Integrated Rice-based Farming Systems for Enhancing Climate Resilience and Profitability in Eastern India

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SUMMARY

Majority of the rice farmers in eastern India possess small land holding (<1ha), which is the only primary source of farm family income. Despite exploiting their land extensively they often fail to achieve the target appreciably owing to high risk involved in the natural calamity. Rice ecosystem in the eastern region is diverse and rich in natural resources but the extremely fragileness of the ecosystem and small and marginal land holdings call for diversification of the persisting/ conventional rice farming for efficient resource management. Adoption of the most compatible multi-crop enterprises into a small system holding would greatly improve the production system in the risk prone ecology and will ensure sustainable food, economic and employment in the small farm thus restricting the migration of farming community to the metro cities for construction and other non-agriculture work.

1. INTRODUCTION

Farming family in tropical India is mainly dependent on rainfed farming with high risk of weather uncertainty. In a constant struggle to survive, the small and marginal farmers over the years have evolved techniques which have benefited them immensely. But without knowing the scientific basis of such integration they have been practicing the system for a long time.In India, traditionally, farming has been family based and majority of them are smallholders. The success of farming family lies not in 'specialization' but in practicing farming to meet diverse household needs rather than market opportunities alone. Hence, income from seasonal field crops alone in small and marginal farms is hardly sufficient to sustain the farming family.

Rice being the staple food is grown in the country in around 43.5 million ha (Mha) under various ecologies of which about 50% area is rainfed. More than 80% of the rice farmers belong to small and marginal groups and the average per capita land holding in India is only about 0.17 ha. In view of the population growth, competition of land with industrialization and urbanization, declining farm holding size and the dietary nutrition requirement of the farm families, it is necessary to look for the optimum use of resources through shift from conventional rice farming to integrated farming systems. Rice based farming system involving rice, other field and horticultural crops, agro-forestry, fish birds livestock and further income generating enterprises will be the right approach in this respect and will be more relevant in the risk prone rainfed ecologies which are mostly located in the eastern part of the country. Because of reducing per capita availability of land in India, there is no further scope for horizontal expansion of land for increased food production. Hence, the best possible allocation of resources and their intelligent management is important to reduce the risk related to land sustainability. Integrated farming system is the potential approach and powerful tool for management of vast natural and human resources in developing countries including India to meet the various objectives of, competitiveness, food security, poverty reduction and sustainability of small and marginal farmers.

Rice farmers in eastern part of India generally work in various risk prone environments leading to low rice productivity. Available resources for modest increment is due to lack of appropriate understanding of interaction and linkages between the components under traditional rice farming system; manpower is underutilized for employment and hence, rice growers are economically poor. Integrated farming system (IFS) has been advocated as one of the tool for harmonious use of inputs and their compounded response to make the agriculture in the region profitable and sustainable.

The Indian economy is predominantly based on agriculture, which is facing a serious challenge in terms of the sustainability and profitability of farming due to the declining trend in size of land holding. The average size of the landholding has declined to 1.1 ha during 2010-11 from 2.28 ha in 1970- 71. If this trend continues, the average size of holding in India would be mere 0.68 ha in 2020, and would be further reduced to 0.32 ha in 2030 (Agriculture Census 2010). As per estimates, more than 95% of the holdings will be under the category of small and marginal holders in 2050. Hence, it is necessary to develop strategies and agricultural technologies that enable adequate employment and income generation, especially for small and marginal farmers who constitute more than eighty per cent of the farming community.

Under the gradual shrinking of land holding, it is needed to integrate land based enterprises like minor livestocks, field and horticultural crops, etc. within the biophysical and socio-economic environment of the farmers to make farming more profitable (Behera et al. 2004). In addition, the dependence upon a few crops in combination with a high biotic and abiotic risk of crop failure exposes the farmers to a high degree of variability with respect to yield and income and therefore risks (Ashby 2001). Further, few authors indicated that commercial farming systems are a threat to the environment through a loss of genetic diversity and the possible negative impacts of these systems and their associated inputs.

It becomes difficult for the small and marginal farmers to sustain with the single farm enterprise unless resorting to integrated farming systems (IFS) for the generation of adequate income and year round employment within their small farms (Mahapatra 1992). Decreasing land-man ratio, poor socio-economic condition of farmers, vagaries of monsoon, new risks from environmental deterioration, population pressure and rapidly changing agricultural input and output markets through globalization, high degree of vulnerability in the rural area proved to be not sustained farmer's livelihood mainly when they are solely dependent on traditional agriculture on their small piece of lands. Therefore, agriculture diversification is utmost important for improving their livelihood and reducing vulnerability.

1.1. Integrated farming system-a promising approach

Integrated farming system is the potential approach and powerful tool for management of vast natural and human resources in developing countries, including India to meet the multiple objectives of poverty reduction, food security, competitiveness and sustainability of small and marginal farmers' livelihood. The approach aims at increasing income and employment from small-holding integrating various farm enterprises and recycling crop residues and by-products within the farm itself (Behera and Mahapatra 1999; Singh etal. 2006). Under the gradual shrinking of land holding, it is necessary to integrate land-based enterprises such as dairy, fishery, poultry, duckery, apiary, field crops, vegetable crops and fruit crops within the bio-physical and socio-economic environment of the farmers to make farming more profitable and dependable (Beheraetal.2004).Integrated farming systems are often less risky, because if managed efficiently, they benefit from synergisms among the enterprises, leading to diversity in produce and environmental soundness (Pullin 1998).

The objective of this Chapter is to analyze the traditionally practiced farming systems nationally /internationally and how the progress has been made in terms of different improved models/cropping systems for sustainable, food, nutrition, employment generation and income of the small and marginal rice growers in diverse agro-ecological situations.

2. STATUS OF RESEARCH/KNOWLEDGE

The cultivation of almost 90% of the world's rice crops in irrigated, rainfed and deep-water systems equivalent to about 134 million hectares offers a suitable environment for fish and other aquatic organisms.The different integrations of rice and fish farming–either on the same plot, on adjacent plots where by-products of one system are used as inputs on the other, or consecutively – are all variations of production systems that aim to increase the productivity of water, land and associated resources while contributing to increased fish production. The integration can be more or less complete depending on the general layout of the irrigated rice plots and fishponds.

Asia accounted for about 90% of 672 Mt of rice produced in the world as of 2010 (FAO 2012). Rice farming in Asia used to be characterized by small scale, labour-intensiveness and on-site recycling of green and animal manures. Although rice farming is still labour-intensive in remote areas of Asian developing countries, it has rapidly been mechanized and agrochemicals- intensive in the name of agricultural modernization and green revolution. In fact, the so-called green revolution has largely resulted from industrial monoculture, genetically modified crops and the excess use of agrochemicals, which caused agricultural land degradation globally. Furuno

(2001)formulated the idea of systematically integrating rice with ducks, based on the notion that two products highly complementary to each other can be jointly produced. In the integrated rice–duck farming (IRDF) system, rice paddies provide food (weeds and pests) for ducks, and ducks play a role in fertilizing rice plants.Integrated farming systems are effectively systems that have traditionally been undertaken by farmers in countries that include Indonesia, China, Malaysia, Vietnam, Rwanda and Thailand (Praphan 2001). However, in many countries these traditional systems have been replaced by the establishment of commercial cash and staple crop production systems that have been promoted by governments (Ruaysoongnern and Suphanchaimart 2001).

As regards the general scale of rice–fish culture, China is the main producer with an area of about 1.3 Mha of rice fields with different forms of fish culture, which produced 1.2 Mt of fish and other aquatic animals in 2010. Other countries reporting their rice–fish production to FAO include Indonesia (92000 t in 2010), Egypt (29 000 t in 2010), Thailand (21000 t in 2008), the Philippines (150 t in 2010) and Nepal (45 t in 2010). Trends observed in China show that fish production from rice fields has increased thirteen fold in the last two decades, and rice–fish culture is now one of the most important aquaculture systems in China, making a significant contribution to rural livelihoods and food security.

Rice–fish farming is being tried and practiced in other countries and continents although to a lesser extent. Apart from Asia, activities have been reported from, among others, Brazil, Egypt, Guyana, Haiti, Hungary, Iran (Islamic Republic of), Italy, Madagascar, Malawi, Nigeria, Panama, Peru, Senegal, Suriname, the United States of America, Zambia, and several countries in the Central Asia and Caucasus region.Rice-fish systems are practiced in China, Egypt, India, Indonesia, Thailand, Vietnam, Philippines, Bangladesh and Malaysia. The rice-fish systems are important in these areas because they provide food security, reduce the impact of agriculture on the environment, and may be less affected than conventional systems by climate change. Integrated rice-fish production can optimize resource utilization through the complementary use of land and water. This practice also improves diversification, intensification, productivity, profitability, and sustainability of the rice agro-ecosystem.

In eastern India about 70% of farmer community comes under the marginal and small farmer category (GOI 2009). Farmers under these categories are economically poor and work in diverse risk prone environments. The income from rainfed rice crop and other seasonal field crops on small and marginal farms is hardly sufficient to sustain their family. Integrated farming system (IFS) has been advocated as one of the tool for harmonious use of inputs and their compounded response to make the agriculture in the region profitable and sustainable. Integrated farming systems aim at an appropriate combination of farm enterprises like field crops, dairy, piggery, poultry, apiculture, goatery, mushroom cultivation etc. for a productive, profitable and sustainable agriculture. IFS interact appropriately with the environment without dislocating the ecological and socio-economic balance on one hand and attempt to meet the farmers need on the other. Thus, IFS is a reliable way of obtaining high productivity with substantial nutrient economy in combination with maximum compatibility and replenishment of organic matter by way of effective recycling of organic residues/ wastes etc. obtained through integration of various land based enterprises (Gill et al. 2010; Sanjeev et al. 2011) An experiment on paddy cum fish culture was started in west Bengal in 1945 in an area of 691.16 acres adjoining the paddy fields and it was remarkably noted that the growth of tank fishes was slower than those liberated in the paddy fields. The then rice committee of FAO in 1948 strongly advocated the practice of fish culture in the rice field for increased production of rice. The farmers of the north-eastern part of India, which includes seven states viz. Assam, Arunachal Pradesh, Nagaland, Meghalaya, Mizoram, Manipur and Tripura cultivate rice as their staple food and a fish crop is traditionally raised only from the paddies of rainfed lowlands (both shallow and deepwater). Traditional rice-fish production systems have an important socioeconomic part in the life of the farmers and fishers in the region. The practice of integrated farming system recorded higher mean average net return (Rs. 3,06,875), gross return (Rs. 3,88,375) and benefit cost ratio (4.58) over farmers practice.employment generation in the farming system under Integrated farming system was 193 days in a year from the Bellari district of Karnataka (Yogeesh et al.2016).Integration of various agricultural enterprises *viz*.,cropping, animal husbandry, fishery, forestry etc. not onlysupplement the income of the farmers but also help inincreasing the family labor employment through out the year (Jayanthi2002).

2.1. Improved integrated rice –fish farming system

Eastern India, in particular with about 5.6 m ha irrigated area and 14.6m ha rainfed lowlands of the total 26.58 m ha rice area, offers high potential for rice-fish farming system, especially in view of the resources, food habits and socio-economic needs of the people. Rice-fish farming system with higher water and land productivity and employment opportunities can ensure food, nutrition and livelihood security for the farming communities, particularly for the largest groups of small and marginal farmers. Rice-fish culture systems can be mixed or concurrent, sequential or rotational. However, the techniques differ based on the physical, biological and socio-economic profiles of the target agro-ecosystem.

2.1.1. Model I: Rice–fish–livestock-horticulture based farming system for rainfed lowland areas: In order to improve and stabilize farm productivity and income from rainfed water logged lowland areas, national Rice Research Institute, Cuttack has developed an adoptable technology of rice-fish diversified farming system. Farm size may vary from minimum of about one acre to one hectare or more. Field design includes wide bunds (Dykes) all around, a pond refuge connected with trenches on two sides(water harvesting come fish refuge system) and guarded outlet. The approximate area allotments will be, 20 % for bunds, 13 % for pond refuge and trenches and rest 67 % for main field. The pond refuge measures 10 m wideand 1.75m deep constructed in the lower end of the field. The two side trenches of 3 m width and average 1 m depth have gentle(0.5%) bed slope towards the towards the pond refuge. Small low cost (Thatched/asbestos top)duck house and poultry unit are constructed on bunds with a floor space of about 1.5 sq.ft. for each duck and 1 sq.ft. for each

Fig. 1.Rice –fish–livestock-horticulture based farming system for rainfed lowland areas

poultry bird. Poultry unit may be projected upto 50% over the water in the pond refuge to utilize the dropping as fish food and manure in the system. In such case birds can be housed in cages made of wire net. A small goat house is made on the bund with floor space of about 2 sq.ft for each animal (Fig. 1 and2).

i. Production Technology

Production Technology broadly involves growing of improved photo-period sensitive semi tall and tall wet season rice varieties with field tolerance to major insect pest and diseases. The suitable rice varieties are Gayatri, Sarala, CR Dhan 500, CR Dhan 505, Jalmani, Varshadhan for Odisha, Sabita, Jogen, Hanseswari for West Bengal, Sudha for Bihar, Madhukar and Jalpriya for eastern Uttar Pradesh and Ranjit, Durga and Sabita for Assam. Management of insect pest in rice crop is done with the use of sex pheromen traps, light traps and botanicals (Netherin/Nimbicidin spray at 1%). Indian major carps (Catla, Rohu, Mrigal) *Puntiussarana*, exotic carps (common carp, silver carp silver barb) and fresh water giant prawn (*Macrobrachiumrosenbergii*) fingerlings of 3-4" size and prawn juveniles of 2-3" size are released in a ratio of 75 % and 25 %, respectively at 10,000 per hectare of water area after sufficient water accumulation in the refuge and in the field. Fish and prawn are regularly fed at 2% of total biomass with mixture containing 95% of oil cake +rice bran (1:1) and 5% of fish meal. After rice, various crops like watermelon, mung sunflower, groundnut, sesame and vegetables are grown in the field with limited irrigations from the harvested rainwater. On bunds different seasonal vegetables are cultivated round the year including creepers on the raised platform, spices and pineapples are grown in shades. The fruit crops on bunds include varieties of dwarf papaya, banana T x D coconut and arecanut. Flowers like tuberose marigold etc. are also cultivated on the bunds. Both straw and oyster mushroom cultivation are done in the thatched or polythene enclose. Bee rearing is practice in 2-3 bee boxes on bunds. Agro-forestry component on the bund include short term plantation of mainly *Accacia* spp. (*A. mangium, A. auriculiformes)*. Animal component constitutes improved breeds of duck, poultry birds and goats. Ducks are raised in the rice field upto the beginning of flowering stage and later in an enclose in pond refuge till the harvest of rice crop. Live *Azolla* is released @ 0.5 -1.0 t ha^{-1} and is maintained to supplement duck feed and also to some extent fish feed, besides nutrition to the rice crop. Fresh water pearl culture is integrated in the system using the host mussel (*Lamellidensmarginalis)* which is normally available in the lowland rice ecology. Components can however, be included in the system based on location – specific requirements are grown along with the rice crop and later in the refuge after the rice crop is harvested.

ii. Productivity and economics

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

Table 1. Cost of raising rice-fish-horticultural model in 1.0 ha area at NRRI.

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

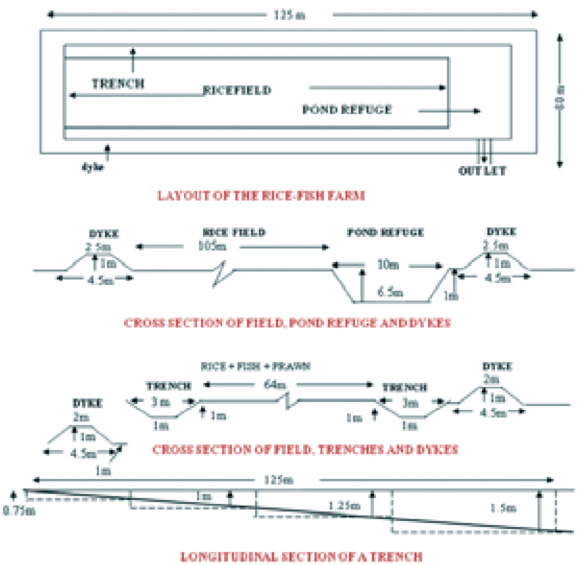

Fig.2. Layout and transverse section of rice based integrated farming system for rainfed lowlands.

2.1.2. Model II:Rice-fish-prawn-horticulture-agro-forestry based farming system for deep water: With the aim of enhancing farm productivity in deep water areas (5-100 cm water depth), a multi-tier rice-fish-prawn horticulture crops-agro-forestry based farming system model has also been developed in 0.06 hectares area at NRRI, Cuttack.

i. Production Methodology

The design of the system includes land shaping in the form of uplands(tier I and tier II) covering about 15% of field area followed by rice field area of 40% as rainfed lowland (tier III) and deep water (tier IV). This rice field is connected to a micro water shed cum fish refuge (pond) of 20% area for growing of fish and prawn with the rice crop. Raised and wide bunds are made all around using 25% of the farm area. The production technology includes growing of high yielding varieties of *rainfed* lowland rice (Gayatri, Sarala)in teir III and deep water rice (Durga and Varshadhan) in tier IV along with the fish and prawn during wet season. Dry season crops like sweet potato, mung, sunflower, groundnut, vegetables are grown after lowland rice in tier III. Dry season rice is cultivated after the deep water rice is harvested in their IV. Harvested rain water in the pond refuge is used for irrigation of the dry season crops. Improved varieties of perennial (mango, guava, sapota) and seasonal fruit crops (Papaya, Banana, Pineapple) are grown in upland (tier I). Round the year different seasonal vegetables and tuber crops (sweet potato, elephant foot yam, yam bean, colocasia and greater yam) are cultivated in tier II(Upland). Agro-forestry (*Acaciamangium*) and plantation crops (coconut and areca nut) are planted on the northern side of the bunds. Greater yam is grown with the support of trunk of agro forestry tree. The productivity of the system is about 8 t of rice crop per hectare, one tone of fish and prawn per hectare, 20-25 t of vegetablesha^{-1} and 8.5 to 51.7 t of tuber cropsha^{-1}. The cropping intensity in this system greatly increases to 170% in field and 360% in the upland.

ii. Productivity and economics

Multi-tier rice fish horticulture based farming system can annually produce about 14-15 t of food crops, 1 t of fish and prawn, 0.5 -0.8 t of meat, 10000-12000 eggs in addition to flowers and 3-5 t of animal feed from 1 hectare farm area. The productivity of food crops further increases to 16-17 t besides, 10-12 t of fiber/fuel wood from eight year onwards due to addition of produce from perennial fruit crops and agro-forestry components. The net income in this system is around Rs. 1,00,000ha^{-1} in the first year. This will increase to Rs. 1,50,000 or more from the eight year onwards.

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

i. Production Methodology

About an acre of integrated farm area has been reoriented for the farming system of which 30% of the area is converted to two rice plus fish fields of 600 sq.m area each with a refuge of 15% area and another 30% area is developed into two nursery fish ponds of equal size of fingerlings rearing (Fig. 3). The remaining 40% (1500 m^2) area is utilized as bunds for growing vegetables, horticultural crops and agro-forestry. Three rice crops are grown in the sequence of kharif rice (Sarla/Durga) followed by rabi rice (Naveen/Shatabdi) and then summer rice(Vandana/Sidhant). Yellow stem borer pest is controlled by using sex pheromone traps or by applying 1% Nethrin/Nimbecidine. Fish culture is taken up with catla, rohu and mrigal species. The fish fingerlings are reared in the two nursery ponds and are used for culture with rice crop in the system. The excess fingerlings are sold out. On the bunds agro-forestry plants like teak, Accacia, sisoo, neem, aonla and bamboo are planted on the northern and southernbunds. Horticultural crops such as banana, papaya and arecanut are grown on the bunds. Pineapple and spices are cultivated in the shade. Flowers like marigold,hibiscus and jasmine are also cultivated in the western bund in 50m^2 area. Two plants of lemon and each of guava, jackfruit, mango and litchi are also planted on the southern bund near the farm house to meet the household requirement. One poultry and one duckery unit are integrated in the system in which 40 poultry birds are raised during the dry seasons(October to April) and 20 ducks are reared during the wet season (July to December).

ii. Productivity and economics

Three crop of rice yields 800 to 1000 kg of grain per year. Entire produce is sufficient to cater the need of the small farm family. The straw is used for the cattle feed, mushroom base and roof of the farm house. Rest of the straw is sold to earn Rs. 500-1000 per year. After 2-3 months of rearing, fish fry worth of Rs. 4000-5000 is sold to the other farmers. Fish are harvested according to the need after the size becomes 250-300 g after 6 months or 0.5-1.0 kg after a year. The income from fish rearing in the system is Rs. 20,000. Pulses (mungbean, blackgram and pigeonpea) taken on the slope and bunds are just enough to meet the protein requirement of the farm family.

Fig. 3. Transverse section of the rice based integrated farming system for irrigated area

2.2. On Station Research

2.2.1. Rice-ornamental fish culture: In order to utilize the rice ecology for value added aquaculture, the technique of breeding and culture of ornamental fishes in irrigated lowland rice field has been developed at NRRI, Cuttack (Fig 4.). The rice field has been renovated to make a pond refuge and raise bunds all around. Ornamental fishes like Blue gourami, Red gourami, Pearl gourami, Guppies are bred and cultured with rice (lowland varieties) crop during wet season. During the dry season, rice (Naveen)cropwas

Fig. 4.Rice + ornamental fish system under irrigated lowlands.

grown along with ornamental fishes with irrigation. About 25,000-6,00,000 ornamental fishes ha^{-1}were produced in the system, in addition to 3.5t and 5.0t of rice grain during wet and dry seasons, respectively (Anonymous 1999).

2.2.2. Lowland weeds and their bio-control: Weed flora of different rainfed lowland ecosystems were studied with special reference to rice-fish system at the farm of NRRI, Cuttack revealed that with increase of water depth, the weed flora decreased by 39% under rice–fish system indicating fish as a potential bio-control agent for aquatic weeds.

The study conducted by Sinhababu et al. (2013) suggested that exotic carps (grass carp, silver barb and common carp in order) were more effective than Indian carps for control of weed in rainfed lowland rice fields and among the Indian carps, rohu showed potential for weed control. Under the categories of grassy, sedges, broadleaf and aquatic weeds total 13 major weeds were observed in the rice fields. Grass carp reduced maximum weed biomass with weed control efficiency (WCE)of 63% at 60 days after transplanting (DAT) and 62% at 100 DAT followed by silver barb and common carp (Table 2). Among the Indian carps, only rohu was effective in control of weeds (WCE 23% at 60 DAT).

Table 2. Weed biomass and weed control efficiency (WCE) in rice alone and rice-fish fields.

Treatments	Weed biomass (gm^{-2}) 60DAT	WCE (%) 60DAT	Weed biomass ($g\ m^{-2}$) 100DAT	WCE (%) 100DAT
Rice + grass carp	0.28^{d}	63.34^{a}	13.87^{d}	62.31^{a}
Rice + silver barb	0.32^{cd}	60.54^{a}	15.62^{cd}	56.55^{ab}
Rice + common carp	0.43^{c}	46.89^{a}	21.72^{c}	41.81^{b}
Rice + rohu	0.61^{b}	23.10^{b}	28.40^{b}	23.22^{c}
Rice + catla	0.77^{a}	4.99^{c}	32.86^{ab}	8.49^{c}
Rice + mrigal	0.76^{a}	3.44^{c}	31.75^{ab}	11.23c
Rice	0.80^{a}	–	36.42a	–

Source:Sinhababu et al. (2013)

2.2.3. Methane and nitrous oxide emission from rice–fish fields and refuge tank: Datta et al. (2009) observed that CH_4 emission from rice field plots sown with the two rice cultivars, with or without fish, varied considerably (cv = 17%). Methane emission was low in all the plots up to 30 days after sowing (DAS). Presence of fish resulted in an increase in CH_4 emission from both the rice cultivars with two sharp peaks recorded at flowering and maturity stages of the rice crop. The mean CH_4 emission (mg CH_4 m^{-2} h^{-1}) from sowing till harvest followed the order: Varshadhan + fish (2.52) >Durga + fish (2.48) >Durga (1.47) >Varshadhan (1.17). Cumulative CH_4 emission was highest in the treatment Varshadhan + fish (96.33 kg ha^{-1})while the lowest emission was reported in field plots planted to cv. Varshadhan without fish (45.38 kg ha^{-1}). Thus, percentage increase in CH_4 emission as a result of fish rearing was 112 in case of cv. Varshadhan and 74 in case of cv. Durga. Methane emission from the pond refuge followed a similar pattern as that from rice fields. On the contrary, Unlike CH_4, N_2O emission flux from rice fields exhibited a peak almost immediately after germination and stand establishment, at 30–36 DAS and declined thereafter (Fig.2). As a whole,N_2Ofluxeswere comparatively low during the entire cropping period become greater only towards maturity of the rice crop when the floodwater receded and the field started drying.

2.2.4. Physio-chemical parameters under rice fish system: Plots from an average of 28.51–28.94 °C in the different field plots in the morning (at 9:00 h) to around 32.23–34.63 °C in the afternoon (at 15:00 h) (Table 1). Field plots without fish exhibited significantly higher range of water temperature. The mean pH values also exhibited significant differences ($p<0.05$) between the mean water temperature increased considerably during the course of the day.

2.2.5. Fish Growth and Performance: Indian major carps, exotic carps and fresh water prawn was reared at a density of $0.6m^{-2}$ (1 Prawn: 8 Fish) in the system. Among the fishes, common carp was found to attain maximum size(2.4 kg) followed by Catla (2.0 kg) and the prawn attained asize of 100 to 270g. Sampling and partial harvesting indicated an estimated productivity of fish and prawn as 350 kg per ha per season from the rice-fish system.

2.2.6. Validation and adoption in the farmer's field: Since last two decades, rice-fish-horticulture based farming system was developed in different villages/blocks of Jagatsinghpur and Puri districts of Orissa, under different project funds. Recently during 2014 and 2015 a farmer Sri.KunjoMullick, from Jagasinghpur district belonged to small farmers category developed his rice growing farm into rice fish integrated farming system under the guidance of NRRI experts. His rice field was prone to flood during wet season due to poor drainage, back water and remain waterlogged for nearly 4-5 months. Rise in salinity level was another problem during end march till monsoon. The farmer mostly grew local rice varieties with low inputs and could get very low rice produce (0.8-1.0 t ha^{-1}) and hence could not sustain his livelihood. An initial investment of Rs 72,000 was done by the farmer for establishment and shaping of his rice area (Total 4 acres) into watershed/pond area of about 1 acre, where he was advised to put the Indian major carps and the dug out soil was transformed into raised dykes where the farmer took banana, coconut and vegetable crops like cowpea, pumpkin, leafy greens, drum stick etc. Poultry and duckery was taken in the house made with locally available materials. At the end of the year he could get the net income of Rs. 1,50,000 with the cost benefit ratio of 1:2.08.

3. KNOWLEDGE GAPS

Traditional agriculture is known to cause environmental degradation because it involves intensive tillage, when practiced in areas of marginal productivity. Technologies and management strategies that can inflate productivity need to be developed. At the same time, ways need to be found to preserve the natural resource base. Within this framework, an integrated farming system represents a key solution for enhancing overall production and safeguarding the environment through judicious and efficient resource use. Though many farmer, practices integrated farming system traditionally in their homestead land but is not foolproof in combating climatic vagaries and is mostly non interactive. The available resources in these areas, for modest growth in land productivity is not utilized efficiently to reduce the risk related to land sustainability *vis-a –vis* employment problem. Poor understanding of interaction and linkages between the components under rice based integrated farming system is the main reason for underutilization of resources and thereby unutilized rural employment leads to poor economic condition of the farmer.The integrated nature of goal-based modelling and the opportunity to play with the system might enhance learning about the different components, their mutual relations and the potentials of the farm system.

4. RESEARCH AND DEVELOPMENT NEEDS

Climate change is already happening and its effects, especially on India's rural communities are particularly adverse. Although integrated crop–livestock systems have been practiced globally for millennia, in the past century, farmers have tended toward increased specialized agricultural production for better profitability, concerning about natural resource degradation, stability of farm income, long-term sustainability. Revitalizing integrated crop–livestock systems could foster crop diversity, better managements of selected areas of the landscape to achieve multiple environmental benefits. Integrated systems inherently would utilize animal manure, mutual benefits of crop and livestock's which enhances soil tilth, fertility, and C sequestration, and adoption would enhance both profitability and environmental sustainability of farms and communities. The system components combination complexity and potential for public benefit justify the establishment of a new national or international research initiative to overcome constraints and move toward greater profitability and sustainability. The approach to climate-resilient agriculture will help increase the response capacity of farmers and the resilience of the ecosystem, and reduce their risks to climate change. The need is to highlight the key issues and understand the practical challenges that must be addressed to build the capacities of rural communities (small and marginal farmer's) to participate and robustly adapt to mitigate the climate change effects on agriculture.

In the climate change scenario, agriculture needs multi-sectoral and multi-agency approach;well planned synchronised efforts for achieving sustainable agricultural productivity and nutritional security and building resilience capacity of the people and their livelihoods. Specific integrated farming system technology 'package of practices' needs to be developed depending upon the farmers' need and requirement to the specific situation. Development of information system for providing timely, accurate crop-weather advisories helps in minimizing risk and losses. Promoting/ reviving of indigenous crop varieties and reverse the loss of agro-biodiversity is essential as indigenous crops are more resilient to climate variations and farmers have better equipped knowledge for handling them, and traditional crops generally meet the food preferences of communities. Reduction and proper utilization of waste generating from agriculture practices and post harvest stages and their utilization and value addition will reduce the carbon footprint.

Weather-based locale-specific agro-advisories, contingent crop planning, promotion of low external input technology, water budgeting, diversification for livelihood security, conservation and promotion of indigenous varieties and biodiversity need to be taken up in the respect of mixed integrated farming system are to be relooked in the newer prospective for successful adoption of farming system in the climate change scenario.

The way forward is to climate-smart sustainable integrated farming system. The healthy soil, land and ecosystem with suitable ecosystem services are the main issues, which will greatly contribute to conservation of precious resources (water, energy, soil health, etc.),while decreasing the carbon footprint in agriculture. Good quality storage facilities and marketing and value-addition of products would protect the income of small-holder producers.

5. WAY FORWARD

The need for diversification of farming practice is thereby needed as the income of farmers who depend solely on the produce of their traditional mono crop of rice pattern is decreasing due to limited profit margin and changed food consuming habits. Over the last two decades dietary pattern has been changed due to higher income generation, change in food habit, population explosion has also changed the supply and demand profiles of food. To meet the continuous rise in demand for food, stability of income and diverse requirements of food grains, vegetables, milk, egg and meat integrated farming systems (IFS) seems to be the feasible solution, thereby improving the nutrition of the small-scale farmers with limited available resources. Integration of different related enterprises with agriculture crops provides ways to recycle products and by-products of one component as input of another linked component which lessen the cost of production and thus raises the total income of the farm.Multiple land use through integration of crops, minor livestock with aquaculture can result in the best and optimum production from unit land area. In other words integrated farming system can be practiced as micro business by farm youthfor achieving regular income. Most of the constraints in agriculture can be removed by integration of diverse enterprises which will solve most of the existing economic and evene cological problems besides increasing productivity many-fold. Moreover,the expenditure on fertilizers also declined due to availability of a good amount of manure, which resulted into a saving of 50% expenditure on fertilizers as compared to arable farming (Tomer et al. 1982). The prospect of improved research methods for the integrated farming system is also an issue. This method should be tested in different agro-climaticzones through out the country and improve it for wide-scale adoption with low invest capital for small and marginal farmers as well as agri-enterprenuers.

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