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Director
ICAR Research Complex for Eastern Region, Patna
ICAR Parisar, Post: B.V. College, Patna-800014, India
Ph: + 91-0612-2223962, FAX: +91-0612-2223956
E-mail: directoricar-rcer@icar.gov.in
Website: www.icar.in

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कक्ष क्र. 101, कृषि अनुसंधान भवन-II, पूसा, नई दिल्ली-110 012, भारत
Indian Council of Agricultural Research
Room No. 101, Krishi Anusandhan Bhavan-II, Pusa, New Delhi-110 012 INDIA

डॉ. सुरेश कुमार चौधरी/ Dr. Suresh Kumar Chaudhari
उप महानिदेशक (प्राकृतिक संसाधन प्रबंधन)
Deputy Director General (Natural Resource Management)

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Foreword

Small and marginal farmers are resource poor, constituting 85 per cent of the total farming community in the country holding 44 per cent of the total operational land. These farmers are often subjected to crop failure due to various biotic and abiotic stresses. Multi-enterprise Integrated Farming System (IFS) model pave the way not only to reduce the risk of farming but also generate income and employment throughout the year. IFS can play an immense role to increase farm productivity and profitability alongwith 40-60 per cent resource saving and ensure household nutritional security.

The bulletin on "Integrated Farming System" has covered all the important aspects including economics, energy budgeting, future strategy and way forward. This document will be helpful for the farmers, researchers, academic personnel, policy makers and planners to a great extent.

I appreciate the efforts of the scientists of ICAR Research Complex for Eastern Region, Patna for bringing out valuable information on IFS in the form of Technical bulletin.

17/03/21
(S.K. Chaudhari)

Phone: +91-11-2584 8364
Fax : +91-11-2584 8366
E-mail: ddg.nrm@icar.gov.in
Website : www.icar.org.in

PREFACE

In Eastern India, rural poverty is primarily associated with non-profitability of traditional agricultural practices. Small and fragmented landholdings, high population density, poor infrastructure facilities, lesser involvement of secondary stakeholders in agriculture, less income opportunities through allied activities and poor investments in agriculture sector have been found as the major constraints in agricultural development. As a consequence, the livelihood options of small and marginal farmers are at stake resulting into high rate of out-migration in search of job. Development of ecologically and economically viable agricultural systems was, therefore, need of the hour, especially for > 80% small holders of the region.

Due to ever increasing population and shrinking land resources in the country, practically there is hardly any scope for horizontal expansion of land for food production. Only vertical expansion is possible by integrating appropriate farming components that require lesser space and time to ensure reasonable periodic income to farm families. Integrated farming system seems to be the possible solution to the continuous increase of demand for food production, stability of income and nutritional security particularly for the small and marginal farmers with limited resources.

Study emphasised that through IFS, average productivity improved by 41.2%, which in turn contributed 2.13-folds higher profitability, irrespective of farming systems. Dependency on external inputs, particularly fertilizers, was curtailed almost by 35% in Lower and Middle Gangetic Plains and 30% in Hill and Plateau region through recycling of within farm renewable resources. The study also suggested that livestock is an integral component of IFS which alone contributes 30-45% of the total returns in farming systems. Adoption of IFS mode of land use resulted in employment generation of 150-535 man-days/year indicating three-to-four-fold higher employment opportunities to farm families compared to rice-wheat cropping system. The water productivity, which has been recorded as 0.37 kg/m^3 of water for traditional agricultural practices, has been improved to 0.68 kg/m^3 in farming system mode of food production. The energy efficiency ratio in different components of IFS ranged from 0.17 to 8.66. Drudgery reduction in farming system was addressed through refinement in traditional tools and implements which could save the energy by 20-25% in agricultural operations.

So far in horizontal expansion of IFS models was concerned, half -acre model has potential for implementation in 4.36 m ha area of EIGP, followed by one and two-acre models (4.0 m ha), livestock based integrated farming system (> 4.0 million ha), agroforestry and horticulture interventions (> 2.0 million ha) and Makhana based IFS model (> 1.0 million ha). Fish based integrated farming systems resulted into the highest net monetary returns (Rs. 4.1-6.2 lakhs/ha). Hence, cattle-fish system followed by poultry-fish integration could be replicated for better returns in 2.5 million ha waterlogged ecologies of the region.

The document advocates that IFS mode of food production is one of the viable options for enhancing the farmers' income in Eastern India. Hence, at this juncture, the policies of the Govt. need to be dovetailed to address the farming system mode of food production in convergence mode. We hope that the information and findings of this study will be of great value and useful to the end users, scientific & academic personnel, line departments, planners and policy makers in devising effective strategies for promotion of integrated farming systems in the country.

Patna
March, 2021 Authors

Contents

Research at a Glance

- Two IFS models were developed at ICAR Research Complex for Eastern Region, Patna Research Farm comprising of Crop + Goat + Poultry (one acre model: 4000m^2) and Crop + Livestock (2 Cows) + Fishery cum Duckery (two-acre model: 8000m^2) for upland and lowland situation which represents more than 75 percent of eastern region.

- Total establishment cost of one acre IFS model was Rs. 1.58 lakhs and for two-acre IFS model was Rs. 2.61lakhs which includes construction of sheds for animals and birds, mushroom, pond, vermi-pits, biogas, boundary plantation and fruit crop unit.

- One acre and two-acre IFS model generates a total yearly employment by 351 and 619 man-days while yearly net returns are Rs. 88,527 and Rs. 1,48,569, respectively which is about three times higher over rice- wheat cropping system.

- Upon recycling of wastes obtained from different components under two-acre IFS, N=56.5 kg, P=39.6 kg and K=42.7 kg were added into the soil which is equivalent to 118 kg urea, 247 kg SSP and 42.7 kg of MOP.

- Upon recycling of wastes of different components under one-acre IFS, N-44.0 kg, P-29.5 kg and K-31.2 kg was added into the soil which is equivalent to 93.0kg urea, 184.0 kg SSP and 52.0 kg of MOP.

- The bio- gas unit of 2 m^3 capacity generates biogas equivalent to 16.2 LPG cylinder of 14.5 kg capacity from which lightening and cooking is practised.

- Total Output/Input Energy ratio in one acre and two-acre IFS model were 2.7 and 2.4, respectively.

- Average body weight of goat (12 months), poultry (5 weeks) and duck (72 weeks), fish (8 months) were found higher (11%) under IFS mode than field condition.

- Cereals + veg. + goat+ poultry + mushroom resulted in higher income sustainability index (0.79) and was followed by Cereal + goat + poultry (0.77) & Veg.+ goat (0.76).

- Net GHG emission from one acre model (Crop + Goat +Poultry) was -1658.2 kg CO_2- e while under two-acre IFS model it was -1670 kg CO_2- e.

Introduction

Indian economy is mainly agriculture oriented where small and marginal farmers are the core of the Indian rural economy constituting 85% of the total farming community but possessing only 44% of the total operational land (GOI, 2014). The average size of operational land holdings has reduced by half from 2.28 ha in 1970-71 to 1.16 ha in 2010-11. The operational farm holding in India is still declining. In Bihar and Kerala, the average size of holding fell by more than three times during the last four decades, whereas in Andhra Pradesh, Karnataka, Madhya Pradesh and Maharashtra, it has reduced by more than two times. This is reflective of the immense population pressure on the limited land resource available for cultivation (NABARD, 2014). The declining trend of per capita land availability poses a serious challenge to the sustainability and profitability of farming (Siddeswaran *et al.*, 2012). Due to ever increasing population and shrinking land resources in the country, practically there is hardly any scope for horizontal expansion of land for food production. Only vertical expansion is possible by integrating appropriate farming components that require lesser space and time to ensure reasonable periodic income to farm families (Gill *et al.*, 2005). From green revolution onwards, farmers are mostly concentrating on single enterprise based agricultural systems that lead to deterioration of soil health, increased risk of crop failure and downward trends of productivity (Rahman and Sarkar, 2012). Rapid population growth, urbanization and income growth in developing countries like India, the demand for food of animal origin is increasing, while also aggravating the competition between crops and livestock (increasing cropping areas and reducing rangelands). A system approach is the need of the hour for fulfilling the demand of ever-increasing population without disturbing the ecological balance. Integrated farming system seems to be the possible solution to the continuous increase of demand for food production, stability of income and nutritional security particularly for the small and marginal farmers with limited resources. It is not only a reliable way of obtaining a fairly high productivity with substantial fertilizer economy but also a concept of ecological soundness, leading to sustainable agriculture. Further, modest increments in land productivity are no longer sufficient for the resource-poor farmers. Hence, intelligent management of available resources, including optimum allocation of resources, is important to alleviate the risk related to land sustainability. Planning and implementation of different enterprises in Integrated farming system in our country lacks scientific and systemic approach. Moreover, proper understanding of interactions and linkages between the components would improve food security, employment generation as well as nutritional security. This approach can be transformed into a farming system that integrates crops with enterprises such as - agro forestry; horticulture; cow, sheep and goat rearing; fishery; poultry and pigeon rearing; mushroom production; sericulture; and biogas production - to increase the income and improve the standard of living of small and marginal farmers.

ICAR Research Complex for Eastern Region is multicommodity and multidisciplinary institute, mandated to conduct the adaptive and strategic research with focus on farming system Research for diverse agro-climatic zones of eastern India. Eastern states though possess only 21.85% geographical area but sustains more than 1/3 of total human and livestock population of the country. The most dominant cropping system of the area is rice- wheat, followed by rice-maize. Similar to human population, the region has high population of cattle (85 - 125/km^2), buffalo (60 - 90 km^2) and goat (50 - 150 / km^2) compared to national average. Goat rearing is quite common across the states mainly for meat production. Similar was the case for pig population (15 - 20/ km^2). In spite of the fact that the region is rich in natural resources, the agricultural productivity is quite low. Fragmentation of land holdings, inadequate farm mechanization, increasing cost of cultivation, inadequate supply of quality seed and planting materials and low per capita income are some of the major constraints for agricultural growth in the region (Kumar *et al*. 2012 a). Food and nutritional security were another core issue of research and extension in eastern India. Keeping these facts in view, an attempt was made to develop location specific farming system models for diverse agro-climatic zones so as to make the farming ecologically and economically viable.

Small holder production system of Eastern India was facing challenges due to aforementioned facts and figures. Sustainability of the resource poor farmers was at the stake. Moreover, synergistic role of livestock in cropping/farming systems was not realized and the production system was non remunerative. To address these problems, integrated farming system (IFS) research was undertaken in Middle and Lower Gangetic Plains, and Hill and Plateau region, integrating suitable crops, livestock, fishery, aquatic crops keeping intact the natural resource base of farming. The present work was conceptualized in the year 2007 at ICAR Research Complex for Eastern Region, Patna (located in between 25^{o}37′ N latitude and 85^{o}21′ E longitude and an altitude of 53m asl) taking in to consideration the different agro-ecological zones and land configuration and size of land holdings. Till the year 2006, no systematic work was carried out on Integrated Farming System particularly in eastern states of the country. Various State Govt. like Govt. of Bihar, Govt. of Jharkhand, Govt. of West Bengal, Govt. of Assam raised the issue to initiate research work on Farming system in different regional committee meetings so as to improve upon the livelihood of the small and marginal farmers of the region. Hence, it was realized to develop and validate location specific farming system models for different agro-ecological situations prevailing in the eastern region *viz.* irrigated ecosystem, wetland ecosystem and rainfed ecosystems. In the initial phase of the project, it was planned to develop half acre, one acre and two-acre IFS models through selection of suitable components (location specific) based on surveys made by the institute in the eastern states where the average size of land holdings is about 0.32 to 0.40 ha living in the fragile.

Further, stakeholders' meetings were organized during the year 2010-11, involving the farmers, State Govt. functionaries, researchers, NGOs and other extension workers in all the eastern states. Accordingly, the state specific researchable and other issues were identified. Resource inventory was also prepared for the region. Based on the interactions and intensive survey, it was felt that farming system mode of food production system could be the possible alternative to make the farming sustainable and economically viable. Rainfed, irrigated, lowland areas, water congested areas and hill and plateau typologies of Eastern Indo-Gangetic Plains (EIGP) were targeted to develop location specific integrated farming system models.

In eastern India, rural poverty is associated with small/fragmented land holdings, high population density, poor infrastructure, poor literacy, social conflict, lesser involvement of secondary stakeholders (extension, credit, input supply and market related) in agriculture, less income opportunities through allied activities and migration of rural labour due to under employment at farm level. Further, declining per capita land and water availability in agriculture would limit the food requirement of the burgeoning population by 2050 in the eastern states to a great extent. Water productivity is also very low (0.37 kg/m^3) in the region. Although the region has 165 million bovines, the crossbred cattle population is less than 5%. This sector has been almost neglected and its synergistic role in the farming practices has not been realized. The region also lacks quality feeds and fodder resources besides adequate animal health care mechanism. In case of fisheries sector, the total area under ponds and tanks in the eastern states is about 0.668 m ha with total fish production of only 1.43 m tonnes. Low productivity in floodplain wetlands, 11.0 million ha of rice fallow land, mono cropping, particularly in the Hill & Plateau region and seasonally waterlogged wetland etc. were other major constraints to increase the productivity and thereby profitability of the resource poor farmers.

Keeping the above facts in view, it was decided to develop location specific farming system models which could extend (i) sustainable production system, (ii) ensure food and nutritional security at household and even at individual level,

(iii) mitigate climate change impact on crop productivity, (iv) improve resource use efficiency and water productivity, and (v) provide gainful employment through farming practices.

Income and diversification through additional or mutually compatible enterprises is the key for improving livelihoods. But capital is needed for income diversification, and most resource-poor people lack capital. Evidence of the traditional perception that large or medium farmers are willing to test new technologies first followed by small and marginal farmers was not clear. Small, marginal farmers, share croppers and landless farm families need such technologies which are economically viable, farmers' friendly and less risky with lesser investment. The role of scientists to assess farmers' needs and demand, soil and land configuration, weather and climate, taste and preferences, technical knowledge of stakeholders about particular technology, risk bearing capacity, social acceptability, technical and economic evaluation, acceleration and dissemination, monitoring adoption, impact assessment and to develop client- oriented and location-specific integrated farming system with the key factors as depicted in Fig. 1.

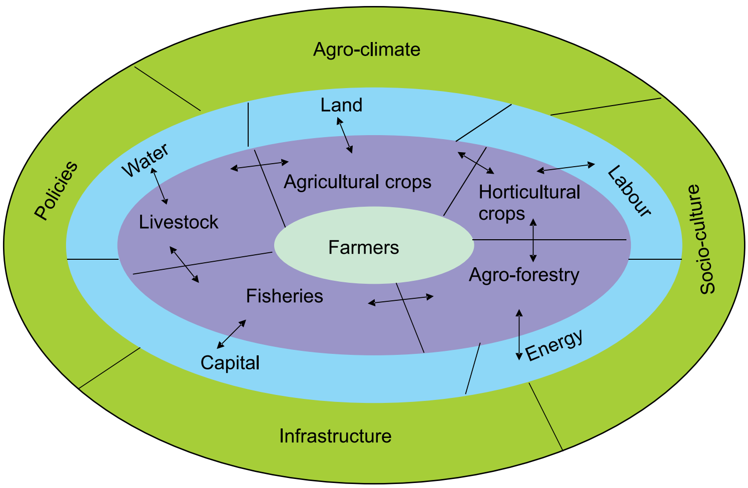

Fig. 1. Major Components of farming systems

Keeping above points in view, two representing Integrated Farming System (IFS) models : 1. One acre IFS model (for mid- land situation) and 2. Two-acre IFS model (for lowland situation) were developed at ICAR Research Complex for Eastern Region, Patna through which Income of the farmers from the same piece of land was enhanced by 3-4 times (Kumar *et al.*, 2011). It lies under middle Gangetic plains of sub-humid region. The average minimum temperature varies from 6-14°C and average maximum temperature between 20-22°C during winter season while average minimum and maximum temperature during summer varies from 22-30°C and 35-45°C, respectively. Average rainfall of the place varies from 1100-1200 mm in the normal monsoon.

IFS Models at a Glance

One acre IFS model	*Two acre IFS model*
Main enterprises: Crop + Goat + Poultry	Main enterprises: Crop + Livestock (2 no.) + Fishery
Allied enterprises: mushroom, vermicomposting	Allied enterprises: Duckery, composting, vermicomposting

Land allocation to different components under two acre IFS model (Fig.2)

(1) Cereal crops (50% area)

Kharif: Rice
Rabi: Wheat/Maize/Gram/Mustard

(2) Horticultural crops (Fruits + vegetables): 12.5% area

Vegetables:
Kharif: Cucurbits/Brinjal/Okra
Summer: Onion/Brinjal/Cowpea/Okra/Bitter gourd/Cucumber etc.
Rabi: Tomato, cabbage, Broccoli, French bean

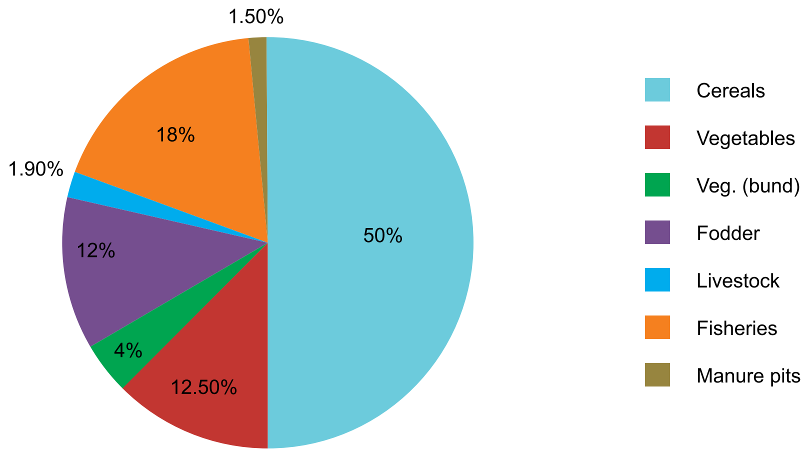

Fig. 2. Area under different components under two acre IFS model

Fruits:
Papaya (On pond's dike and field bunds)
Banana (On pond's dike)
Lemon (On pond's dike and Horticultural block)
Guava (On pond's dike and Horticultural block)

(3) Boundary plantations (4% area)

All around the fields, drumsticks and dhaincha plants were planted to provide fodder to animals and seeds for green manure crop. On field funds, fencing was done and cucurbits, pigeon pea and soybean crops are being raised for maximum utilization of land and to provide protein supplements to farm families.

(4) All around the field bunds cucurbits or seasonal vegetables having lesser water requirement may be raised by making wire fences.

(5) Fish + Duck integration (17.8% area)

(a) Mix carp culture: Rohu (20% as column feeder), Catla (30% as surface feeder), Mrigal/common carp (50% as bottom feeder)

(b) Duck: For 1000 m^2 water area 40- 45 number of ducks are found sufficient.

Khakhi Campbell breed of duck is right choice for this area (Dual purpose). A thatched hut of 10 x 15′ size is optimum for 40 ducks above the water or on the pond's dike.

(6) Livestock (1.80% area) + Bio- gas unit

A size of 2 adult cows + 2 calves is optimum for two-acre land in respect of FYM requirement for the fields and fodder requirement for the livestock. A thatched hut of 20′ X 30′ with sufficient paddock space is sufficient for above number of animals. The Cow shed was connected with the pond with a drainage channel so that urine and water can move into the pond. A storage hut for storing of animal feed was also made near the animal shed. A bio- gas unit of $2m^3$ capacity was also constructed under livestock area for production of bio-gas for energy and slurry to making vermicompost to the crops. It was found that for $2m^3$ capacity of bio-gas unit, by product obtained from two adult cows are optimum.

(7) Fodder production (12.5% area)

For feeding of 2 cows and 2 calves 1000 m^2 land is sufficient if year-round fodder production is carried out. In addition to green fodder, straw, leaves, stems of different cereals and vegetables can be also used as animal feed.

Kharif: M.P. Chari/Sudan grass/ Napier/Maize
Summer: Boro/Lobia/Maize/Sudan grass
Rabi: Berseem/Oat/Maize etc.

(8) **Spices**: In the sheds or where light intensity is less like orchards, spaces between the huts etc. turmeric, ginger or guinea grass are being taken.

(9) **FYM/vermicomposting pits**: (1.4% area)

Optimal sizes pits (9′ x 3′) for preparation of FYM (3 pits) and Vermicompost (4 pits) has been made. Sizes may depend upon land available near the livestock shed so that required raw materials for making manures should be made available nearby for convenience and to avoid transportation charges.

Note: Cattle shed should always be constructed away from birds to avoid attack of any transmissible or contagious diseases to animals or vice-versa.

Land allocation to different components under one acre IFS model (Fig.3)

(1) **Cereal crops** (50% area)
Kharif: Rice
Rabi: Wheat/Maize/ Lentil/Til

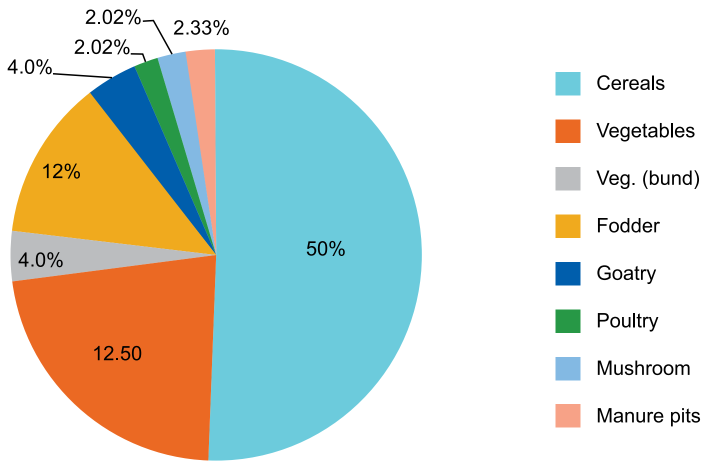

Fig. 3. Area under different components under one acre IFS model

(2) **Horticultural crops** (Fruits + vegetables): 22.5% area

Vegetables:
Kharif: Cucurbits/Brinjal/Okra
Summer: Brinjal/Cowpea/Okra/ Bitter gourd/Cucumber etc.
Rabi: Tomato, Cauliflower, spinach

Fruits:
Banana (On field bund)
Lemon (In Horticultural block)
Guava (In Horticultural block)

(3) **Boundary plantations** (4% area)

All around the field, Karaunda, drumsticks and dhaincha plants were planted to provide fodder to animals and seeds for green manure crop. On field funds, fencing was done and cucurbits, pigeon pea and soybean crops are being raised for maximum utilization of land and to provide protein supplements to farm families.

(4) **Livestock (Goat)**: 2.5% area

A size of 20 female goat + 1 buck is optimum for one acre land in respect of manure requirement for the fields and fodder requirement for the livestock. A thatched hut of 20′ X 30′ with sufficient fenced paddock space (to move goats freely as goats have to kept on stall feeding) is sufficient for above number of animals. The goat shed was made airy and sunny. A storage hut for storing of animal feed was also made near the animal shed. Black Bengal breed of goats are found suitable for this region.

(5) **Poultry** (200 birds)

200 birds (broiler) are being reared in an area of 225 sq. ft. by making a thatched hut. All around the thatched hut's walls, wire meshing has been done at the inner walls to protect the birds from predators and hunting animals. The hut was made airy and proper arrangement of bulbs was made before rearing the chicks.

(6) **Mushroom**

Year-round mushroom production is being done in an area of 25′ x 20′ by making a thatched hut for optimum return. In this shed about 200 mushroom bags are being kept at a time by making bamboo shelves.

Selection of the mushroom strains is done on the basis of climate, temperature and humidity in the atmosphere as:

March - September: Straw/Paddy/Milky mushroom
October- February: Oyster/ Button mushroom

(7) Fodder production (12.5% area)

For feeding of 20 + 1units of goat an area of 600m^2 is sufficient if year-round fodder production is carried out. In addition to green fodder, dry husks, leaves, stems of different cereals and vegetables are also being used as feed.

Kharif: M.P. Chari/Sudan grass
Summer: Boro/Lobia/Maize/Guinea grass
Rabi: Berseem/Oat/Maize etc.

(8) Spices: In the sheds or where light intensity is less like orchards, spaces between the huts etc. turmeric, ginger or guinea grass can be taken.

(9) Compost pits/ vermicomposting pits (1.4% area)

Optimal sizes pits for preparation of goat manure and Vermicompost should be made depending upon availability of land near goat shed so that required raw materials for making manures should be made available nearby field and livestock.

Note: Goat shed should always be constructed away from poultry shed to avoid attack of any transmissible or contagious diseases to animals.

Income and Recycling of Resources within IFS model

The farming system models were started in the year 2010, and on the basis of 10 years data, now it can be analysed that by integrating Crop + Livestock + Fish/ duck in two-acre area of land, a net income of Rs. 1,48,569/- can be achieved with a B:C ratio of 1.85 which is about 4 times higher over rice-wheat cropping system (Table 1) with an additional income equivalent to 93 kg urea, 184 kg SSP and 52 kg MOP under one acre IFS model (Table 2) and 118 kg urea, 247 kg SSP and 71.2 kg MOP as due to nutrient recycling within the system 56.5 kg N, 39.6 kg P and 42.7 kg K were added to the soil which will be utilized by the next crop (Table 3). To start up with all these components an initial investment of Rs. 2,05,000/- may be required.

Table 1. Income and expenditure statement for developed one acre IFS model

IFS Components	Establishment Cost (Rs.)	Annual Expd. (Rs.)	Net Income (Rs.)
Crop (0.2 ha)	-	15,320	13,100
Hort. (0.09 ha)	3,000	7,840	11,416
Fodder	-	4,120	7,285
Goat (0.018 ha)	43,220	17,810	20,832
Mushroom (0.003 ha)	9,000	5,240	5,493
Poultry (700 chicks- 0.0015 ha)	15,000	38,100	20,141
Vermicompost/ Crop waste	8,000	3,430	6,260
Total	1,58,220	1,03,860	88,527
		B: C:: 1.85	

Table 2. Recycling of farm waste and gain/saving of nutrients through 1 acre IFS model at ICAR-RCER, Patna

Farm waste	Quantity produced (q)	Production/use pattern (q)	Nutrient gain (kg)	Total Nutrient Gain Upon Recycling	Saving due to resource recycling (Rs.)	Fertiliser Saving (kg)
Goat (20+1) droppings	24.9	18.5(GM- 7.2) 6.4 (VC- 1.7)	N- 10.0 P- 5.8 K-11.6	N- 44.0 P- 29.5 K- 31.2	3125	93.0 kg urea 184.0 kg SSP 52.0 kg MOP
Veg. waste	66.2	18.4 (VC-6.8) 50.0 q - As fodder	N- 14.1 P- 10.2 K- 14.8			
Poultry manure (600)	17.8	Used in crops (35.2)	N- 20.7 P- 17.5 K- 9.6			
RWMML Straw	46.4	4.4- mush.shed 1.6- hut 42.8 q- sold				

Table 3. Recycling of farm waste and gain/saving of nutrients through 2 acre IFS model at ICAR-RCER, Patna

Farm waste	Quantity produced (t)	Production/ use pattern (t)	Nutrient gain (kg)	Total Nutrient Gain from recycling	Saving (Rs.)	Fert. equivalent (kg)
Cow dung (2 +2)	13.8	8.2 (FYM- 3.6) 2.5 (VC: 1.3) 4.0- Pond treat.	N-21.5 P- 12.2 K-13.3	N = 56.5 P = 39.6 K = 42.7	Total: Rs.4826/-	118 kg urea 247 kg SSP 71.2 kg MOP
Veg. waste	11.3	6.2 (VC-1.6) 6.5 As fodder	N- 28.6 P- 22.2 K- 24.7			
Duck drop. (35**)**	1.21	As fish feed/silt	N- 6.4 P- 5.2 K- 4.7			



For development of a particular IFS model, selection of components play an important role towards contributions to income from different enterprises of the model. While selecting the components one should be enough careful about his needs, technical knowledge about the component, water, land and labour availability, transportation and marketing facilities etc. to get maximum profit. In the developed two-acre IFS model, Fish integration has resulted in maximum contribution to income and was followed by Horticulture and dairy components while maximum contribution to income was gained towards poultry and was followed by Goatry and horticulture under one acre IFS model, respectively (Fig. 4).

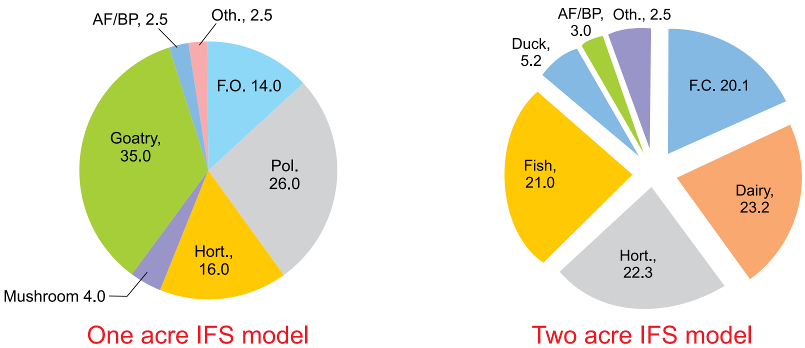

Fig.4. Percent contribution to the income by different components under IFS models

Nutrient Recycling

Nutrient recycling within the system is prerequisite for development or integration of any component in the IFS model. Priorities should be given to those components whose by-product can be recycled within the system or can be reused as input for another component to increase nutrient use efficiency on one hand and also for decreasing the cost of cultivation and addition of organic forms to the system for its sustainability. Under two-acre IFS model, 13.8 t of cow dung from two cows, 11.3 t of vegetable wastes and 1.21 t of duck dropping were produced and recycled within the system which added an amount of Rs. 4,826/ year to the income (Kumar *et al*., 2012b). Likewise, under one-acre IFS model 2.5 t of goat manure, 6.62t of vegetable wastes, 1.78 t of poultry droppings and 4.64t of rice/maize/lentil straws were recycled within the system which contributed Rs. 3,175 to the income and added 44.0 kg N, 29.5 kg P and 31.2 kg K in the soil which was equivalent to 93.0kg urea, 184.0 kg SSP and 52.0 Kg MOP (Table 4). In addition to these nutrients an ample quantity of micronutrients was also added to the soil through nutrient recycling. A nutrient flow diagram for the purpose of nutrient recycling in an IFS model has been represented as Fig.5.

Table 4. Conversion efficiency of different biomass used for vermicompost

Source of material	Quantity of biomass + cow dung (D.W. basis (kg.)	Worms released per m^2	Worms obtained after vermicom-posting/m^2	Days required to make the vermicom-post	Quantity of vermi-compost produced (kg)
Common weeds	258.0	2000	4000	65	102.0
Foliage of *Erythrina indica*	63.8	2000	3527	80	18.8
Trianthema portulacastrum	98.45	2000	3000	52	27.6
Maize	135.0	2000	2950	80	28.7
Spent spawn of mushroom	96.0	2000	4450	60	48.5

Recycling of farm renewable resources through vermicomposting

Earth worm species *Eisenia foetida* has been found most efficient so far in conversion efficiency of biomass into vermicompost was concerned. Different source of materials were tested for vermicomposting. It has been observed that 50 to 80 days were required for preparing vermicompost of various materials while *Trianthema portulacastrum* (one of the common aggressive weeds of *Kharif* and summer season) took lowest period (52 days) for vermicompost. Foliage of *Erythrina indica* took maximum time (80 days) for the same. The multiplication of worms also varied depending on the source of material. However, maximum

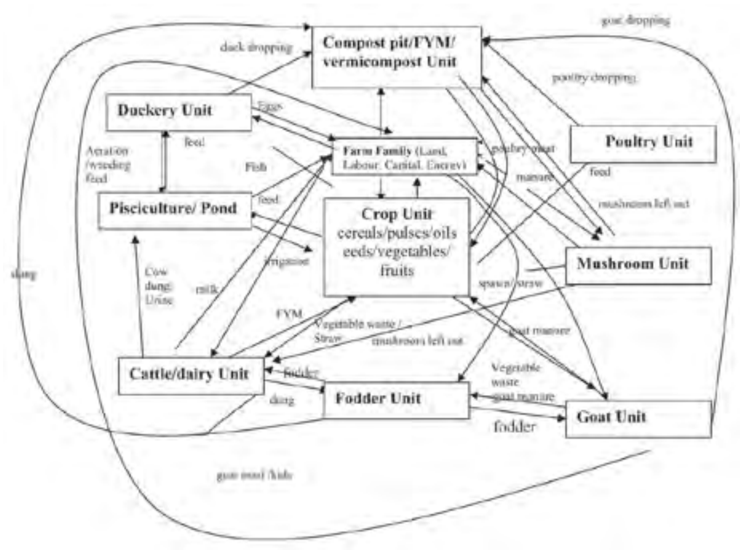

Fig. 5. Input and output flow diagram under IFS model

worms were obtained from spent spawn of mushroom used for vermicompost, i.e., 4450 and lowest (2950) in maize straw (Table 4). The nutrient content in vermicompost varied based on the material used. The conversion efficiency of the worms could also be manipulated by increasing their stocking density. Usually, 2000 worms are released per square meter of biomass. Increased worm population per unit of biomass to be recycled, could convert the waste biomass into vermicast at a much faster rate.

Employment Generation

It is often said that there is hidden unemployment in Agriculture which can be best descried with an example with seven members in a family (four adults and three children), they possess a land of one acre in which rice- wheat cropping system is being followed. It is observed that all the members are engaged in the farming itself while it is not required. Most of the time they are sitting idle. IFS model here is ready to overcome this type of problem by integrating a greater number of remunerative components in the system. By integrating one or two small components say 500 no. of poultry and 500 bags of mushroom cultivation, about 110 man-days requirement is enhanced and these family members are able to perform these works easily. Women and children can be also involved in many of agriculture-based activities like nursery raising, mushroom cultivation, poultry farming, vermicomposting etc. Man power requirement under one acre IFS model (Crop + Goat + poultry + mushroom) and two-acre model (crop + fish/

duck + livestock) has been depicted in the Fig. 6. Man- power requirement by different combinations and component wise were also studied in the farmers' field and presented in table 5. It was observed that livestock based IFS model engaged the maximum number of man- days and generated an additional 281man- days over cereal based cropping system only.

Table 5. Employment generation (man-days) by different IFS models

Farming Components	Crop	Hort.	Poult	Duck	Fish	Goat	Dairy	FYM/V. comp.	System emp.	Add. M-days
Crop alone (cereals)	137		-	-	-	-	-	-	137	-
Crop + Hort.	172	242						21	435	120
Crop/Hort. + Fish + poultry	135	145	110	-	36	-	-	20	446	181
Crop/Hort. + Fish + Duckery	155	145	-	40	36	-	-	25	401	136
Crop/Hort. + Fish + Goat	135	145	-	-	36	110	-	30	456	191
Crop/Hort. (0.4 ha) + Fish + Cattle	133	145	-	-	36	-	210	32	568	281
Crop/Hort. + Fish + P + D	135	145	110	40	36	-	-	20	486	221
Crop(c/v) + Mush. + Goat	155	145	-	-	-	110	Mush. 40	20	470	205
Crop / Hort .+ P + Mush. + Goat (1 acre)	72	84	63	-	-	110	Mush 40	32	351	86
Crop / Hort. + Fish + D + Cattle (2 acre)	133	145	-	40	36	-	210	32	619	382

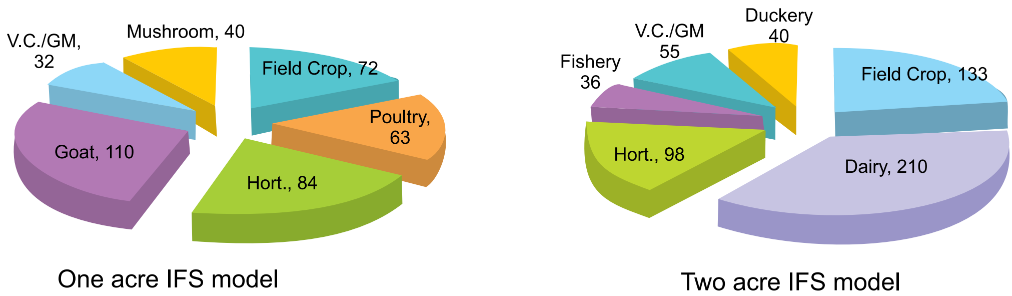

Fig. 6. Man-days requirement by different components in IFS mode of food production system (*Source:* Kumar *et al.*, 2018)

IFS mode of production system generates 3-4-fold higher employment opportunity to farm family compared to rice- wheat cropping system. By integrating one or two small components *viz.* 500 nos. of poultry birds and 500 bags of mushroom cultivation employment of 110 man-days was enhanced. Man-power requirement under one-acre IFS model (Crop + Goat + Poultry + Mushroom) and two-acre model (Crop + Fish/Duck + Livestock) has been depicted in the Fig. 6. It was observed that livestock-based IFS model engaged the maximum no. of man- days and generate an additional employment of 281 man- days over cereal based cropping system.

Effect on Soil Fertility and Water Quality due to Different Integrations

Integrated farming system provides ample number of organic wastes in form of organic manures after its recycling which contains abundant quantity of NPK and other micronutrients. It was observed that due to incorporation of organic manures in form of FYM + poultry droppings or goat + poultry droppings to IFS plots, available N, P & K increased over the plots in which only inorganic fertilizers were applied over a period of ten years (Table 6b and Fig.11). A clear-cut decrease in organic carbon content was also observed in the soils which was fertilized with inorganic sources only. While a slight increase was observed in respect of organic carbon content in the plots where organic sources were applied along with inorganic sources. This finding advocated the utility of INM practices for getting an optimum yield level for a longer period of time. Nutrient content in vermicompost and duration for preparation of vermicompost from different sources varied in respect of material used, substrate used and enriching material used. It was found that when vermicompost was prepared from leaves then it took only 75-80 days and nutrient content was also higher over other sources. Cow dung was used for enriching the compostable materials. The details about other sources are presented in Fig. 7.

Soil fertility built up (C- stock, Microbial biomass and nutrient dynamics)

In the eastern states, a huge number of animal population (172 million) exists but its by-product is being used mainly as dung cakes for fuel purpose and therefore limited amounts of cow dung is used as manure. In farming system approach, however, by- products of animals/birds/vegetable wastes etc. are recycled and an appreciable amount of nutrients are added into the soil. The study revealed appreciable amount of fertility build up in farming system approach. The field where crop + goat + poultry + mushroom was integrated has

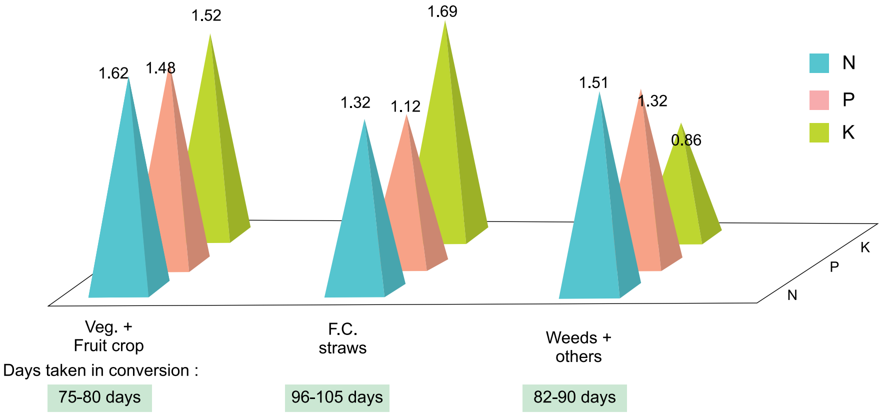

Fig. 7. Percent NPK and time taken to prepare vermicompost from different sources

shown maximum increase by 15.9, 21.1, 22.8 and 10.2 per cent in respect of N, P, K and organic matter content, respectively (Table 6a & b).

Effect of different land use on total soil organic carbon (TOC) under integrated farming system model was clearly visible. The orchard system registered highest TOC content (12.4 g kg^{-1}) which was considerably higher than other systems

Table 6a. Soil fertility status and soil fertility build up under different integrated farming systems in the midland irrigated system of Bihar (2010 - 2020)

Systems	Soil fertility status in 2020				Soil fertility build up in per cent after 10 years of experimentation			
	N (kg/ha)	P (kg/ha)	K (kg/ha)	OC (%)	N	P	K	OC
Rice- wheat	210.2	26.5	220.5	0.59	-2.9	-2.0	-2.6	0.0
Field crops + dairy + fishery	242.9	31.5	251.0	0.63	12.2	15.8	15.8	6.8
Field crops + dairy + fishery + duck	249.2	34.1	260.1	0.63	15.1	25.4	25.4	6.8
Field crops + goatary + fishery	250.4	32.8	261.8	0.65	15.7	18.6	20.6	8.5
Field crops + goatary + poultry + mushroom	251.0	33.2	256.2	0.64	15.9	21.1	22.8	10.2
Field crops + fruits + dairy + mushroom	237.6	30.5	247.5	0.62	9.7	12.1	12.1	5.1
Field crops + vegetable + goatry	247.5	31.8	258.6	0.63	14.3	16.9	16.9	6.8
Field crops + vegetable + poultry	245.6	29.2	251.6	0.63	13.4	7.4	7.4	6.8
Field crops + fruits + Goatry	249.8	30.5	252.3	0.63	12.1	15.8	15.8	6.8
Field crops + vegetable + mushroom	223.9	27.9	234.6	0.61	3.4	2.6	2.6	3.4

Initial soil fertility: N - 216.5 kg/ha, **P -** 27.2 kg/ha, **K -** 226.5 kg/ha, **OC -** 0.59%

Table 6b. Nutrient supplementation under different integrated farming systems in the midland irrigated system of Bihar (2010-2020)

Systems	Nutrient added/yr (kg/ha)					
	Inorganic source			Organic source		
	N	P	K	N	P	K
Rice- wheat	200	100	80	-	-	-
Field crops + dairy + fishery	150	75	60	42.6	39.4	35.2
Field crops + dairy + fishery + duck	150	75	60	62.8	60.3	58.5
Field crops + goatary + fishery	150	75	60	54.4	47.8	38.4
Field crops + goatary + poultry + mushroom	150	75	60	78.7	73.2	74.3
Field crops + fruits + dairy + mushroom	150	75	60	65.2	54.7	56.7
Field crops + vegetable + goatry	150	75	60	63.2	58.1	60.4
Field crops + vegetable + poultry	150	75	60	54.6	48.6	50.2
Field crops + fruits + goatry	150	75	60	57.2	52.5	60.2
Field crops + vegetable + mushroom	150	75	60	35.8	32.0	33.1

(10.1-10.4 g kg^{-1}) in 0-15 cm soil layer. In contrast, in the second layer (15-30 cm), the highest TOC content was measured in fodder system (9.1 g kg^{-1}) which was followed by field crops (8.5 g kg^{-1}) and vegetables (7.9 g kg^{-1}), and least SOC content was found in orchard system (6.2 g kg^{-1}). Further down the layer, the SOC content ranged between 7.3-8.4 g kg^{-1} among different systems. The higher SOC content under orchard system could be attributed to leaf fall and resulting decomposition with time (Fig. 8).

Irrespective of land use pattern, all systems registered a positive C-balance in 1-acre IFS model. The highest SOC build-up in the surface layer was noted in guava orchard (22.6 Mg ha^{-1}) followed by lemon orchard (22.1 Mg ha^{-1}), vegetable

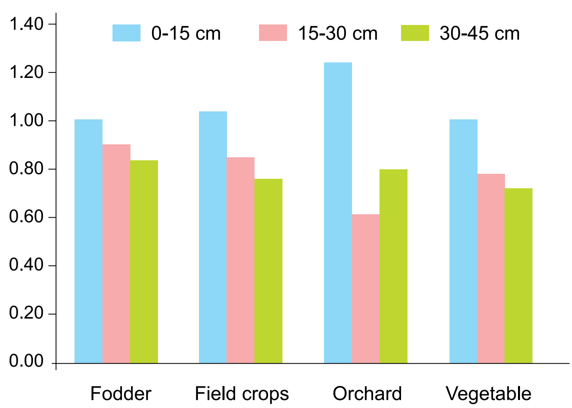

Fig. 8. TOC (%) as affected by different land use under IFS

crops (21.4 Mg ha^{-1}), field crops (20.8 Mg ha^{-1}), virgin land (19.1 Mg ha^{-1}) and least SOC stock was observed in fodder system (18.6 Mg ha^{-1}). The trend was almost similar in the second layer and SOC among different systems varied between 19.5-16.0 Mg ha^{-1}. Similar to 1-acre model, 2-acre model also registered a similar pattern in SOC stock among different land use systems. The highest (23.6 Mg ha^{-1}) and lowest (14.5 Mg ha^{-1}) SOC stock was logged by guava orchard and fodder system, respectively in the surface 0-15 cm soil layer. in the next layer, the SOC stock varied between 11.3-20.2 Mg ha^{-1} among different systems (Fig. 9).

Microbial biomass carbon (MBC) also varied considerably among different land use systems in 2-acre IFS. Field crops noted higher (19-55%) MBC than other systems in the upper 15 cm soil layer. In the succeeding layer (15-30 cm), the pattern changed and it followed the trend of fodder crops (36 mg kg^{-1}) > field crops (34 mg kg^{-1}) > vegetables (18 mg kg^{-1}) > orchards (13 mg kg^{-1}). In the deeper soil layer, all the systems registered almost similar MBC content (27-34 mg kg^{-1}) except the vegetable system that registered relatively lower (40-53%) MBC than others (Fig. 10).

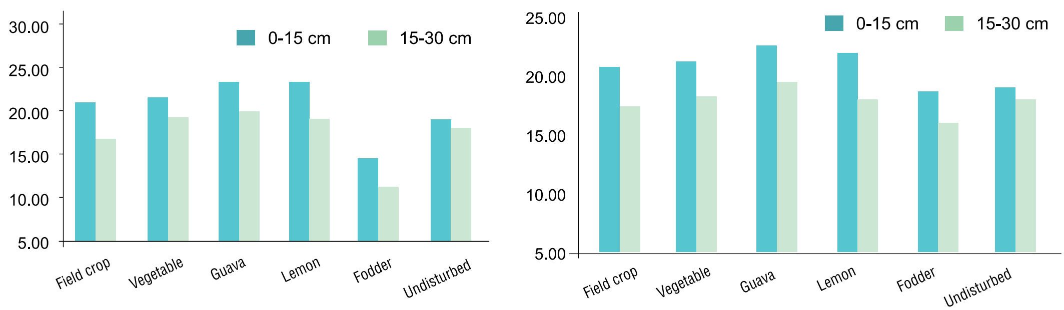

Fig. 9. Soil organic carbon stock (Mg ha^{-1}) as affected by different land use under IFS (*Source:* Kumar *et al.*, 2017, 2018)

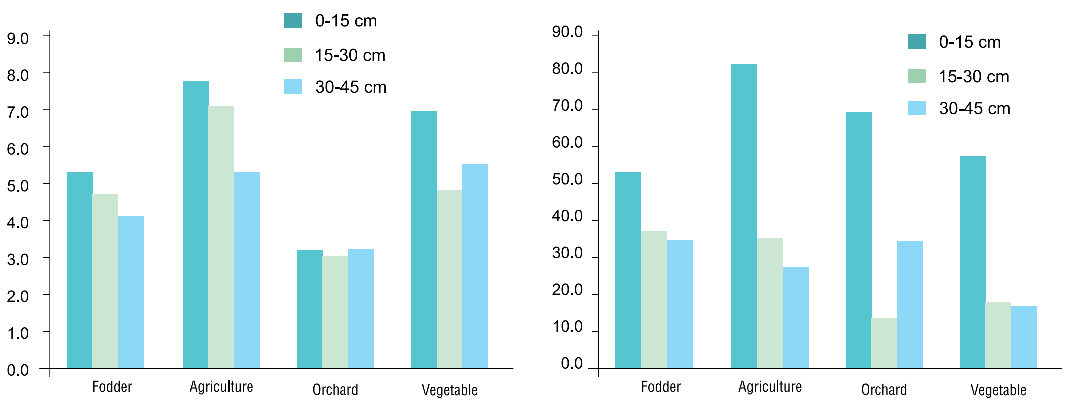

Fig. 10. Microbial biomass carbon (mg kg^{-1}) and dehydrogenase activity (µg TPF h^{-1} g^{-1} soil) under IFS due to varied land use

- Dehydrogenase activity, indicates microbial activity in soil, was measured in 2-acre IFS model. It was observed that field crop systems registered highest dehydrogenase activity 7.72 µg TPF h^{-1} g^{-1} soil followed by vegetable (7.0 µg TPF h^{-1} g^{-1}) and fodder systems (µg TPF h^{-1} g^{-1}) and the lowest value was noted for orchard system (3.2 µg TPF h^{-1} g^{-1}) in the plough soil layer. In the subsurface soil layer (15-30 cm), only field crop system resulted in highest dehydrogenase activity of 1 µg TPF h^{-1} g^{-1} while all other systems logged a similar value and ranged between 3.0-4.8 µg TPF h^{-1} g^{-1} (Fig.10).
- The adoption of the IFS system resulted in an increase in nutrient content in the soil. Irrespective of different combination of components, all systems registered an increase in available nitrogen, available phosphorous and exchangeable potassium content 11.5-14.6, 9.5-12.7 and 1.8-13.5%, respectively (Table 7). Crop in combination with goat, poultry and mushroom was the most effective system in enhancing the nutrient content in the soil while only cereal system was the least effective one.

Table 7. Nutrient dynamics under different land use system in IFS

Farming System	2008	2020 (kg ha^{-1})			Increase%		
	Initial (kg ha^{-1})	N	P	K	N	P	K
Cereals only	N 216.5	248.5	29.8	230.6	12.9	9.5	1.8
Cr+Veg (50%)	P 27.2	244.6	30.1	255.8	11.5	9.8	11.5
Cr+F+P (50%)		249.2	31.0	257.4	13.1	10.0	12.0
Cr+F+Duck (50%)	K 226.5	250.6	31.3	256.7	13.6	10.7	11.8
Cr+F+Goat (50%)		252.4	31.7	260.1	14.2	12.5	12.9
Cr+F/D+Dairy (50%)	OC 0.59 (%)	252.1	31.0	261.4	14.1	11.6	13.4
Cr+G+P+ Mushroom		253.6	31.9	261.7	14.6	12.1	13.5
Cr+Mushroom +Goat		252.6	31.8	258.6	14.3	12.7	12.4

Effect on Soil Fertility

It was observed that due to incorporation of organic manures in the form of FYM + poultry droppings or goat + poultry/duck droppings in farming system plots, available N, P & K increased considerably (Fig. 11). A clear-cut decrease in organic carbon content in the soils was also observed which was fertilized only with inorganic sources while a slight increase was observed in respect of organic carbon content in the plots where organic sources were applied along with inorganic sources too. This finding advocated the utility of INM practices for getting an optimum yield level for a longer period of time.

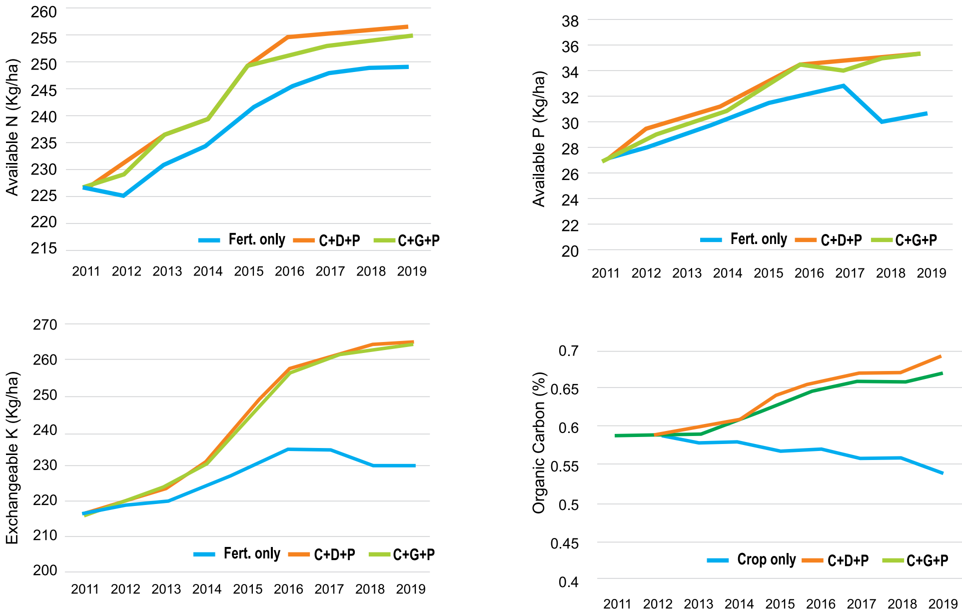

Fig. 11. Changes in fertility status due to nutrient recycling
C- Cow dung; D- Duck droppings; G- Goat droppings, P- Poultry droppings

Improvement in water productivity

The water productivity in traditional agricultural practices of Eastern India has been recorded to be 0.37 kg/m^3 water for rice-wheat cropping system with highest (0.61 kg/m^3) in Eastern UP and lowest (0.21 kg/m^3) in Odisha. The overall water productivity of cereal based cropping systems of the region is quite low compared to Punjab, where the water productivity is more than 1.0 kg/m^3 of water. However, the water productivity in Eastern India could be improved significantly through farming system approach. The data indicated the average water productivity of 0.68 kg/m^3 of water in farming system compared to 0.37 kg/m^3 in traditional cropping systems indicating 1.83-fold increase in water productivity. West Bengal, followed by Eastern UP and Bihar, has tremendous potential to improve the water productivity through farming system approach (Fig. 12). Likewise, the water productivity of fish based integrated farming system has been observed to be 0.26 kg/m^3 in Eastern India compared to 0.14 kg/m^3 in traditional fish rearing practices. Cattle-cum-fish integration, followed by buffalo-cum-fish integration registered highest water productivity compared to other integrations (Fig. 13).

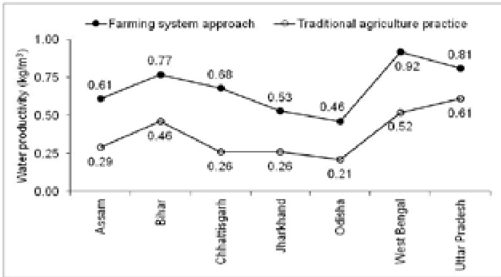

Fig. 12. Water productivity in farming system mode of food production system

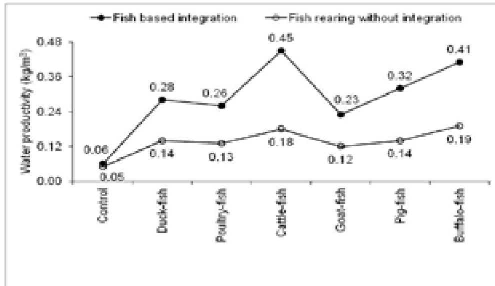

Fig. 13. Water productivity of fish based integrated farming system

(*Source:* Sarma *et al*. 2019)

Duck-fish integration

Duck-fish integration is one of the promising integrations for low lying areas where water is stagnated upto a period of 4-5 months in a year. For a pond area of 1000 m^2 a total no. of 40-50 ducks can be incorporated and duck droppings may be used as feed source for the fishes (mix carp culture, 1000 fingerlings). There is no need to supplement with outside feed source if ducks were integrated. Some fodder like berseem/napier and banana leaves may be applied in the pond for fishes as surface feeder. It was observed that due to duck dropping, amount of dissolved oxygen decreases in the winter season because of slow decomposition rate of organic sources in winter while pH increases slightly during the winter season (Fig. 14). It was also observed that the pond in which duks were integrated

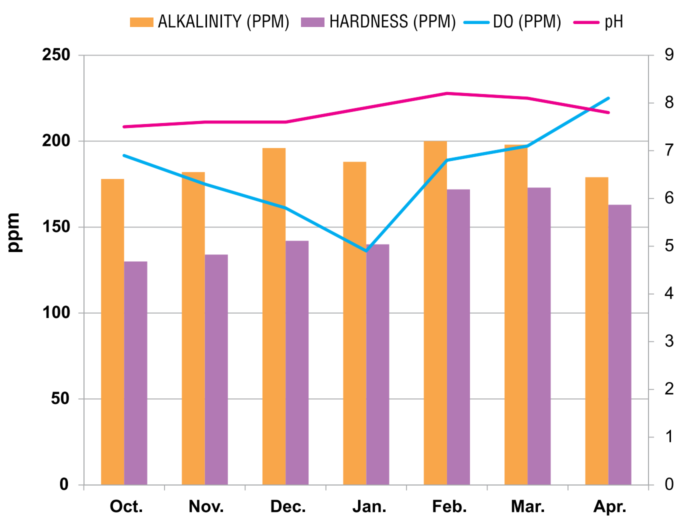

Fig. 14. Pond Water quality under Fish-Duck Integration

and allowed for swimming throughout the year, dissolved oxygen content was maintained to a optimum required level. Duck also act as natural weeder and they keep the pond clear by consuming the aquatic weeds and other things. From 40 ducks one can get about 6000 nos. of eggs/year and from a water area of 1000 m^2 about 300-350 kg of carps can be harvested in a year which is highly profitable for a small farmer.

It was observed from Fig. 15 that average growth rate of birds was more in traditional system where commercial feed was fed to the birds upto the age of 5 weeks (1.4 kg) over the birds which were fed on the feed prepared by IFS produce like mixture of lentil, maize, rice bran, oil cakes etc. (1.02 kg) but when we consider the profitability, IFS reared birds surpass in terms of net returns (Rs. 20-22/bird) over commercial fed birds (Rs.10-12/bird) due to high cost of commercial

Table 7a. Production performances of goat under IFS

IFS		Field condition	
Adult wt. M):	13.6 kg	Adult wt. M):	12.2 kg
Adult wt. (F):	11.8 kg	Adult wt. (F):	11.1kg
Age at Ist oestrous:	8-9 month	Age at Ist oestrous:	9-10 month
Age at Ist Kidding:	422 days	Age at Ist Kidding:	445 days
Kidding interval:	225 days	Kidding interval:	255 days
Av. Litter size:	2.1	Av. Litter size:	1.5
Single kidding:	32.3%	Single kidding:	51.3%
Twining:	44.5%	Twining:	30.5%
Triplicate:	23.2%	Triplicate:	18.2%
Av. growth rate:	37.3g/day	Av. growth rate:	33.4g/day

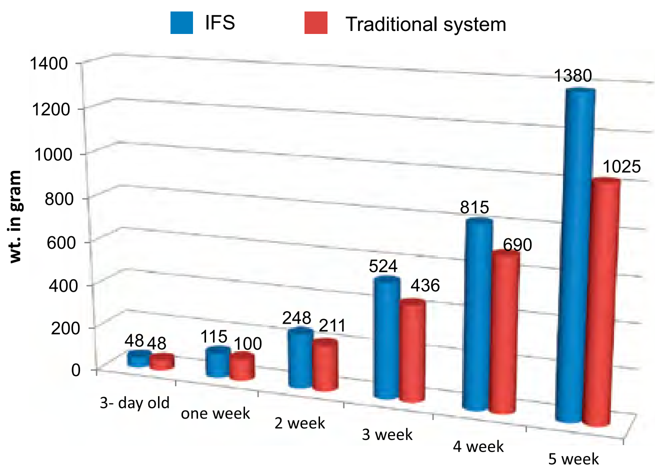

Fig. 15. Av. Growth rate in poultry (IFS vs Traditional System)

feed over self-made feed by using system produce. In contrast of body wt. of poultry, it was observed that average body weight of goats (12 months age) was more by 1.3 kg under IFS over goat reared in traditional system (Table 7a). It may be due to the fact that the goats reared under IFS have got sufficient fodder throughout the year with balanced ration over traditionally fed goats that have faced fluctuated dietary supplements, i.e., not balanced feed and care.

Round the year Fodder Production in Farming System

Round the year fodder production system was developed under IFS models to sustain livestock component and to meet out fodder demand within the system. Multi-cut sudan, cow pea, maize, rice bean and soybean have been grown during rainy season whereas, berseem, maize and oat during winter season (Fig. 16).

It is estimated that total biomass production of 67.90 t during rainy season and 51.99 t during winter season from one ha area could be obtained in EIGP (Table 8). It was observed that 15% area in an acre is required to sustain one milch cattle in farming system.

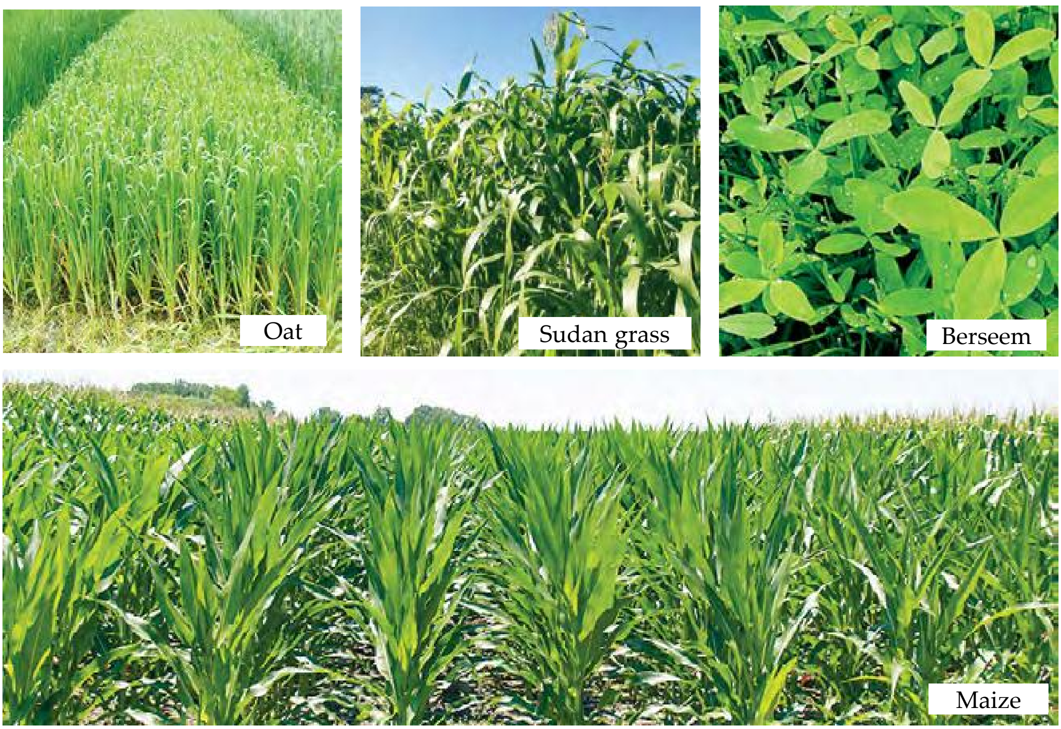

Fig. 16. Round the year fodder production in farming system

(*Source:* Gupta *et al.*, 2014)

Table 8. Season-wise production of various fodders

Particulars	Total fodder yield (t/ha)	Dry matter (%)	Crude protein (% DM)
Rainy season			
Sudan in 3 cuts at 60, 105 & 145d	74.78 ± 2.92	14.48	8.72
Cowpea at 90d	29.06 ± 4.06	12.77	15.18
Rice bean at 90d	35.67 ± 1.52	17.19	15.30
Soybean at 90d	22.15 ± 0.65	26.53	19.45
Winter season			
Berseem in 4 cuts at 50, 85, 115 & 145 days	67.84 ± 1.22	11.65	15.83
Oat in 2 cuts at 50 & 105d	28.23 ± 0.64	14.18	11.14

So far in nutritive value of green fodder was concerned, significantly higher ($P < 0.05$) digestible crude protein (DCP) was obtained in berseem fodder. The nutritive value of maize and Sudan forage in terms of dry matter intake (DMI), crude protein digestibility (CPD) and digested crude protein (DCP) was recorded the lowest and seems to be poor, hence supplementation of legume fodder is advocated for balance feeding.

The nutritive value of berseem and oat indicated that berseem forage had significantly ($P<0.01$) higher DMI, CPD and DCP values than oat forage. Similarly, the DMI, DMD, CPD and DCP intake values were significantly ($P < 0.01$) higher in cow calves than buffalo calves. It is concluded that nutritive value of berseem forage is better than the oat. The oat forage requires supplementation of legume forage to make balance nutrient contents. The forage intake and their nutrients digestibility in cattle calves are depicted in Table 9.

Table 9. Nutritive value of forage crops in cattle heifers

Forage crops	DMI (kg/100kg B. Wt.)	DMD (%)	CPD (%)	DCP (%)
Berseem (Wardan)	2.71cd ± 0.09	78.36bc ± 1.77	74.01bc ± 1.19	14.29d ± 0.23
Oat (JHO-822)	2.43bc ± 0.05	84.61d ± 1.25	65.87b ± 1.91	7.57b ± 0.22
Wheat (VL-829)	2.61cd ± 0.03	77.99b ± 0.59	72.84bc ± 0.09	12.72c ± 0.01
Annual Rye	2.84d ± 0.11	84.31cd ± 1.55	77.27c ± 2.25	13.23c ± 0.38
Maize Hybrid	2.13ab ± 0.05	66.60a ± 2.13	46.07a ± 3.68	3.99a ± 0.32
Multicut Sudan	2.09a ± 0.07	65.47a ± 0.51	43.83a ± 0.89	3.84a ± 0.08

Growth Performance of Livestock/Birds under IFS

The average body weight in different categories of indigenous and improved strains of livestock was also measured in farming systems for a period of 13 years. The average birth weight of indigenous and improved cattle was found to be 18.60±3.58 and 28.70±0.25 kg, respectively. After 24 months of age, body weight was recorded 118.60±9.11 and 312.60±8.60 kg in indigenous and improved cattle, accordingly.

The livestock is reared on low input feeding practices in traditional animal husbandry practices. Grazing is practiced on an average 4-5 hrs daily. Average fodder consumption in cattle was estimated to be 1220.25±67.50 and1706.66±56.01 kg/yr of dry and green fodder, respectively. The data clearly indicate that dry fodder contributed more than 60% of total energy inputs to indigenous cattle.

Table 10. Details about the one-acre IFS model

Sl. No.	Integration	Area (m^2)	Component	Output Main (kg)	Byproduct (kg)
1	Field crops	4000	Rice	2280.0	2530.0
			Wheat	400.0	580.0
			Maize	640.0	760.0
			Gram	230.0	290.0
			Mustard	220.0	380.0
2	Vegetables	500	Okra	450.0	410.0
			Tomato	700.0	315.0
			Cabbage	650.0	250.0
3	Fruit crops	500	Lemon	112.0	30.0
			Guava	250.0	50.0
			Banana	312.0	350.0
4	Fodder crop	1500	Sorghum	1400.0	nil
			Cowpea	550.0	nil
			Berseem	835.0	nil
			Oat	615.0	nil
			Maize	1140.0	nil
5	Fish	1000	Catla, Rohu, Mrigal	545.0	nil
6	Duck	30 Nos.	Meat Eggs (kg)	72.0 2150.0	1080.0 manure
7	Cattle	2 Nos.	Milk (lit.)	2573.0	4250.0 kg manure + 6500.0 lit. of urine
8	Vermi-compost	100	Vermicompost	1600 .0	0

Fowl and duck were integrated in farming system. The average body weight in different categories of traditional and improved poultry was measured. The average body weight at day 1, was recorded to be 32.80 and 38.0 g, respectively in indigenous and improved duck. After 24 months of age, improved and indigenous ducks were able to attain the body weight of 1610.0 and 1375.0 g, respectively, indicating daily weight gain of 2.2 g in improved and 1.8 g/day in indigenous strains. Similarly, the average body weight at day 1, was recorded as 23.40 and 31.13 g in indigenous and improved fowl, respectively. After 24 months of age, the body weight of indigenous fowl was 1471.0 g as against 2609.25 g in improved fowl, indicating daily body weight gain of 3.6 g in improved and 2.01 g in indigenous fowl, accordingly. In case of improved layer farming, the body weight at day 1 was recorded at 36.2 g and attained a live weight of 1.725 kg at an age of 2 years. However, in broiler, the weight at day 1 was recorded at 38.2 g which was increased at 1.52 kg at an age of 35 days.

Energy Budgeting under IFS

Farming system is a resource management strategy to avail maximum efficiency of a particular system. Studies conducted at Goa revealed the higher energy use efficiency of IFS with rice. Integration of poultry and mushroom enterprises with rice-brinjal system required highest energy input whereas rice cropping alone recorded the least requirement of energy (Table 12). The energy output was maximum under rice-brinjal + mushroom + poultry. The output of multi-rice-based enterprise was reasonably good varying from100.91 to105.63 MJ/ha. It is thus evident that efficient utilization of scarce and costly resource is the need of the hour and can be accrued by following the concept of IFS through supplementation of allied agro-enterprises (Korikanthimath and Manjunath, 2009).

It was observed that under one acre IFS model (Crop + Goat + poultry + mushroom), developed at ICAR Research Complex for Eastern Region, Patna total input and output energy was calculated as 68, 491 MJ and 2,17,548 MJ respectively (Input/output ratio:: 1: 3.2) while under two acre IFS model (crop + fish/duck + livestock) was reported as 296709 MJ and 7,52,415 MJ, respectively (Input/output ratio:: 1: 2.5), means crop + goat + poultry + mushroom integration is more energy efficient over crop + fish/duck+ livestock integration (Fig. 21). Component wise total energy input/output, efficiency and net energy gain for one acre and two-acre IFS models have been depicted in Fig. 18 & 19.

Further, during the investigation, it was observed that total energy input required for the cattle rearing was estimated to be 90.30 GJ/2 milking cow/year, majority of energy was consumed through feed intake and resulted energy efficiency ratio (EER) as 0.13. The least EER in dairy could be because of the energy stored in their body in the form of muscles, tissues or bones and their calves were not accounted in the analysis, but still, most balanced ration as cattle feed is needed to enhance the milk production.

The total energy input in field crops was estimated to be 14.53 GJ and duckery required 13.79 GJ. However, energy efficiency ratio (EER) was obtained to be highest from fodder crops (13.38) followed by field crops, vegetables, fruits, fish, cattle and duck, i.e., 7.91, 2.7, 2.03, 0.64, 0.16 and 0.13, respectively Table 11. It is here to mention that the energy efficiency ratio for the main output was also obtained to be highest from fodder crops, i.e., 13.38 as it has not produced any by-product, while field crops, fruits, vegetable, fishery, duckery and dairy units have resulted in EER as 3.97, 0.54, 0.45, 0.64, 0.1 and 0.09 etc. (Table 11 and Fig. 17). Here, it can be mentioned that the studied integrated model can be adopted in the irrigated ecologies of eastern region of the country. Furthermore, the results have revealed that in individual manner farming of fish, duck and cattle is not sustainable in terms of energy gain and energy utilization but overall, two-acre integrated farming system has resulted energy efficiency ratio as 1.66. Hence, integrated farming system is more energy efficient which can be promoted and

Table 11. Energy indices for one-acre IFS model

Energy indices	Field Crop	Vegetable	Fruits	Fodder	Fish	Duck	Cattle	Vermi-compost
TEi (GJ)	14.53	4.32	3.32	6.11	3.94	13.79	90.30	2.93
TEo (GJ)	114.96	11.69	6.72	81.72	2.51	1.65	11.59	0.80
TEo main (GJ)	57.69	1.94	1.78	81.72	2.51	1.32	8.10	0.80
EER	7.91	2.70	2.03	13.38	0.64	0.12	0.13	0.27
EERm (main output)	3.97	0.45	0.54	13.38	0.64	0.10	0.09	0.27
NEG (GJ)	100.44	7.36	3.40	75.61	-1.42	-12.14	-78.71	-2.13
EP (GJ)	6.91	1.70	1.03	12.38	-0.36	-0.88	-0.87	-0.73
DE (GJ)	4.89	1.44	0.67	2.23	1.34	1.15	1.85	0.49
IE (GJ)	9.63	2.89	2.65	3.87	2.60	12.65	88.45	2.44
RE (GJ)	1.98	0.91	0.97	1.03	0.96	13.19	89.71	2.93
NRE (GJ)	12.55	3.41	2.35	5.07	2.98	0.60	0.59	0.01
HEP (GJ GJ^{-1})	63.75	14.06	11.59	78.97	5.13	2.63	8.85	1.63
WEP (GJ GJ^{-1})	83.49	14.32	19.38	47.13	1.23	-	-	-

Note: TEi: Total input energy; TEo: Total output energy; EER: Energy efficiency ratio; NEG: Net energy gain; EP: Energy profitability; DE: Direct energy; IE: Indirect energy; RE: Renewable energy; NRE: Non- renewable energy; HEP: Human energy profitability; WEP: Water energy profitability

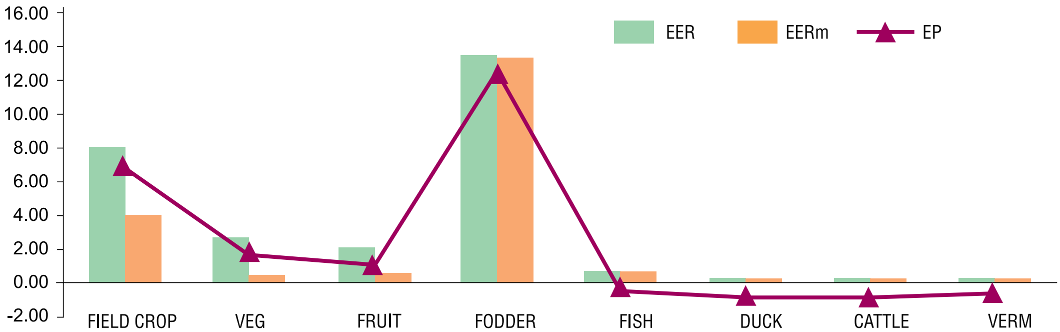

Fig. 17. Energy efficiency ratio and energy profitability of various IFS components under two-acre IFS model

adopted rather cultivation of livestock and fish in isolation. The net energy gain (NEG) was estimated maximum from field crops, subsequently followed by fodder crops, vegetables, fruit crops, respectively while dairy, fishery, duckery and vermi-composting have resulted negative trends in terms of net energy mileage Table 11. The energy profitability (EP) was found to be pre-eminence in fodder crops that is equal to 12.38 followed by field crops, vegetables and fruit crops, respectively. The overall, total energy input in this experimental two-acre integrated farming model was estimated to be 139.23 GJ while total energy output obtained 231.64 GJ and energy efficiency ratio as 1.66 GJ GJ^{-1} (Kumar *et al*., 2019).

Table 12. Energy (x 10^3 MJ/ha) budgeting for rice based integrated farming systems

Integrated farming system	Pooled mean energy		
	Total input	Total output	Efficiency
Rice-fallow	11.56	78.18	6.76
Rice-groundnut+ mushroom+poultry	46.08	102.86	2.24
Rice-cowpea+mushroom+poultry	43.79	105.63	2.41
Rice-brinjal+mushroom+poultry	52.03	165.33	3.18
Rice-sunhemp+mushroom+poultry	41.44	100.91	2.44

Green House Gas Emission in developed IFS models

Emission of greenhouse gases (GHGs) is the most important driver of human-induced climate change. Agricultural activities contribute 10%-14% of global anthropogenic GHG emissions, mostly from enteric fermentation and animal wastes (methane), application of synthetic fertilizers (nitrous oxide), and tillage (carbon dioxide) practices.

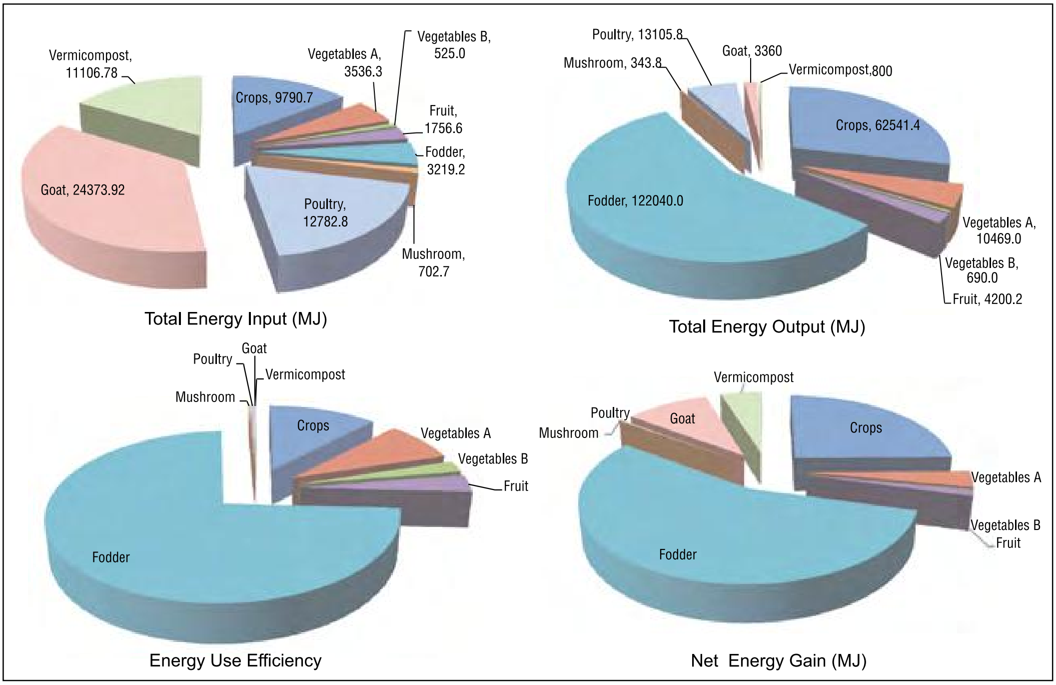

Fig. 18. Energy budgeting for one acre IFS model

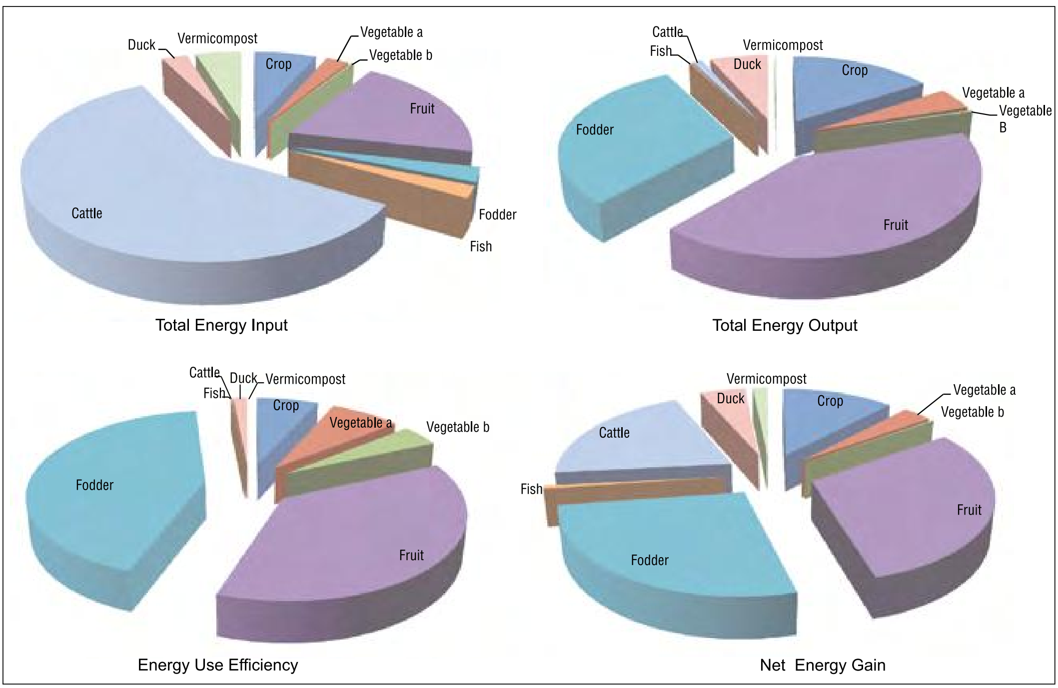

Fig. 19. Energy budgeting for two acre IFS model

From the study on GHGs emission in one acre and two-acre IFS model, it was observed that C- sink and C-source relation is very important. For the safe environmental condition sink should be always larger than source. Her, in one acre and two-acre IFS models, total C- sink is 3211.4 and 4940.1 CO_2-e while total C- source is 1553.2 and 3270.1 CO_2-e and therefore, net GHG emission from both the models shows negative balance of CO_2-e GHGs which advocates that the developed model is environmentally safe and more activities can be added into the system for better synergism with economics and clean environmental (Table 13).

This study showed that developed integrated farming systems can be a viable measure contributing to greenhouse gas mitigation in the agricultural sector.

Table 13. Annual greenhouse gas emission (CO_2 eq.) from different IFS models (MJ/year) in indigenous and improved livestock in farming systems

C- source	Enterprises	CO_2 -e (One acre)	CO_2 -e (Two acre)
Cropping System			
CS1	Rice-wheat	84.9	145.6
CS2	Rice-maize	59.3	130.1
CS3	Rice-lentil	44.1	111.7
CS4	Rice-linseed	50.8	98.3
	Fruit-Veg. crops	128.2	69.6
	Paddy-special	75.6	151.2
	Goat/Livestock	396.9	1552.3
	Poultry/Duck	542.5	4.5
	Kichen garden	170.8	178.7
	Pond- Fishery	0.0	828.0
C- sink	Agro-Forestry- SINK	1378.6	3439
	Biomass/compost added	1832.8	1500.9
	Total SOURCE	1553.2	3270.1
	Total SINK	3211.4	4940.1
	GHG-IFS	-1658.2	-1670.0

Note: CO_2 -e *means carbon dioxide equivalent GHGs* (Kumar *et al*., 2020. Compiled data of 2016-20), Annual Report. 2020., ICAR-RCER, Patna.

Income Sustainability Index

Income sustainability index gives an idea about sustainable income from an IFS model for a longer period of time for its existence. It is assumed that for better sustainability of the IFS model sustainability index should be more than

0.5. Developed IFS models were evaluated based on sustainability index (SI) as described by Vittal *et al.* (2002). The SI for any IFS model can be computed as ***SI= (NR- SD) / (MNR)*** where, NR stands for net returns obtained under any model, SD stands for standard deviation of net returns of all models and MNR stands for maximum net returns attained under any model. A suitable and viable IFS model could be identified for their existence based on net return, sustainability index, employment generation and improvement in soil fertility attained over a period of time. Here, among different IFS model evaluated, Crop +goat +poultry + mushroom integration provided highest ISI (79. 2) and was followed by Crop + goat + fish + duck (77.2) which was again followed by Crop + goat + poultry (75.7) and vegetable + goat integration (75.1) whereas, income sustainability index (ISI) from rice- wheat system was negative (Table 14).

Table 14. Annual net return and Income Sustainability index of different farming systems

IFS components	RGEY (t)	Gross Income (Rs.)	Net Income (Rs.)	B:C ratio	Man-days	I.S.I.
Rice - wheat	8.1	105650	30534	1.4	237	-0.037
Crop + goat	13.5	189000	77449	1.7	322	28.9
Crop + cattle	15.5	201350	72950	1.5	405	21.3
Veg. + goat	19.0	254845	139414	1.8	452	75.1
Hort. + Cattle	19.9	259690	116585	1.8	535	58.7
Crop + poultry	18.4	238985	96425	1.7	390	44.9
Crop + goat+ fish	18.9	245720	99524	1.7	333	47.0
Crop +goat + fish + duck	23.6	306840	142214	1.8	398	77.2
Crop + cattle + fish	16.2	211030	77030	1.6	435	31.7
Crop + cattle + fish + duck	18.5	242530	100530	1.7	470	47.7
Crop + goat + poultry	22.8	296445	140614	1.8	416	75.7
Crop+goat +poultry+ mush.	24.5	318240	144315	1.9	439	79.8
S. D.	18.6	43247.9	30588.7	0.14	64.4	-
C.V.	10.8	17.8	29.6	8.5	15.4	-

Expected Outcomes and Future Strategies

Less than 1/4th of geographical area of eastern India is sustaining 1/3rd of human and bovine population which clearly shows that there is tremendous pressure on natural resources. As of now, contribution of eastern India to national food basket is almost 50% in case of rice, more than 40% in vegetable production and more than 30% in fresh water fish production. However, sustainability of small holder resource poor farmer is key issue which needs to be addressed. Farming system approach, therefore, have a great scope of expansion in this part of the region. The expected outcomes of the work are depicted below: -

- Half acre IFS model has the potential for implementation in 4.36 m ha area of EIGP. This model is able to boost the overall production by 35%. Simultaneously profitability will increase by 2-fold with highest in Bihar, followed by West Bengal and Eastern UP.
- One and two-acre IFS model has the potential for implementation in approximately 8.0 m ha area of EIGP, resulting into increase in overall production by 52%. The profitability is expected to increase by 2.8-fold in Middle and Lower Gangetic Plains.
- Aquaculture and livestock based IFS has the potential for implementation in nearly 4.0 m ha area of EIGP. These models have been found ecologically and economically most viable with increase in productivity by 50% besides two-fold increase in profitability.
- The developed models have potential to increase an additional employment of 160 - 300 man-days/ha on yearly basis.
- Saving of inorganic fertilizer by 25-40% through recycling of different by-products/ within farm renewable resources is possible in farming system mode of food production system.
- By adopting farming system models, dependency on external inputs is curtailed by 27-30%.
- The developed models have also potential to increase soil fertility, soil productivity, and maintaining soil sustainability on long term basis due to addition of sufficient carbon into the soil. In the study, it was found that different models have capacity to increase the organic carbon by 3.4 - 10.2% over a period of 10 years.
- The developed IFS models are able to provide food and nutritional security to the resource poor farm families in terms of calories, proteins, vitamins, and minerals due to diversification in the existing farming practices based upon their needs, resources and preferences.
- Integration of makhana with fish and water chestnut has a scope of horizontal expansion in more than 1.0 million ha area which is otherwise restricted only to less than 20000 ha area. The productivity is expected to increase by 80% with three-fold increase in profitability.

- Eastern India has more than 4.0 million ha under wetlands. Rice-fish integration, followed by other fish-based farming system models could be replicated in such areas. The fish productivity is expected to increase by 60% with three-fold increase in profitability. The neglected common property resources like pond, ahar, pines etc. could also be used effectively for livestock-fish production.
- Landless farm families, unemployed rural youth and women has avenue to generate income and employment through mushroom production, goatry, vermicomposting and beekeeping.

Concrete Recommendations

- One and two-acre models with different integrations have clearly indicated that combination of enterprises should be done in the light of land situation, resource availability, family needs and local market force. A single model is not essentially to be adopted if situation is not permitting. Alternate options need to be adopted for higher resource use efficiency, maximum net profit and system sustainability.
- In high populous density and high rainfall situation, food crops especially rice, wheat, maize and pulses are needed to be integrated with share of 40 -50% lands for food security and round the year fodder availability.
- Being small holder domination (around 90% families with one acre or less land holding) in eastern India, animal components are contributing more than 50% to net income in IFS. So, need based integration of cow, goat, poultry, fish in one or more numbers should be done with production support of fodder, forage, feed within the system in order to increase interdependency of the enterprises and resource recycling for high input use efficiency.
- Around 30-35% farm families having less than 0.5 acre including share croppers have sufficient man power for agricultural operation. They have ability to integrate a greater number of enterprises in smaller form for reducing the risk and regular income as well as employment generation. In half acre model, this finding has been verified with income generation of Rs. 0.55 lakh per year.
- In irrigated areas, vegetables should be integrated with the cereals as vegetables are high yielders, more remunerative and has regular demand in the market. The by-product of cereals and vegetables are able to sustain livestock and also helpful in resource recycling.

- In irrigated uplands, crop + vegetable + goat + poultry integration is best suited in terms of productivity and economic viability. In irrigated lowlands, where water stagnates in the field for 2 - 3 months and rice is the only option in *Kharif* season, rice - fish culture is more profitable. For such areas, crop + vegetable + livestock + fish/duck is the best integration.
- For wetlands situation, where water stagnates for 4 - 5 months, rice + fish, makhana - water chestnut + fish, fish/ duck farming in trenches and vegetables and fruits like papaya, lemon, guava, banana, pomegranate on the bunds are more suitable in terms of productivity and profitability.
- For perennial water bodies, integrated aquaculture with livestock/ birds and horticulture is more suitable for productive utilization of water. Apart from this, carp culture can be done with makhana allocating 10 percent central refuge area. Water chestnut can also be integrated as tertiary crop in the system.
- For small farm holders, small animals viz. poultry, piggery, goatry, duckery etc. should be preferred for integration rather than big animals for more income and energy output.
- On the bund of the fields, creeper vegetables (seasonal) or agroforestry (drum stick, karonda, forage trees etc.) should be raised for better economics and meeting out farm family and livestock needs along with larger sink for Co_2 which will add harmony and clean environment by lesser emission of greenhouse gases.

Convergence with ongoing govt. schemes like NFSM, RKVY, BGREI, ISOPAM, IFS, NHM, Farm mechanization, CMHM, Integrated PHM, National Micro-irrigation mission as well as linkage with developmental agencies, financial and related technical institutions are required to harness the maximum benefit of the IFS.

Summary

- Under two-acre IFS model, Cereals + Hort. + Fish + Dairy integration fetches a net return of Rs. 1,48,569/annum, i.e., Rs. 407/day (savings: Rs. 59,274/annum after availing family food requirements) with an initial investment of Rs. 2,61,500.
- Under one acre IFS model, Cereals + Hort. + Goat + Poultry integration model fetches a net return of Rs. 88,527/annum, i.e., Rs. 243/day (savings Rs. 34,151/annum after availing family food requirements) with an initial investment cost of Rs.1,58,220/-.

- Among different IFS models analyzed, Crop + Goat+ Poultry + Mushroom integration resulted in the highest net return of Rs. 1,44,315/annum/ha, followed by Crop + Goat + Fish +Duck integration (Rs. 1,42,214/annum/ha).
- Crop + Fish + Poultry + Goat integration resulted in significant addition of nutrients in respect of O.C., available N, P and exchangeable K.
- Upon recycling of wastes of different components under two-acre IFS, N = 56.5 kg, P = 39.6 kg and K = 42.7 kg were added into the soil which is equivalent to 118 kg urea, 247 kg SSP and 42.7 kg of MOP.
- Upon recycling of wastes of different components under one-acre IFS, N - 44.0 kg, P - 29.5 kg and K - 31.2 kg was added into the soil which is equivalent to 93.0 kg urea, 184.0 kg SSP and 52.0 kg of MOP.
- A stocking density of 1000 fingerlings was found optimum for 1000 sq m. pond with 35 no. of ducks.
- In terms of employment, Crop/Hort. + Fish + Dairy integration added 359 more man-days and was followed by Crop/Hort. + Fish/Duck + Poultry (86 man-days).
- Crop + Goat + Mushroom + Poultry combination is more energy efficient over Crop + Dairy + Fish/Duck integration.
- Total output/Input Energy ratio in one acre and two-acre IFS model were 2.7 and 2.4, respectively.
- Av. body wt. of goat (12 months), poultry (5 weeks) duck (72 weeks) and fish (8 months) were found higher (11%) under IFS mode than field condition.
- Cereals + Veg. + Goat + Poultry + Mushroom resulted in higher income sustainability index (0.79) and was followed by Cereal + Goat + Poultry (0.77) & Veg.+ Goat (0.76).
- Net GHG emission from one acre model (Crop + Goat + Poultry) was -1658.2 kg CO_2- e while under two-acre IFS model it was -1670 kg CO_2- e.

Conclusion

Integrated farming system provides an opportunity to integrate any component with crop based upon farmers' choice, preferences and location. It provides enhanced income with balanced nutrition for a farm family and maintains soil-health on long run. Wastes/by-products of different components can be best used as organic residue (form of animal and plant wastes) help in improving the soil physical condition and thereby productivity over a longer period of time with lesser environmental hazards with increased profit margin. It also minimizes the risk in farming. IFS model comprising of crop components, dairy, poultry and fishery is the most suitable and efficient farming system model giving the highest system productivity for irrigated agro-ecosystem of North eastern plain zone while suitable IFS model for Indian Central Himalaya region is fishery + poultry + vegetable farming which has considerable potential to provide food security, nutritional benefits, employment generation and providing additional income to resource poor small farmers. In general, IFS enable the agricultural production system to become sustainable, profitable (3-4-fold) and productive on long term. About 90-95 percent of nutritional requirement is self-sustained through resource recycling which curtails the cost of cultivation and increases profit margins and employment. Therefore, it is imperative to state that to sustain food and nutritional security, IFS approach is promising and will conserve the resource base through efficient recycling of residues and wastes within the system. IFS models developed for different ecological ecosystems and sub systems can be tuned through farmers' participatory trials with multilevel interventions itself on the farmers' fields.

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Glimpses of Integrated Farming System Models

Poultry rearing

Diversified Cropping system

Oyster mushroom farming

Button mushroom farming

Ducks in pond & bund plantation

Fish-cum-duck-cum-quail

Goatry unit under one acre IFS

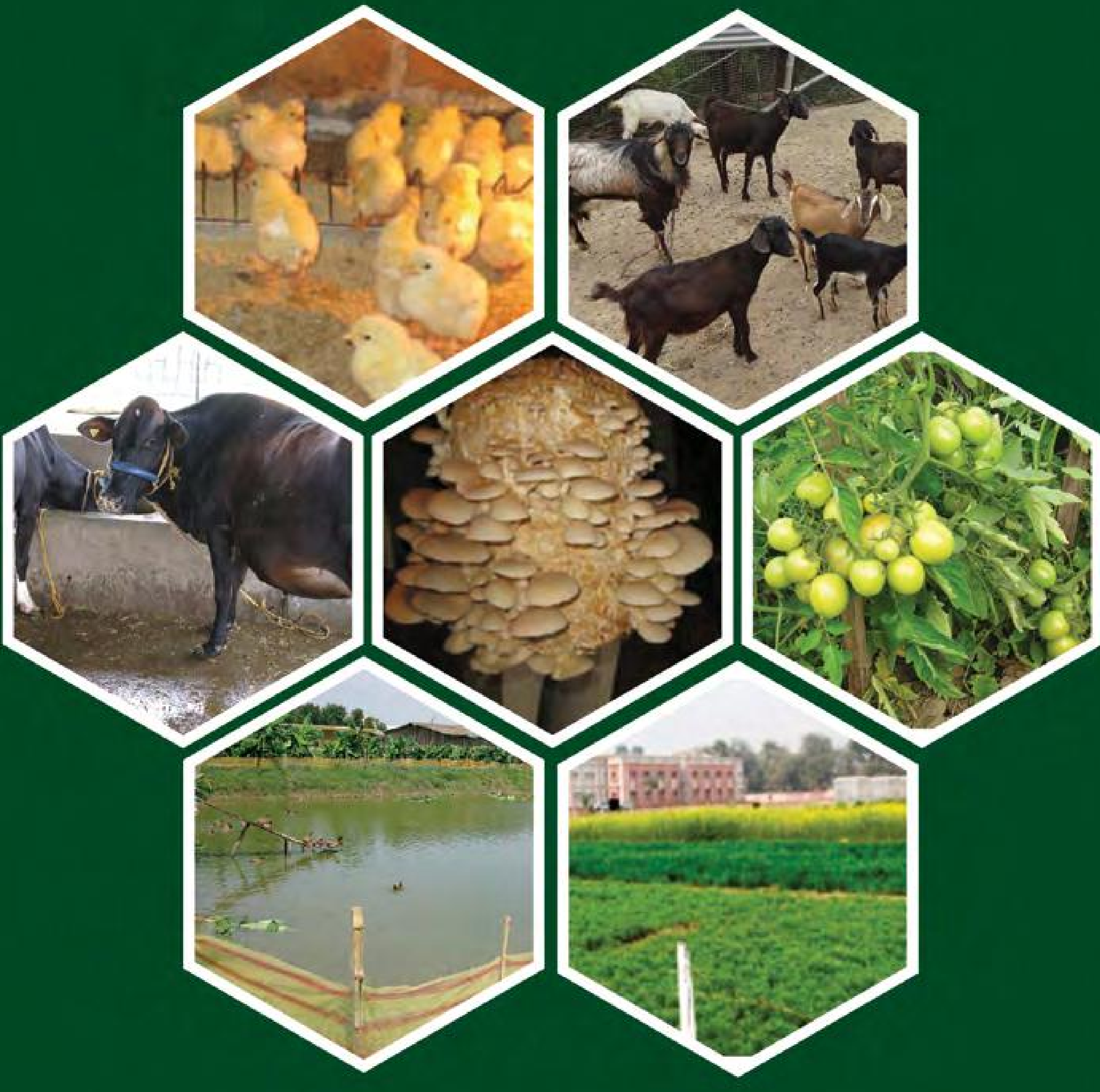
Dairy unit under two acre IFS

Pigeon pea on field bunds

Vegetable-cum-Fruit block

Director, IIFSR visiting the IFS site

Vermicompost & Gobar-gas unit



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