25. Mean values for indicators of Water quality, indicators of soil quality (physico-chemical) SQIpc, and indicators of biological soil quality, along with rice equivalent yields (REY) in four land management systems. (WQI: water quality indicator (based on water physic-chemical properties, phyto and zooplankton and microbial population); SQIpc,: soil quality indicator (based on physical and chemical parameters of the soil), SQI_{Biol}: soil quality biological indicator (based on abundance and diversity of macro benthos population observed in different farming system). CRF : Conventional rice farming; RF : Rice fish; RD : Rice duck; RFD : Rice fish duck)

9. Economics

Adoption of IFS with combination of region-specific compatible IFS enterprises (Crop, fishery, livestock and agroforestry) positively influences soil health, financial and economic viability, enhanced profitability and generate additional employments as compared to the conventional mono-cropping (Lal et al., 2018; Nayak et al., 2018b). Pilot studies conducted at ICAR-NRRI, Cuttack indicates higher profitability and economic returns in various combinations of enterprising components depending upon the type of enterprises and extent of integration (Table 8).

Table 8. Comparison of profitability in different type combination of components (enterprises) in Integrated Farming System.

Integrated farming systems	Combination and numbers of animals	OVCC ratio
Rice (R)	R	1.55
Rice +duck (RD)	R+150	1.86
Rice+duck+fish (RFD)	R+ 150+ F	2.13
Rice+duck+fish+goat (RFDG)	R+150+F+10	2.33
Rice+duck+fish+goat+Poultry (RFDGP)	R+150+F+10+100	2.45
Rice+duck+fish+goat+Poultry+Horti (RFDGPH)	R+150+F+10+100+Hort	2.96

OVCC : Output value and cost of cultivation; R : Rice; F : Fish; D=Duck; G : Goat; P : Poultry; H : Horticulture

10. Off-farm impact assessment

To assess the impact and performances of IFS technology at farmer's levels, a field survey was made among the IFS adopted farmers of Puri, Kendrapara and Angul district of Odisha. The farmers of the area grow rice as a principal food crop during *kharif* and *rabi* season. Besides rice, some farmers also take vegetables, fruit crops, dairy, poultry, mushroom cultivation, fishery, silviculture crops as a component of integrated farming system. The dominant farming systems prevailing in the districts are rice-based *i.e.,* Rice+fish+ horticulture, Rice +fish+horticulture+poultry+dairy+silviculture, Rice+fish+poultry+ horticulture. The individual IFS adopted farmers, enterprise combination and economic performances are given in Table 9.

Table 9. Success stories of adoption of Integrated Farming System among farmers

Sl No.	Name of the farmer with address	Farming System	Area	Benefits
1	Sri Tapan Nayak, Vill: Terundia, Block: Nimapada, Dist: Puri	Rice+fishery+poultry+horticulture+dairy+silviculture	5.0 acre	Net return: Rs.1130000/- Man-days generated per annum: 958, B:C = 1.31
2	Shri Sanakarsan Nayak, Vill: Terundia, Block: Nimapada, Dist: Puri	Rice+fishery+horticulture+mushroom+silviculture	3.0 acre	Net return: Rs. 480000/- Mandays generated per annum: 630, B:C = 1.22
3	Shri Parasuram Panda, Vill: Ashapuran, Block: Nimapada, Dist: Puri	Rice+fishery+horticulture+dairy+silvicultur	14.0 acre	Net return: Rs.836000/- Mandays generated per annum: 1300, B:C = 1.87
4	Shri Pratap Kumar Jena, Vill: Dahinga, Block: Nimapada, Dist: Puri	Rice+fishery+poultry+horticulture	2.5 acre	Net return: Rs.517000/- Mandays generated per annum: 608, B:C = 1.25

5	Shri Govinda Swain, Vill: Kuanarpur, Block: Nimapada, Dist: Puri	Rice+fishery + dairy horticulture + mush-room + silviculture	10.0 acre	Net return: Rs.527000/- Mandays generated per annum: 1696, B:C = 1.71
6	Shri Sricharan Nayak, Vill: Mukundapur, Block; Rajkanika, Dist: Kendrapara	Rice+fishery +dairy horticulture + mushroom + backyard poultry	1.5 acre	Net return: Rs.47400/- Mandays generated per annum: 188, B:C = 1.76
7	Shri Surendra Nath Lenka, Vill: Derabal, Block; Derabis, Dist: Kendrapara	Crop+dairy+goater y+fishery+backyard poultry	2.5 acre	Net return: Rs. 120000/- Mandays generated per annum: 447, B:C = 1.89
8	Shri Pitambar Biswal,Vill: Jarisahi, Block: Rajkanika, Dist: Kendrapara	Crop + dairy+Back yard Poultry + horti-culture	1.5 acre	Net return: Rs. 34000/- Mandays generated per annum: 207, B:C = 1.58
9	Shri Bharat Bhusan Mahanty, Vill: Kanya-pur, Block; Derabis, Dist: Kendrapara	Rice+diary+goatery+ mushroom+fishery+h orticulture	2.5 acre	Net return: Rs 132000/- Mandays generated per annum: 313, B:C = 2.0
10	Shri Raghunath Sahu, Vill: Kosala, Block: Kansmali, Dist: Angul	Rice+diary+back yard poultry +fishery	2.5 Acre	Net return: Rs. 87300/- Mandays generated per annum: 303, B:C = 1.77
11	Shri Ramesh Chandra Sahu, Vill: Kosala, Block: Kansnali, Dist: Angul.	Crop+dairy+fishery +Horticulture+ back yard poultry	2.10 Acre	Net return: Rs. 81000/- Mandays generated per annum: 237, B:C = 1.90
12	Shri Prafulla Prad-han, Vill: Gulasar, Dist: Angul.	Crop+dairy+fishery +horticulture+ back yard poultry	2.20 Acre	Net return: Rs. 102000/- Mandays generated per annum: 340, B:C = 1.72
13	Shri Ushaba Behera, Vill: Jamunali, Angul.	Crop+dairy+fishery +horticulture+ back yard poultry	3.8 Acre	Net return: Rs. 85300/- Mandays generated per annum: 213, B:C = 2.01
14	Shri Trilochan Sahu, Vill: Handiguda, Angul.	Crop+dairy+fishery +horticulture+ back yard poultry	3.0 Acre	Net return: Rs. 132000/- Mandays generated per annum: 333, B:C = 1.85

B:C- Benefit Cost ratio

The survey result indicated that IFS is an economically viable and environment friendly farming system. As design of the farming system initially needs some financial investments, therefore, sufficient credit facilities along with training will be helpful for easy adoption of technologies.

11. Way forward and Future thrust

In India, various type of region-specific farming systems with varied enterprise combinations in respect to topography and agro-climatic condition are available (Panwar et al., 2018; Srivastava, 2018; Nayak et al., 2018b). Rice-based IFS including crop-livestock-agroforestry based IFS (CLAIFS) 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 operationalised 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 both crop and animal husbandry with rational use of natural resources (conservation and sustainable use) through adoption of integrated farming systems.

11.1. Future thrust

The following area of research needs for further strengthening for adoptability as follows:

- Refinement and on-farm testing of developed modules in accordance of farmer's needs and socially acceptable systems.
- Creation of database on IFS: Enterprise selection, type and size of IFS, resource allocation, economics and sustainability in IFS under different agro-ecological zone.
- Waste utilization, recycling of organic resources in the form of plant and animal wastes needs special emphasis.
- Capacity building for harnessing the benefit of specialized components (rice, fish, livestock, and horticulture etc.), training requirements of rural farmers needs to be suitably addressed.
- Strong policy support for its promotion with easier credit flow, subsidy and agricultural insurance, market linkage with establishments of village cluster development programme.

12. Conclusion

Integrated crop-livestock-agroforestry systems 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. The CLAIFS enhances the farm productivity, ensures livelihood security, diversify and enhances the farm income and improves soil health. These systems are having potentials for climate change resilience and mitigation potentials and thus enables the farmer's participation in climate risk management for building a climate resilient production system.

13. References

Agriculture Census 2010-11 (2015). Department of Agriculture, Cooperation & Farmers Welfare. Ministry of Agriculture & Farmers Welfare New Delhi.

Ahmed, N., Wahab, M.A., Thilsted, S.H., (2007). Integrated aquaculture-agriculture systems in Bangladesh: potential for sustainable livelihoods and nutritional security of the rural poor. Aquaculture Asia 12(1), 14–22

Alluvione, F., Moretti, B., Sacco, D., Grignani, C., (2011). Energy use efficiency of cropping systems for a sustainable agriculture. Energy 36(7), 4468-4481.

Bailey, A.P., Basford, W.D., Penlington, N., Park, J.R., Keatinge, J.D.H., Rehman, T., Yates, C.M., (2003). A comparison of energy use in conventional and integrated arable farming systems in the UK. Agriculture, Ecosystems & Environment 97(1), 241-253.

Bengtsson, J., Ahnstrom, J., Weibull, A., (2005). The effects of organic agriculture on biodiversity and abundance: a meta-analysis. Journal of Applied Ecology 42, 261-269.

Bhattacharyya, P., Nayak, A.K., Mohanty, S., Tripathi, R., Shahid, M., Kumar, A., Raja, R., (2013). Greenhouse gas emission in relation to labile soil C, N pools and functional microbial diversity a influenced by 39 year long-term fertilizer management in tropical rice. Soil and Tillage Research 129: 93-105.

Bihari, P., Nayak, A.K., Gautam, P., Lal, B., Shahid, M., Raja, R., Tripathi, R., Bhattacharyya, P., Panda, B.B., Mohanty, S., Rao, K.S., (2015). Long-term effect of rice-based farming systems on soil health. Environmental Monitoring and Assessment, 187(5): 296.

Carsan, S., Stroebel, A., Dawson, I., Kindt, R., Mbow, C., Mowo, J., Jamnadass, R., (2014). Can agroforestry option values improve the functioning of drivers of agricultural intensification in Africa? Current opinion in Environmental Sustainability 6, 35–40.

Channabasavanna, A.S., Biradar, D.P., Prabhudev, K.N., Hegde, M., (2010). Development of profitable integrated farming system model for small and medium farmers of Tungabhadra project area of Karnataka. Karnataka Journal of Agricultural Sciences 22(1), 25-27.

da Silva Jr, A.P., Pontes, A.R.M., (2008).The effect of a mega-fragmentation process on large mammal assemblages in the highly-threatened Pernambuco Endemism Centre, north-eastern Brazil. Biodiversity and Conservation 17 (6), 1455-1464.

Datta, A., Nayak, D.R., Sinhababu, D.P. and Adhya, T.K., (2009). Methane and nitrous oxide emission from an integrated rainfed rice-fish farming system of eastern India. Agriculture, Ecosystems & Environment 129, 228-237.

Dehadrai, P. V., (1988). Rice in field and fish in water. Indian farming. Nov, 29-32.

Deike, S., Pallutt, B., Christen, O., (2008). Investigations on the energy efficiency of organic and integrated farming with specific emphasis on pesticide use intensity. European Journal of Agronomy 28(3), 461-470.

Eilers, E.J., Kremen, C., Greenleaf, S.S., Garber, A.K., Klein, A., (2011). Contribution of pollinator-mediated crops to nutrients in the human food supply. PLoS ONE 6 (6), e21363; doi: org/10.137/journal.pone.0021363

FAO (2000). Carbon sequestration options under the clean development mechanism to address land degradation FAO, Rome http://www.fao.org/forestry/15528-0534f06d08a9c3cbcd73deefd8d06c674.pdf. Accessed in March 2015.

FAO (2012). The State of Food Insecurity in the World 2012. FAO, Rome. http://www.fao.org/docrep/016/i3027e/i3027e.pdf. Accessed in January 2015.

Huang, Y.B, Wen, B.Q, Tang, J.Y, Liu, Z.Z., (2001). Effect of rice-azolla-fish system on soil environment of rice field. Chinese Journal of Eco-Agriculture 9(1), 74-76 (in Chinese with English Abstract).

Jayanthi, C., Rangasamy, A., Chinnusamy, C., (2000). Water budgeting for components in Low land integrated farming systems. Agricultural Journal 87 (7/9), 411- 414.

Jhingran, V. G. and Ghosh, A., (1987). Aqua-farming in coastal India. J. Indian. Soc. Coastal Agric. Res. 5(1),1-9.

Kochiwad, S.A., Meena, L.R., Kumar, D., Kumar, S., Meena, L.K., Singh, S.P., and Singh, K., (2017). Livestock based integrated farming system for livelihood improvements in small and marginal farmers. South Asian Journal of Food Technology and Environment 3(1), 526-532.

Korikantimath, V.S., Manjunath, B.L., (2008). Integrated farming systems for sustainability in agricultural production. Proceedings of national symposium on new paradigms in agronomic research. Indian Society of agronomy. Navsari Agriculture University. Gujarat, 279- 281.

Kremen, C., miles, A., (2012). Ecosystem services in biologically diversified verses conventional farming system: benefits, externalities and trade-off. Ecology and Society 17(4), 40.

Kumar, A., Nayak, A.K., Mohanty, S., Das, B.S., (2016). Greenhouse gas emission from direct seeded paddy fields under different soil water potentials in Eastern India. Agriculture Ecosystems and Environment 228, 111-123.

Kumar, R., Patra, M. K., Thirugnanavel, A., Deka, B. C., Chatterjee, D., Borah, T. R., Rajesha, G., Talang, H. D., Ray, S. K., Kumar, M., Upadhay, P. K., (2018). Comparative evaluation of different integraed farming system models for small and marginal farmers under eastern Himalyas. Indian Journal of Agricultural Sciences 88 (11), 1722-29.

Lal, M., Patidar, J., Kumar, S., Patidar A., (2018). Different integrated farming system model for irrigated condition of India on basis of economic assessment: A case study: A review. International Journal of Chemical studies 6 (4), 166-175.

Lu, J., Xia, L., (2006). Review of rice-fish-farming systems in China—one of the globally important ingenious agricultural heritage systems (GIAHS). Aquaculture 260(1), 106-113.

Mahajan, M.S., Kolage, A.K., Desale, S.B., Nerkar, S.C., (2012). Economics of Integrated Farming System Modules in Dhule, Maharashtra. In: Munda, G.C., Ngachan, S.V., Das, A., Mohapatra, K. P., Choudhury, B.U., Ramkrushna, G.I., Tripathi, A.K., Azad Thakur, N.S., Malngiang, S. and Chowdhury, S. (2012). Book of Extended Summaries. The National Seminar on Livelihood Options for Small and Marginal Farmers in Fragile Ecosystems. ICAR Research Complex for NEH Region, Umiam– 793 103, Meghalaya.

Mottet, A., Henderson, B., Opio, C., Falcucci, A., Tempio, G., Silvestri, S., Chestermsan, S., Gerber, P.J., (2016). Climate change mitigation and productivity gains in livestock supply chains: insights from regional case studies. Regional Environmental Change 1-13.

Nayak, P.K., Sinhababu, D.P., Rao, K.S., Sahu, P.K., (2008). Ornamental fishes; Breeding and culture in rice ecologies. CRRI Technology Bulletin 33. Central Rice Research Institute, Cuttack, Odisha, India.

Nayak, P.K., Panda, B.B., Khanam, R., Kumar, U., Paneerselvam, P., Satapathy, B.S., Kumar, A., Nayak, A.K., Pathak, H., (2018a). Rice-fish-livestock based integrated farming system: a viable option for farm sustainability and doubling of farmer's income in eastern India. In: Extended summaries of XXI biennial National Symposium of Indian society of Agronomy, 24-26 Oct, 2018 at MPUAT, Udaipur, Rajasthan, 374-375.

Nayak, P.K., Nayak, A.K., Panda, B.B., Lal, B., Gautam, P., Poonam, A., Shahid, S., Tripathi, R., Kumar, U., Mohapatra, S.D., Jambhulkar, N.N., (2018b). Ecological mechanism and diversity in rice based integrated farming system. Ecological Indicators 91.

Nayak, P.K., Tripathi, R., Panda, B.B., Poonam, A., Shahid, M., Mohapatra, S.D., Nayak, A. K., (2018c). Integrated farming system; An eco-efficient sustainable practice for food and nutritional security. In Compendium of invited lectures of DEVIL food security workshop, India, page: 71-75.

Nimbolkar, P. K., Awachare, C., Chander, S., Husain, Firoz., (2016). Multi Storied Cropping System in Horticulture - A Sustainable Land Use Approach. International Journal of Agriculture Sciences 8 (55), 3016-3019.

Panwar, A.S., Ravisankar, N., Shamim, M., Prusty, A.K., (2018). Integrated Farming Systems: A viable option for doubling farm income of small and marginal farmers Bulletin of the Indian Society of Soil Science, No. 32. pp 68-88.

Pathak, H., Samal, P., Shahid, M., (2018). Revitalizing rice-system for enhancing productivity, profitability and climate resilience. In Rice Research for enhancingproductivity, profitability and climate resilience. ICAR- National Rice Research Institute, Cuttack, Odisha, India, pp 1-17.

Ramasamy, C., Natarajan, S., Jayanthi, C., Sureshkumar, D., (2007). Intensive integrated farming system to boost income of farmers. In: Proceedings of 32nd IAUA vice chancellors annual convention on Diversification in Indian Agriculture, Birsa Agricultural University, December 20 - 21. pp. 28-47.

Reddy, R.V.S.K., Sree, E.K., Reddy, A.D., Deppthi, V., Nirmala, T.V., Raju, G.S., Subbaiah, K.V., Prsad, J.V., (2018). An evaluation study on viable integrated farming system IFS model in Godavari delta of Andhra Pradesh. Journal of Pharmacognsoy and phytochemistry Sp1: 2361-2368.

Soussana, J.F., Dumont, B., Lecomte, P., (2015). Integration with livestock. Agroecology for food security and nutrition. Proceedings of the FAO Intenational Symposium, 18-19 September 2014. pp 225-249. Rome, FAO.

Srivastava, A.P., (2018). Selected integrated farming system models for enhanced income. Indian Farming 68(01):13-16.

Walia, S.S., Kaur, N., (2013). Integrated farming system – An eco friendly approach for sutainable agricultural.

Xu, G., Liu, X., Wang, Q., Yu, X., Hang, Y., (2017). Integrated rice-duck farming mitigates the global warming potential in rice season. Science of the Total Environment 575, 58–66.

ICAR-National Rice Research Institute
Cuttack, Odisha 753 006
Phone: 0671-2367768-783 (EPABX); Fax: 0671-2367663
Email: crrictc@nic.in | director.nrri@icar.gov.in
URL: http://www.icar-nrri.in

स्वच्छ भारत
एक कदम स्वच्छता की ओर

150 YEARS OF CELEBRATING THE MAHATMA

BSCIC NABCB QM 036
ISO 9001 REGISTERED
BN10448/9364:0914
AN ISO 9001:2015 CERTIFIED COMPANY