Integrated Farming Systems: A Viable Option for Doubling Farm Income of Small and Marginal Farmers

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Integrated Farming Systems: A Viable Option for Doubling Farm Income of Small and Marginal Farmers

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Crop and livestock cannot be separated for small holder agriculture in India as crop + livestock is the pre-dominant farming system existing in the country and livelihood of 117 million marginal and small farm holdings revolves around this system. Small categories of farms are often subjected to weather vagaries like flood, drought and other natural calamities and farming remains risky. Vertical expansion in small farms is possible by integrating appropriate farming system components requiring less space and time and ensuring periodic income to the farmers. Integrated Farming System (IFS) is considered to be powerful tool and holds the key for ensuring income, employment, livelihood and nutritional security in a sustainable mode for small and marginal farmers who constitute 84.97% of total operational holdings and operated 44.31% of area. Integrated system meets the above goals through multiple uses of natural resources such as land, water, nutrients and energy in a complimentary way thus giving scope for round the year sustainable income from various enterprises.

Farming Systems and its Composition in India

Characterization of existing farming systems throughout the country indicates existence of 19 pre-dominant farming systems with majority as crop + livestock (85%). Although crop + livestock system is dominating in the country, based on the% contribution to net income, the systems are classified as crop, horticulture, livestock, fisheries dominant systems where in dominant component contributes more than 50% of the total net returns. Accordingly, it was found that crop dominant farming systems are existing in the states of Andhra Pradesh, Bihar, Chhattisgarh, Goa, Haryana, Jammu and Kashmir, Jharkhand, Kerala, Karnataka, Madhya Pradesh, North-East, Maharashtra, Odisha, Punjab, Tamil Nadu, Uttar Pradesh and Uttaranchal while livestock dominant systems are observed in Rajasthan and Gujarat. West Bengal, parts of Odisha and Assam states have the fisheries as a major source of income to the existing farming systems. The scope for promotion of horticulture (fruit) based systems exists in Jammu and Kashmir, Himachal Pradesh, Maharashtra, parts of Uttar Pradesh and in Sikkim while plantation crops (coconut, arecanut) dominant systems are found in Andaman and Nicobar Islands and Kerala.

In selected states and locations, highly diversified systems also exists where in none of the component contributes for 50% or more to the returns. Though the various farming systems are existing naturally in the country, integration of output as input to

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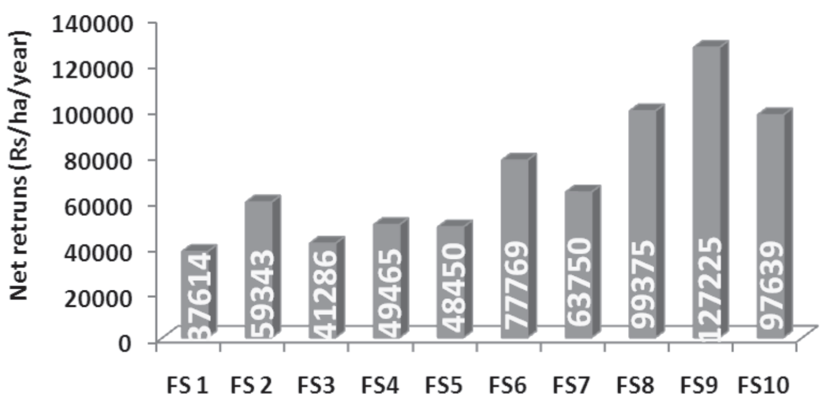
other components within the system is either completely lacking or at partial. Competition exists within and outside the farm for various byproducts generated. Cow dung is the best example as dung is required for improving the fertility of soil and meeting the household fuel. Hence, synergy needs to be made by appropriate allocation for making farming as a profitable option. Sustainable farming systems should aim for long term productivity, profitability, recycling of resources and employment generation. The monetary returns under different farming systems practiced in different parts of the country are given in Fig 1. Naturally existing crop + dairy system (FS1) practiced by close to 85% households is able to provide only Rs 37614/ha/year which is very low for the marginal and small holders to sustain their livelihood. Among the various naturally existing systems in the country, coconut + banana + cocoa + pineapple + nutmeg (FS9) gives the higher return of Rs 1.27 lakhs/annum. The results indicate the importance of fruits and plantation crops in enhancing the net returns of prevailing crop + dairy farming system. Diversified systems having the components of horticulture, fisheries, apiculture, poultry and goat are able to provide higher income compared to farming systems having two or three enterprises only.



FS1	Crops + dairy	FS6	Crops+dairy+horticulture+poultry+fish
FS2	Crops +dairy+horticulture	FS7	Rice+fish
FS3	Crops+dairy+poultry	FS8	Coconut +banana
FS4	Crops+dairy+goat	FS9	Coconut+banana+cocoa+pineapple nutmeg
FS5	Crops+fishery+dairy+poultry	FS10	Crop +dairy+horticulture+apiary+fish

Fig. 1. Monetary returns of different naturally existing farming systems in India

Under on-farm research component of AICRP on Integrated Farming Systems, performance analysis of existing farming systems in 732 marginal households in the country was taken up in 30 districts in 20 states. The composition of the farming systems clearly reveals that existence of 35 types of farming systems with components ranging from 1 to 5. Out of the sample surveyed and sub group of crop+ livestock system, crop + dairy is the major system practiced by 48% of marginal holders followed by crop + dairy + goat (11%). Among the livestock category, dairy is practiced by 86% marginal holders followed by goat (24%) and poultry (21%). The other components such as fish, fruits, apiary, sheep *etc* are found to be location specific. Further analysis of number of enterprises present in different farming systems across country indicates, 52% households are having two (example crop+dairy), 28% farm households are having 3 (example crop+dairy+goat) and 11% households are having 4 (example crop+dairy+goat+fish). Around 7% households are having the single enterprise (either crop or dairy alone). The contribution of crop and livestock to gross income of marginal households in various NARP zones indicates that in majority of the place crop component contributes > 50% while at few districts such as Samba (Jammu), Aurangabad (Maharashtra), Mehsana and Panchmahal (Gujarat), livestock component contributes either equally or more(Gangwar et al., 2015). Further, the study conducted through on-farm centres reveals that marginal households are having the effective field workable persons of 3 to 4 as the family size is up to 7 with mean family size of 5. Even at bare minimum of 3 persons / household is considered, 1095 man/women days (8 hrs in a day) is available per household which is sufficient to take up the farming in the tiny holdings. Therefore, marginal farms offer greater scope for agricultural diversification.

Need and Approach for Diversification of Natural Systems

Desirable change in the existing system towards more balanced cropping/farming system to meet ever increasing demand of food, feed, fibre, fuel and fertilizer on the one hand and maintenance of agro-ecosystem on the other. Diversification is considered to be a good alternative to improve system yield with enhanced profitability. Further, the farming systems approach is a "highly location specific approach involving appropriate combinations of complimentary farm enterprises *viz*., cropping systems, livestock, fisheries, forests, poultry and the means available to the farmers to raise them for profitability". Two approaches of farming systems such as holistic and innovative are considered to be a powerful tool to increase the income and employment opportunities for the farm family. Holistic approach deals with improving the productivity of existing components in totality while innovative approach aims for improving the profitability of existing farming systems with user perception based new introduction of components.

Integrated Farming System Approach and its Objectives

IFS approach can be described as "A judicious mix of two or more components using cardinal principles of minimum competition and maximum complementarity with advanced agronomic management tools aiming for sustainable and environment friendly improvement of farm income, family nutrition and ecosystem services". Preservation of bio-diversity, diversification of cropping/farming system and maximum recycling is the base for success of the farming systems approach (Singh and Ravisankar, 2015). In general, farming system approach is based on the following objectives:

- Sustainable improvement of farmhouse hold systems involving rural communities
- Farm production system improvement through enhanced input efficiency
- Satisfying the basic needs of farm families along with nutritional improvement
- Raising the family income through optimum use of resources and proper recycling within the system

The prevailing farming situation in India calls for an integrated effort to address the emerging issues / problems. The integrated farming systems approach is considered to be the most powerful tool for enhancing profitability of farming systems, especially for small and marginal farm-holders to make them bountiful. In fact, our past experience has clearly evinced that the income from cropping alone is hardly sufficient to sustain the farmers' needs. With enhanced consumerism in rural areas, farmers' requirements for cash have also increased to improve their standard of living. Therefore, farmers' income and food requirements would have to be augmented and supplemented by adoption of efficient secondary/ tertiary enterprises like animal husbandry, horticulture (vegetables/ fruits/ flowers/ medicinal and aromatic plants), apiary, mushroom cultivation, fisheries etc. However, these integrated farming systems will be required to be tailor-made and designed in such a manner that they lead to substantial improvement in energy efficiencies at the farm and help in maximum exploitation of synergies through adoption of close cycles. These systems also need to be socially acceptable, environment friendly and economically viable.

IFS Models for Irrigated Regions

Irrigated regions play a significant role in national food security. However, in the recent times, it has been observed that the income of farmers are not in commensuration with market led input costs. This has resulted in re-orienting the approach towards integrated farming systems.

Intensification and diversification of crop component of farming system: The strategy to produce more from less specially to ensure high income for small holders can be achieved through bio-intensive complimentary cropping systems in which land configurations are used to accommodate more than two crops of synergistic nature at a time. This type of system offers scope for improvement of use efficiency of resources such as water, nutrients besides offering natural management of weeds, pests and diseases. The various land configurations evolved over the years offers scope for growing more than two crops at the same time in the same piece of land. Ten bio-intensive complimentary cropping systems evaluated for higher productivity and profitability reveals that bio-intensive system of raising maize for cobs + vegetable cowpea in 1:1 ratio on broad beds (BB) and *sesbania* in furrows during *kharif* and mustard in furrows and 3 rows of lentil on broad beds in *rabi* while 3 rows of green gram on beds in summer was found to be remarkably better than others which produced highest yield of 24 t ha^{-1} as rice equivalent with productively of 50.2 kg grain $ha^{-1}day^{-1}$ and profitability of Rs.500 $ha^{-1}day^{-1}$ (Gangwar and Ravisankar, 2013) The complimentary effects could be reflected in the system as in broad bed and furrow (BBF) system, the furrows served as drainage channels during heavy rains in *kharif* which were utilized for in-situ green manuring with 35 t ha^{-1} green foliage incorporated after 45 days of sowing. Intensification could save up to 30% of irrigation water as water was applied only in furrows.

Diversification of components for higher income: Rice based farming system comprising of crop components (Rice-pea-okra and sorghum-berseem-maize), dairy, poultry and fishery was the most suitable and efficient system and recorded higher system productivity and profitability under irrigated ecosystem of eastern Uttar Pradesh (Singh et al., 2006). The land based enterprises such as dairy, poultry, fishery, mushroom, biogas etc were included by Behera and Mahapatra (1999) to complement the cropping programme to get more income and employment for small farmers of Odisha. A net return of Rs 58367 can be realized with an investment of Rs 49286 in 1.25 ha area which also generated 573 man days of employment with a resource use efficiency of Rs 2.18/Re invested thus ensuring the livelihood of small farmers. A range of water management practices for crop-fish system are available to strengthen resilience to climate variability. Crop-fish integration in the unlined on-farm reservoirs is technically feasible and economically viable as compared to lined system for increasing the agricultural productivity. The water productivity and farm income was higher in crop-fish system in comparison to the sole system of any of these two independent methods (Sinhababu, 1996). Integrated farming system components comprising field crops, vegetables, floriculture, poultry, fishery and cattle in the lowlying valley areas are found to give net return of Rs 2.11 lakhs/ha with B:C ratio of 2.5 besides additional employment generation of 221 man days (Ravisankar *et al.,* 2006*).*

Sustainable livelihood security through scientifically designed intensive integrated farming systems: Many studies from India have shown significant improvement in livelihood of small and marginal farmers through adoption of IFS models. A brief description of various on station integrated farming system models developed in different NARP zones of country through AICRP on Integrated Farming Systems is given in Table 1. The production on equivalent basis was higher in model comprising cropping systems (81% area) + dairy (6 cows) + horticulture (6% area) + fishery (10% area) + poultry (200 nos.)+vermicompost (2% area) + mushroom (1% area) developed for Middle Gangetic Plains (47 t/ha) and highest net returns was observed with cropping systems (64% area)+ dairy (2 cow) + horticulture (20% area)+ fishery 20% area)+ agroforestry (3%)+vermicompost (1%)+Apiary (5 boxes) recorded maximum net return of Rs 2.68 lakhs/ha/year. The homestead model developed for 0.2 ha are under Kerala situation comprising of cropping systems (80% area)+ dairy (1cow+1 buffalo)+duck (150 nos.) + fishery (20% area) + vermicompost (1% area) gave net return of Rs 0.60 lakhs in 0.20 ha area/year (FAI, 2016).

Synthesized diversified farming system models: Farming system models can be synthesized using the primary, secondary data and research results from on-station and on-farm experiments. A farming system model was synthesized using the scientific inputs from the on-station experiment conducted at IIFSR, Modipuram to improve the productivity and profitability of the farm. Accordingly, the cropping systems were modified by including pulses, oilseeds, vegetables, fruits to meet the family demand. The area allocation was also made accordingly. The synthesized cropping systems included sugarcane (spring) + onion-ratoon (12% area, 0.12 ha), rice-potato-wheat (0.15 ha) /marigold (0.15 ha)-dhaincha (26% area, 0.30 ha), maize for cobs +arhar-wheat (11% area, 0.13 ha) and sorghum-rice-mustard (0.21 ha)/oat (0.07 ha)/berseem (0.07 ha) (28% area, 0.35 ha). Arhar and mustard were added mainly to produce the sufficient pulses and oilseeds for the family. The livestock component of 2 buffalo and 1 cattle was kept as such but

Table 1. On station farming systems developed in various regions of India, their productivity and profitability

Sl. No.	NARP zone (location of centre)	Farming system	Area (ha)	Mean production (Equivalent yield of base crop of region) (t)	Mean net returns (Rs)
I. Western Himalaya					
1	Chhata (Jammu and Kashmir)	Cropping systems (0.49 ha) + dairy (1 cow + 1 buffalo) + horticulture (0.30 ha) + apiary (0.001 ha) + fishery (0.10 ha) + poultry (0.001 ha) + vermicompost (0.05 ha) + biogas (2 m^3)	1.00	12.4	189502
2	Palampur (Himachal Pradesh)	Cropping systems (0.75 ha) + dairy (2 cows) + horticulture (0.17 ha) + vermicompost unit (0.01 ha)		16.5	78738
3	Pantnagar (Uttarakhand)	Cropping systems (0.52 ha) + dairy (2 cows) + horticulture (0.19 ha) + agroforestry (0.23 ha) + vermicompost (0.005 ha)		24.2	147989
II. Eastern Himalaya					
4	Umiam (Meghalaya)	Cropping systems (0.70 ha) + horticulture (0.20 ha) + poultry (600 Broiler + 50 layer) + piggery (3nos.) + fishery (0.05 ha)	1.00	20.6	155820
III. Lower Gangetic Plains					
5	Kalyani (West Bengal)	Cropping systems (0.42 ha) + dairy (2 cows) + horticulture (0.11 ha) + fishery (0.09 ha) + vermicompost (0.018 ha)	0.66	26.2	80128
IV. Middle Gangetic plains					
6	Varanasi (Uttar Pradesh)	Cropping systems (0.81 ha) + dairy (6 cows) + horticulture (0.06 ha) + fishery (0.10 ha) + poultry (200 nos.) + vermicompost (0.004 ha) + mushroom (0.002 ha)	1.00	47.0	250465
7	Patna (Bihar)	Cropping systems (0.40 ha) + dairy (2 cows) + horticulture (0.10 ha) + fishery (0.12 ha) + duck (35 nos.) + vermicompost (0.01 ha) + biogas (2 m^3)	0.80	21.5	133367
V. Upper Gangetic plains					
8	Modipuram (Uttar Pradesh)	Cropping systems (0.38 ha) + dairy (2 buffalo + 1 cow) + horticulture (0.30 ha) + vermicompost (0.01 ha) + biogas (1.5 m^3) + mushroom (0.002 ha)	0.70	31.9	192839

Contd...

VI. Trans Gangetic Plains					
9	Ludhiana (Punjab)	Cropping systems (0.64 ha) + dairy (2 cows) + horticulture (0.20 ha) + fishery (0.20 ha) + agroforestry (0.03 ha) + vermicompost (0.005 ha) + apiary (5 boxes)	1.00	35.5	268106
10	Hisar (Haryana)	Cropping systems (0.90 ha) + dairy (2 buffaloes) + horticulture (0.06 ha) + vermicompost (0.01 ha) + mushroom (0.002 ha)		30.0	152555
VII. Eastern Plateau and Hills					
11	Raipur (Chhatisgarh)	Cropping systems (0.60 ha) + dairy (2 cows) + horticulture (0.22 ha) + fishery (0.072 ha) + poultry (0.003 ha) + vermicompost (0.003 ha)+ biogas (1.5 m^3) + mushroom (0.003)	1.00	16.5	144126
12	Ranchi (Jharkhand)	Cropping systems (0.80 ha) + dairy (2 cows) + fishery (0.10 ha) + vermicompost (0.026 ha) + mushroom (0.014 ha)		14.2	107909
VIII. Central Plateau and Hills					
13	Jabalpur (Madhya Pradesh)	Cropping systems (0.90 ha) + dairy (3 cows) + horticulture (0.0024 ha) + fishery (0.06 ha) + poultry (300 nos.) + vermicompost (0.0039 ha) + mushroom (0.0024 ha)	1.00	16.05	80128
14	Durgapura (Rajasthan)	Cropping systems (1.00 ha) + dairy (2 cows) + horticulture (0.25 ha) + poultry (50 nos.) + goat (6 nos.)	1.45	19.38	177839
IX. Western Plateau and Hills					
15	Akola (Maharashtra)	Cropping systems (0.70 ha) + horticulture (0.25 ha) + goat (12 nos.) + vermicompost (0.004 ha) + mushroom (0.0024 ha)	1.00	25.1	104858
16	Rahuri, Maharashtra	Cropping systems (0.72 ha) + dairy (2 cows) + horticulture (0.20 ha) + poultry (400 nos.) + vermicompost (0.01 ha)		28.6	184417
17	Parbhani (Maharashtra)	Cropping systems (0.71 ha) + dairy (2 cows + 1 buffalo) + horticulture (0.20 ha) + poultry (150 nos.) + vermicompost (0.05 ha)		20.8	86236
X. Southern Plateau and Hills					
18	Rajendernagar (Andhra Pradesh)	Cropping systems (0.70 ha) + dairy (3 buffaloes) + horticulture (0.20 ha) + poultry (20 nos.) + goat (35 nos.) + vermicompost (0.015 ha)	1.00	26.5	97341
19	Coimbatore (Tamil Nadu)	Cropping systems (1.02 ha) + dairy (2 buffaloes + 1 cow) + horticulture (0.16 ha) + vermicompost (0.005 ha)	1.20	27.2	241728

Contd...

20	Kathalgere (Karnataka)	Cropping systems (0.65 ha) + dairy (1 buffalo + 2 cows) + horticulture (0.15 ha) + sheep (13+1 nos.) + vermicompost (0.10 ha)	1.00	60.2	188608
21	Siruguppa (Karnataka)	Cropping systems (0.74 ha) + dairy (2 buffaloes + 2 cows) + horticulture (0.20 ha) + fishery (0.045 ha) + vermicompost (0.0034 ha)	1.00	14.3	148091
XI. East Coast Plains and Hills					
22	Bhubneswar (Odisha)	Cropping systems (0.32 ha) + horticulture (0.19 ha) + dairy (2 cows) + fishery (0.33 ha) + poultry (380 nos.) + duck (20 nos.) + agroforestry (0.094 ha) + vermi-compost(0.0033ha) + mushroom (0.010 ha) + biogas (0.0048 ha) + apiary (2 boxes)	1.25	22.8	75129
23	Thanjavur (Tamil Nadu)	Cropping systems (0.61 ha) + horticulture (0.10 ha) + dairy (1 cow + 1 buffalo) + fishery (0.08 ha) + poultry (150 nos.) + vermicompost (0.002 ha)	0.80	15.0	138325
XII. West Coast Plains and Hills					
24	Karjat (Maharashtra)	Cropping systems (0.50 ha) + horticulture (0.40 ha) + dairy (3 cows) + poultry (90 nos.) + goat (6 nos.) + vermicompost (0.0018 ha)	1.00	23.6	99000
26	Karmana (Kerala)	Cropping systems (0.20 ha) + dairy (1 cow + 1 buffalo) + duck (150 nos.) + fishery (0.02 ha) + vermicompost (0.0004 ha)	0.20	8.2	60555
27	Goa (Goa)	Plantation crops (cashew, coconut, arecanut with intercrops) (0.70ha) + piggery + poultry + seedling production unit	0.79	24.0	86756
XII. Gujarat Plains and Hills					
28	S.K. Nagar (Gujarat)	Cropping systems (0.70 ha) + dairy (2 buffaloes) + horticulture (0.25 ha) + vermicompost (0.01 ha)	1.00	36.9	237607
XV. Islands					
29	Port Blair (A&N)	Rice (0.5 ha) + vegetables/flowers & fish in BBF system (0.4 ha) + livestock (2 cows) + vermicompost unit	1.00	27.0	145000
30	Port Blair (A&N)	Plantation crops (coconut) + spices (clove, nutmeg) + pine apple + tapioca + sweet potato (0.90 ha) + piggery (4 no's) + fish (0.06 ha) cum poultry (25 no's) + lined pond for azolla (0.01 ha) + vermicompost	1.00	28.0	224000

provision for producing sufficient green fodder was kept by including oat and berseem in the cropping systems. In order to enhance, the income and resource recycling, complementary enterprises such as apiary, vermicompost (0.7% area, 100 m2) and karonda, citrus, jackfruit, beal and subabul as boundary plantation were incorporated. Karonda serves as the live fence and produces fruits which can be used for making pickles. Further, it can also protect the farm from blue bull or stray animals. Mixed plantation of fruits including mango, guava, peach & pear and intercropped with seasonal vegetables like brinjal& tomato (16% area, 0.20 ha) and fishery (7.5% area, 0.08 ha) was added as income supplementing activities in the model. A 7 member family having 5 adults and 2 children's requires 1550, 200, 130, 900, 200, 1120 and 154 kg of cereals, pulses, oilseeds, vegetables, fruits, milk and fish per annum as per ICMR standards to meet the nutritional requirement. It has been found that the synthesized model for the 1.2 ha is able to produce sufficient quantity of these produces required for the family. Apart from this, the system also generates marketable surplus of 3585, 106, 3200, 2218, 5001, 276 kg of cereals, oilseeds, vegetables, fruits, milk and fish respectively ensuring sufficient income for the family besides improving the availability of these products in the market. Additional production of cereals and milk was 265 and 1033 kg/annum respectively. In order to meet the green and dry fodder requirement of 2 buffalos and 1 cattle, around 27 t of green fodder and 5.5 t of dry fodder /annum are required but existing system was producing only 21 t of green fodder. In the improved farming system, the green and dry fodder production increased to 36 and 6.4 t/annum respectively which is the main reason for additional production 1033 kg of milk. The total production in terms of sugarcane equivalent yield in the improved system was found to be 108 t/annum compared to 56 t/annum only in the existing system (Fig 2). The net profit increases by 88% while the cost of the system increases by 35% only. Internal supply of N, P_2O_5 and K_2O was found to be

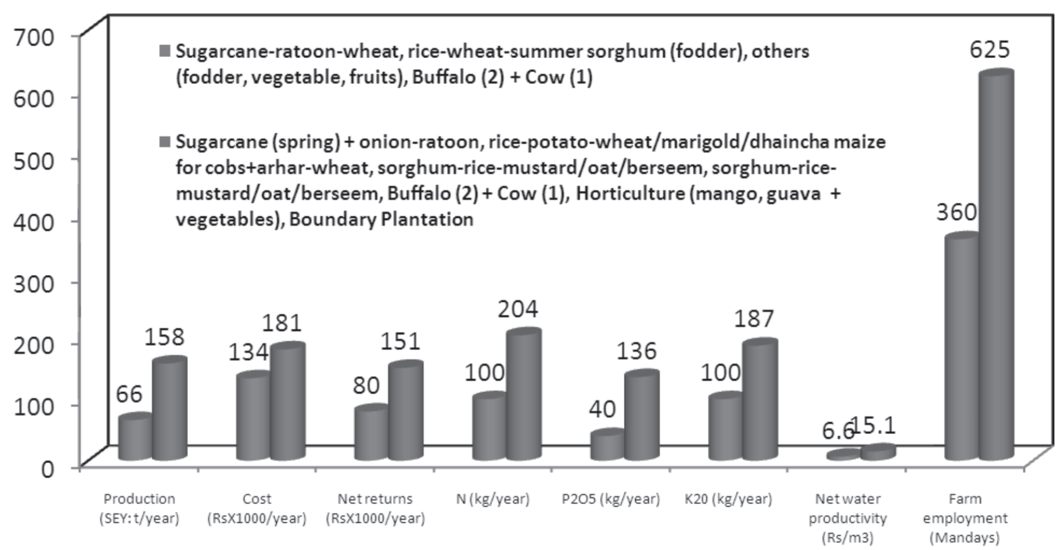


Fig. 2. Production, cost, returns, recycling and employment of existing and diversified system in Western Plain Zone of Uttar Pradesh

204, 136 and 186 kg against only 100, 40 and 100 kg in the existing system. In the improved system, it is estimated that 65, 85 and 100% of N, P_2O_5 and K_2O requirement can be met with in the farm. Further, the recycled resources are expected to supply sufficient level of micronutrients. Employment for the family increases from 360 man days to 625 man days.

Family Farming Model for Nutrition and Round the Year Income

A one hectare area with 5 member family farming model comprising of diversified cropping systems (0.78 ha) + horticulture (0.14 ha)+ dairy (2 cows) + goat (11 no's) + fish (0.1 ha) + ducks (25 no's) + boundary plantation (subabul, 225 plants & Moringa, 50 plants) developed for the South Bihar Alluvial Plain zone (BI-3) in Middle Gangetic Plains region provides round the year income which ranges between Rs 13,160 (September) to 51,950 (April)/ha/month (Fig 3). The diversified cropping systems [rice - wheat - greengram (grain + residue incorporation), rice - maize + potato - cowpea (fodder), rice - mustard - maize (grain) + cowpea (fodder), sorghum + rice bean – berseem / oat- maize + cowpea

Crop + horticulture + dairy + goat +fish + duck + boundary plantation family farming model at AICRP on IFS centre, Sabour (Bihar)

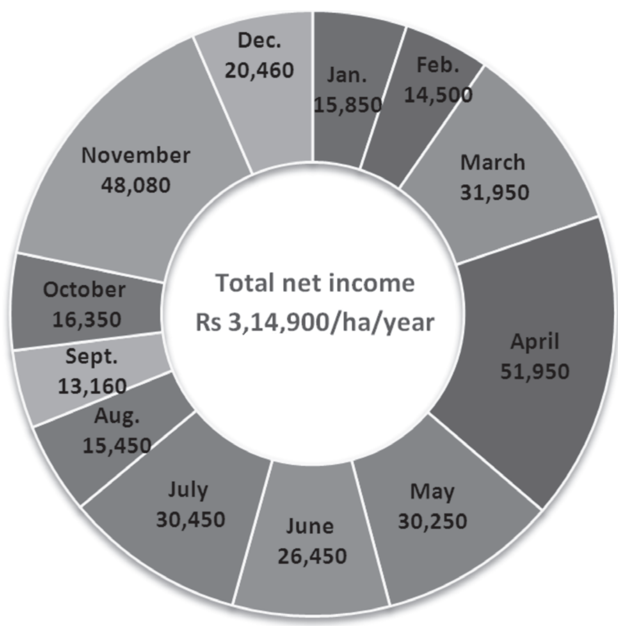


Fig. 3. Round the year net income (Rs/ha) for the family from crop (0.78 ha) + horticulture (0.14 ha) + dairy (2 cows) + goat (11 no's) + fish (0.1 ha) + ducks (25 no's) + boundary plantation (subabul & moringa) farming system model at Sabour (Bihar)

(fodder) and seasonal vegetables (brinjal, tomato, cauliflower, cabbage, vegetable pea, okra, lettuce) grown in 0.78 ha area could meet the full family requirement of 1100, 95, 125, 185 & 640 kg of cereals, pulses, oilseeds, fruits (guava & papaya) and vegetables and livestock requirement of 29.5 & 6.6 t of green and dry fodder per annum. The model also meets the milk, egg and fish requirement of 550 litres, 900 no's and 120 kg respectively. Besides meeting the family and livestock requirement, the model produced marketable surplus of 4810, 986 and 35 kg of cereals, vegetables and fruits with surplus of milk, egg and fish of 4243 litres, 950 numbers & 124 kg respectively which resulted in round the year income. The model also ensured fuel wood availability of 4 t/year for the family and could add 4 t of enriched vermicompost and 2.3 t of manure to improve the soil health. The value of recycled products and by-products model works out to be Rs 1.29 lakhs which reduces the total cost (Rs 3.1 lakhs) of the model by 42%. The family labour (730 man days) contributed to save 37% of cost. Hence, only 21% (Rs 0.68 lakhs) of total cost is involved in the form of inputs purchased from the market. A total net return of Rs 3.14 lakhs which is 3.2 times higher than existing pre-dominant crop+dairy system of the zone (DARE, 2015).

IFS Models for Rainfed / Dryland Regions

Rainfed agriculture is predominant in arid, semi-arid and sub-humid regions of the country. These regions are home to about 81% of rural poor in the country. Hence, rainfed agriculture has a crucial role to play in sustaining the economy and food security of India (CRIDA, 2012). At present, about 55% of the net sown area is rainfed contributing 40% of the total food production, supports 40% of human and 2/3rd of livestock population. However, aberrant behaviour of monsoon rainfall, eroded and degraded soils with multiple nutrient and water deficiencies, declining ground water table and poor resource base of the farmers are major constraints for low and unstable yields in rainfed areas. In addition, climate variability including extreme weather events resulting from global climate change poses serious threat to rainfed agriculture. Traditionally, farmers in rainfed regions practice crop-livestock mixed farming systems, which provide stability during drought years, minimize their risk and help them to cope with weather aberrations. However, these traditional systems are low productive and cannot ensure immediate livelihood security. The decline in size of land holdings, eroded and degraded soils with multiple nutrient deficiencies, aberrant weather and low investments pose a challenge to the sustainability and profitability of farming. The farming systems approach is considered important and relevant especially for the small and marginal farmers as location-specific integrated farming systems (IFS) will be more resilient and adaptive to climate variability. The IFS approach also has the potential to overcome multifarious problems of farmers including resource degradation, declining resource use efficiency, farm productivity and profitability.

On-station and on-farm research in different regions of the country has resulted in identification of a number of sustainable and profitable IFS models for rainfed areas; some successful models are discussed in this section. In general, in regions with rainfall of 500 to 700 mm, the farming systems should be based on livestock with promotion of low water requiring grasses, trees and bushes to meet fodder, fuel and timber requirements of the farmers. In 700 to 1100 mm rainfall regions, crop, horticulture and livestock based farming systems can be adopted depending on the soil type and the marketability factors. Runoff harvesting is a major component in this region in the watershed based farming system. In areas where the rainfall is more than 1100 mm, IFS module integrating paddy with fisheries is ideal. There are several modules of rainfed rice cultivation along with fisheries in medium to low lands of rainfed rice growing regions in the eastern states of India. In an on-farm trial involving different small and marginal farmers in Anantapur district of Andhra Pradesh, it was found that farmers having crop production alone incurred losses due to complete failure of pigeonpea and poor groundnut yields as a result of drought/prolonged dry spells in both the years (2010 and 2011). However, integration of livestock rearing with crop production gave higher economic returns compared to crop production alone for both marginal and small farmers. Hence, integrated farming systems assume greater importance in rainfed areas for sustaining the productivity and profitability of small and marginal farms in the context of climate change induced extreme weather events (Gopinath et al., 2012).

A model farming system for small holders with 1.15 ha area in an Alfisol has been developed by CRIDA covering arable crops, vegetables, green manuring, bushes on bunds, fruit plants on the lower side and grasses on the upper topo-sequence in a micro-watershed. Pigeonpea, vegetables and babycorn were raised by using harvested rain water in a farm pond. Twenty ram lambs were raised by utilizing crop residues and fodder crops. Economic analysis of the model after a 6-year period (2005-11) indicated that the economic efficiency of the farming system module (Rs. 52,356/ha) was highest as compared with popular cropping systems in the zone, sorghum + pigeonpea intercropping (Rs. 12,340/ha) and castor cultivation (Rs. 3,550/ha) (Table 2). The individual enterprises of arable cropping, agro-forestry, vegetables, grasses and bushes contributed 38.2, 10.3, 27.2, 7.1 and 17.2%, respectively to the total net income (CRIDA, 2011).

Table 2. Farming system module for a small farmer (1.12 ha) in Southern Telangana of Andhra Pradesh

Farming system	Net income (Rs/ha/year)
Improved farming system	
Crop (Pigeonpea, bajra, castor, horse gram	31556
Vegetables (Okra, brinjal, cluster bean)	
Fruit crops (custard apple)	
Fodder crops (Stylo, cenchrus, gliricidia and sorghum)	
Ram lamb: 20	20800
Total	52356
Existing farming/cropping system	
Sorghum + pigeonpea	12340
Castor	3550

Source: CRIDA (2011)

The integrated farming system model in dryland vertisols at Kovilpatti (Tamil Nadu) showed that crop + goat (4) + poultry (20) + sheep (6) + dairy (1) recorded the highest net income (Rs. 17,598/ha/year) followed by crop + goat + poultry + dairy (Rs. 14,208/ha/year), while the conventional system having crop cultivation alone gave a net income of only Rs. 2,057/ha/year (Table 3). Employment increased from 185 man-days/ha/year in conventional cropping system to 389 man-days/ha/year in integrated farming system model (Solaiappan *et al.,* 2007). Based on the sustainability index derived for different models, the farming system involving crop + goat (4) + poultry (20) + sheep (6) + dairy (1) was found superior with a sustainability index of 65.3 compared to other models.

Table 3. Performance of different farming system models at Kovilpatti, Tamil Nadu

Farming system	Net income (Rs/ha/year)	Benefit: cost ratio	Employment (man-days/ha/year)	Sustainability index
Crop alone	2057	1.28	185	-23.0
Crop + goat + poultry	8274	1.92	297	12.3
Crop + goat + poultry + dairy	14208	1.72	343	46.1
Crop + goat + poultry + sheep	7265	1.47	343	6.6
Crop + goat + poultry + sheep + dairy	17598	1.75	389	65.3

Source: Solaiappan *et al.* (2007)

In Southern dry zone of Karnataka, a farming system involving crop + dairy + sheep + poultry + sericulture + fodder generated a higher net income (Rs. 1,15,584/ha) closely followed by crop + dairy + sheep + goat + fodder system (Rs. 1,04,078/ha) compared to other farming system models under rainfed conditions of Chamarajnagar district (Shankar *et al.*,2008). Similarly, in drylands of Karnataka, mango orchards are very suitable for adopting sustainable farming system with cattle, sheep or goat along with intercrops of finger millet, groundnut or horse gram, which is extensively followed in traditional mango belt of Kolar district. Some more components like bamboo can also be added to make the system more sustainable. Even cashew and tamarind trees are commonly interspersed with mango trees (Shankar *et al.,* 2007). The benefit-cost analysis for mango based farming system in Karnataka is presented in Table 4.

Table 4. Benefit-cost analysis of mango based farming system

Farming system	Expenditure (Rs)	Net income (Rs)
Crop (0.4 ha) + 1 cow + 2 sheep + 10 birds	17575	45925
Crop (0.4 ha) + 2 cow + 4 sheep + 10 birds	32046	56954
Crop (1 ha) + 1 cow + 2 sheep + 10 birds	25825	91675
Crop (1 ha) + 2 cows + 4 sheep + 10 birds	35900	107100

Source: Shankar *et al.* (2007)

Based on an ex-post facto study involving 120 farmers, Desai *et al.* (2009) have identified the most economical rainfed farming system models for Andhra Pradesh, Karnataka and Tamil Nadu (Table 5). They observed the prevalence of different farming

Table 5. Farming systems providing higher economic returns in different States

State	Farm size			
	Marginal	Small	Medium	Large
Andhra Pradesh	Maize-paddy-caprine (Rs. 14,334)	Castor-maize-bovine (Rs. 18,625)	Castor-paddy-bovine (Rs. 28,581)	Maize-paddy-pulses (Rs. 18,886)
Karnataka	Pulses-bovine (Rs. 13,180)	Bajra-pulses-groundnut-bovine (Rs. 17,690)	Sorghum-pulses-sugarcane-bovine (Rs. 16,280)	Pulses-banana-sugarcane-bovine (Rs. 1,74,105)
Tamil Nadu	Paddy-sorghum-onion-bovine-poultry (Rs. 30,082)	Groundnut-sesame-onion-bovine-caprine (Rs. 19,490)	Paddy-sesame-vegetables-bovine-caprine (Rs. 23,500)	Paddy-sesame-groundnut-bovine-caprine (Rs. 29,058)

Source: Desai *et al.* (2009)

systems in vogue across farm sizes and States. The major components of the farming system were found to be cereal crops, oilseeds, vegetables, fruits, bovines and caprines.

IFS Models for Lowlands

Rice-fish System in rainfed lowlands: Rice field-fish culture, also popularly referred to as rice cum fish culture, is a traditional integrated fish-rice production system. The earliest practices can be traced back to more than 2,000 years ago. China is the largest producer of fish and rice in the world. Rice-fish culture has achieved significant development in China in the past three decades, in spite of the major socioeconomic changes that have occurred during this period. There are some 1.55 million ha of rice-fish culture in China now, which produces approximately 1.16 million tons of fish products (2007), in addition to about 11 million tons of high quality rice. Fish production from rice–fish culture has increased by 13-fold during the last two decades in China. Rice-fish culture is now one of the most important aquaculture systems in China. While making significant contribution to rural livelihood and food security, development of rice-fish culture is an important approach for environment friendly holistic rural development, and epitomizes an ecosystems approach to aquaculture. Rice-fish culture in China utilizes a range of production systems and practices, but all contribute to eco-environmental benefits and sustainable development. Many factors have contributed to these developments, but equally and still, there are challenges that need to be addressed for up-scaling these production systems and practices. It is estimated that the area under rice cultivation in Asia approximates 140.3 million ha, accounting for 89.4% of the world total. The potential for development of rice-fish culture is very high in the region. The successful experiences and lessons of rice-fish culture development drawn from China can be a good reference for sustainable rice-fish culture development in the region as well as other parts of the world, thereby contributing further to food security and poverty alleviation.

Integrating aquaculture with agriculture assures higher productivity and year round employment opportunities for farmers. The plots utilized for rice cum fish system is mainly based on organic fertilization with a varieties of animals excreta such as poultry dropping, pig excreta, cow dung and wastes of plants such as rice husks and ashes from household burnt and remains of burnt straws after the harvest is over. The rice field can be utilized for fish culture in the following two ways. Fishes can be reared from the month of May to September when the paddy crops grow in the field. The fish culture can also be taken up from the month of November to February after harvesting of paddy crops is completed and transplantation for the next season begins. The culture of fishes in paddy fields, which remain flooded even after the paddy is harvested, may also serves as an occupation for the unemployed youths. Paddy field is suitable for fish culture because of having strong bund in order to prevent leakage of water to retain up to desired depth and also to prevent the escape of cultivated fishes during floods. The bunds built strong enough to make up the height due to geographical and topographic location of the paddy field. Bamboo mating can be done at the base of the bunds for its support. Trenches of fish culture in rice fields can have three functions: as a refuge should water levels drop, a passageway providing fish with better access for feeding in the rice field and as a catch basin during harvest. There are several ways the trenches could be dug. Simplest way is to dig trenches of about 3 m width and 1.5 m depth is to be dug around the field. The excavated soil can be used for making raised bunds of about 1.5 m width at the top around the field to avoid overflow of water. Ridges can be used for round the year growing vegetables and other high value crop (cauliflower & capsicum). Trenches will serve as shelter for fishes. During wet season, the centre land can be used for long duration paddy cultivation while in dry season, vegetables can be grown on the same land. Due to the production of crops like vegetables and fodder on the bed and paddy and fish cultivation in the furrows, it is expected to improve the total net income, besides the regular income from the scale of vegetables to meet the expenditure. Fishes like grass carp, catla, rogue, mirgal can be reared. It is estimated that around Rs 3 lakhs as net returns can be obtained from one ha area. In a rice-fish integrated farming system, a gross return of Rs 44382 and net return of Rs 11226 was obtained from 0.5 ha area (Rautaray *et al.,* 2005) besides generating employment of about 350 man days.

Rice-fish farming systems can be broadly classified as capture or culture systems depending on the origin of the fish stock. In the capture system, wild fish enters the rice fields from adjacent water bodies and reproduce in the flooded rice fields. In the culture system, fishes are stocked either simultaneously or alternatively with the rice crop. Rotational culture is also practiced in some deep water areas where in the land is used for fish culture during flooding and followed by rice cultivation when the water levels are subsided. Rice and fish can be integrated with livestock as livestock droppings can serve as supplemental feed for fishes in the rice environment or in ponds.

Rice-fish+azolla system: The dual culture method of growing azolla with rice can accumulate 2 to 4 kg of N ha^{-1} day^{-1}. Azolla improves the fish feed availability in rice field. The field experiment conducted at Bhavanisagar of Tamil Nadu on rice-fish-azolla farming , rice-rice-fish+azolla system with 75% recommended dose of N as well as incorporation of green leaf manure (Table 6) resulted in higher productivity with increased net returns and improved soil fertility through recycling of organic residues (Balusamy, 1996). The

Table 6. Nitrogen added through recycling of organic residue (kg/ha)

Treatments	N applied through residue recycling					
	Fish trench	I crop	II crop	Azolla	GLM	Total
Rice-rice	0	9.2	9.9	0	0	19.1
Rice-rice+ fish +100% N	12.9	8.7	9.6	0	0	31.2
Rice-rice+azolla+fish+100%N	16.9	9.0	10.5	102.2	0	138.6
Rice-rice+fish+ GLM+100%N	13.4	9.2	11.1	0	19.4	53.1
Rice-rice+azolla+fish+GLM+100%N	17.3	9.2	11.3	107.5	19.4	164.7
Rice-rice+ fish +75% N	12.4	6.8	7.5	0	0	26.7
Rice-rice+azolla+fish+75%N	16.5	8.0	11.1	0	19.4	52.1
Rice-rice+azolla+fish+ GLM+75%N	17.0	9.1	11.2	106.3	19.4	163.0

Source: Balusamy (1996)

unutilized fish feed, decayed azolla and fish excreta settled at the fish trench bottom had a higher nutrient value, which can be recycled to enrich the soil.

Broad Bed and Furrow (BBF) based farming system involving rice + vegetable + fodder + fish for coastal waterlogged areas: Raised and Sunken Bed (RSB) system can serve as climate resilient practice in the rice based farming systems especially in the coastal areas where in inundation of rice fields are expected due to the sea level rise. It is a technique of land manipulation to grow vegetables, fish and fodder together right in the midst of rice fields. The system is found to increases cropping intensity from the present level of 100% in the rice to 300% in the beds and 200% in the furrows of the BBF system besides, reducing the salinity problem in degraded land & water. Net return of Rs 1.2 lakhs/year can be obtained from one ha area (Ravisankar et al., 2010).

Multi Enterprise Farm Pond based System for Coastal Degraded Lands

Harvesting of rainfall and surface runoff from surrounding areas are the major objectives of farm pond with the aim of recycling the water for crops, animals during dry season. In the process, multi enterprise farm pond based production system can be developed to ensure multiple uses of water and income from components. Due to the factors of soil salinity and back waters in coastal areas especially in the forthcoming scenario of climate change having the influence of sea level rise, the farm ponds in coastal/degraded lands are expected to have either fresh or brackish water. In brackish water based farming system, apart from saline tolerant lines of rice up to an extend of 6 dS/m of electrical conductivity, ducks can serve as an important component as no mortality was observed when introduced gradually to saline water of different concentrations up to 15 ppt. The body weight recorded at different week intervals do not pronounce much difference in different concentration of salinity for a period of one, two and three week's interval. Additional return of Rs 4000/- from 600 m^2 pond can be obtained from the duck component within four months through sale of eggs for ensuring rotational livelihood of farmers especially in the disadvantaged areas having coastal salinity as a constraint. Saline tolerant fodders can also be grown on the bunds of farm pond to support livestock production (cattle & goat). Brackish water prawn can be reared in the ponds. After testing the water quality in the pond, water can be utilized for irrigation during dry period (Ambast *et al.,* 2011).

Organic Farming System model for improving productivity and livelihood of tribal areas : Promotion of organic farming in niche locations especially low nutrient consuming tribal areas have great scope to enhance soil and crop productivity along with livelihood for the people. Organic agriculture in systems approach tends to manage the inputs for crop & livestock especially seeds, water, nutrients, pest & disease, green and dry fodder within the farm. Mean nutrient and pesticide consumption in Meghalaya was found to be 18 kg of NPK/ha which is far below than the national consumption (144.35 kg/ha) and gives scope for promotion of organic farming. A 0.43 ha organic farming system model comprising of cereals *viz.* rice and maize, pulses and oilseeds *viz.* soybean, lentil and pea, vegetable crops *viz.* french bean, tomato, carrot, okra, brinjal, cabbage, potato, broccoli, cauliflower, chilli, coriander, fodder, fruits *viz.* Assam lemon and papaya, dairy (1 cow + 1 calf) and a farm pond of 0.04 ha with depth of 1.5 m for life saving irrigation and fisheries was developed at Umiam under Network Project on Organic Farming (NPOF) for improving the productivity and livelihood. FYM (6 t) and vermicompost (2 t) could able to meet the nutrient requirement of all the crops. Total net return of Rs 58,321/year can be realized which is 5.7 times higher than existing system (Rice-fallow +dairy (1 cow) being practiced in the local areas. Crop component contributed 57% towards net income while dairy and fisheries contributed 22 & 21% respectively. The model is also being up-scaled in Mynsain village in Ri-Bhoi district of Meghalaya under Tribal Sub Programme.

Organic Farming System model under NPOF at Umiam (Meghalaya)

Soil health and nutrient recycling

Residue recycling is an integral part of the farming systems which is one of the most promising approaches of recycling agriculture residues for sustainable development, the adoption of which paves way for higher input use efficiency, reduction of risks, employment generation that ultimately culminates in higher farm income (Issac et al, 2015). The residues generated at Jorhat and Pant Nagar (32.63 and 31.58 t ha^{-1} respectively) from Integrated farming system models recycled comparable amount of nitrogen (359 and 350 kg ha^{-1} respectively), which was significantly higher to the rest three models developed under humid at Kalyani, Arid at SK Nagar and Coastal at Thanjavur. Under the humid agro-ecosystem, the recycling of nitrogen was recorded lowest (114 kg ha^{-1} from 20.0 t ha^{-1} residues at Kalyani, West Bengal). Higher amount of recycling of P_2O_5 (140 kg

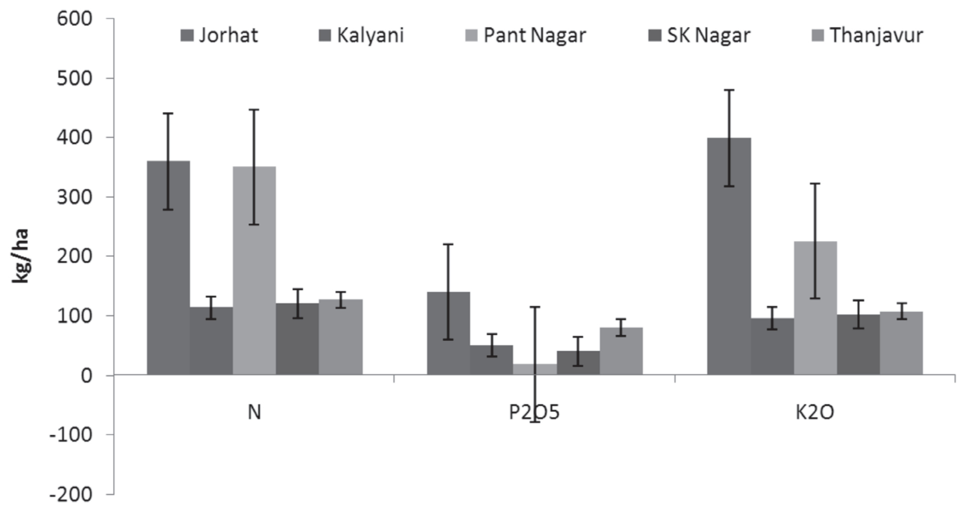


Fig. 4. Nutrients recycling in integrated farming system (kg ha^{-1})

ha^{-1}) was recorded from the model developed in humid agro-ecosystem at Jorhat and the recycling of the P_2O_5 observed below 80 kg ha^{-1}in the rest others models. The lowest recycling of P_2O_5 was recorded at Pant Nagar. The IFS model recycled K_2O in the range of 399 kg ha^{-1}at Jorhat to 95 kg ha^{-1}at Kalyani. Model developed at Jorhat and Pant Nagar recorded significantly higher amount of K_2O than the others models developed at Kalyani, SK Nagar and Thanjavur (Fig. 4). Availability of nutrients in the soil particularly at the critical growth stages of crop is considered to be the most important input for enhancing its productivity. It is intrinsically linked to food, nutritional, environmental as well as livelihood security of the country. To meet out the crop demand of these nutrients farmers are totally dependent on the chemical fertilisers. The mean annual rate of fertiliser use in India is more than that of the world and the rate is expected to increase in the future (Lal, 2016). Increasing use of chemical fertilisers higher than the recommended not only resulted in diminishing marginal rate of returns but also deteriorated the soil health. However, providing nutrients to the crops through their residue recycling has reported tremendous improvement in of soil quality. The average rate of residue recycling in to N, P_2O_5 and K_2O over the location was recorded 214, 66 and 186 kg ha^{-1} respectively. Recycling of all the crop residues, animal and farm wastes and use of leguminous crops as green manure or dual purpose crops and bio-fertilizers could save more than 36% of plant nutrients (Singh et al., 2011). It is pre-requisite in farming system to ensure the efficient recycling of resources particularly crop residues, because 80-90% of the micronutrients remain in the biomass. In the Indo-gangetic plains, where rice straw is not recycled in an effective way and even in Punjab where rice cultivation is practiced on 2.6 m ha produces about 16 m tonnes of paddy straw which is destroyed by burning. To curtail such precious input loss, the use of second generation machinery for efficient crop residue management to conserve moisture, improve soil micro-organism activities, regulate soil temperature, check soil erosion, suppress weed growth and on decomposition improves soil fertility (Manjunatha et al., 2014). Resource recycling improves fertility led to 5 to 10 q ha^{-1} crop yield increase, generate 50-75 mandays family^{-1} year^{-1} and reduce the cost of production by Rs.500-1,000 ha^{-1}. Therefore, there is an urgent need to promote the IFS concept under all agro-climatic conditions of the country (Manjunatha et al., 2014).

Round the year income and employment generation

Out of twelve months IFS model under coastal hot semi arid agro ecosystem of Thanjavur recorded lowest monthly income during seven months across the location however IFS model of Pantnagar under sub humid Agro ecosystem showed consistent monthly income round the years and none of the months recorded lower income than the other location. During seven months (February, March, April, June, July, August and October) the monthly income was recorded higher at Pantnagar over the others locations. Out of five IFS model developed under humid agro ecosystem at Jorhat (Assam) generated highest man days during five months in a year whereas employment generation of SK Nagar IFS model was remained lower and did not record higher monthly income even in a single month over the others centre. Total man days generated in a year was recorded highest in IFS model of Jorhat developed under humid agro ecosystem (479 man days) and it was lowest at SK Nagar under arid agro ecosystem (279 man days) (Table 7).

Table 7. Month wise economics and employment generated in IFS models (As per 5thyear of evaluation, 2015-16)

Months	Jorhat@		Kalyani*#		Pantnagar#		SK Nagar#	
	Net return (Rs ha^{-1})	Employment generation (man days)	Net return (Rs ha^{-1})	Employment generation (man days)	Net return (Rs ha^{-1})	Employment generation (man days)	Net return (Rs ha^{-1})	Employment generation (man days)
July	3624	70	8630	27	20224	40	18540	30
August	13779	17	6473	34	28926	33	18710	31
September	11064	17	2158	37	18141	36	70112	15
October	38541	70	1079	20	48091	38	28710	21
November	20484	52	6473	24	20616	38	23512	30
December	61234	47	2158	34	29036	37	26695	18
January	92608	23	6473	34	44220	29	29910	29
February	25937	43	10788	20	37144	27	13821	30
March	11733	56	15103	27	36851	24	19820	18
April	13080	21	12945	37	84549	43	12712	28
May	13939	22	15103	31	50574	32	18710	31
June	8033	41	20497	13	43070	32	31656	16
Total	314056	479	107880	338	461442	409	312908	297

@IFS Model comprises of crop production + horticulture + cow + Fish + Poultry + Apiary + vermicompost + Liquid Manure + Bio Gas; *=4thyear; # IFS model details in Table 1

Conclusion

It can be concluded that diversification of existing farming systems with change in crop (s), cropping systems, addition and improvement of livestock components, inclusion of horticulture, kitchen garden, primary and secondary processing, boundary plantations are essential to improve the on-farm income of small holders in India. This also paves way for meeting the household demand of balanced food, improved recycling of nutrients and water besides increasing the on-farm employment for family. Diversification of existing farming systems clearly demonstrated the advantages. It has been observed that productivity gain of 2 to 3 times and increase in net return of 3 to 5 times is possible with improved systems. Further, resource saving of 40 to 50% can also be ensured besides enhancing the income of household to the level of at least Rs 400 to 500/day. Additional employment generation of 70 to 80% is also possible. Improved diversified systems also ensure household nutritional security.

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