

Integrated Farming Systems for Sustainable Agricultural Growth: Strategy and Experience from Research

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Abstract

The challenges of increasing population (1.93% per year), soil degradation (5-10 m ha/year), desertification (6 m ha/year), declining irrigated area per person (1.3% per year) and declining per capita forested area (0.78% per year) in India are to be addressed to provide nutritionally rich food. Every year around 1% of population is added under food insecure category which is mainly due to poor food affordability. Demand for commodities like rice, wheat, pulses, fruits, vegetables, milk, fish, meat and egg are expected to increase annually. The consumption pattern is also undergoing major changes with the improvement in per capita income, especially in urban areas. The share of calories in Indian diet will be around 50% only from food grains while non-food grain crops and animal products share is expected to increase. The farm income is increasing at lower rate which is one of the major causes for agrarian stress and moving of youth away from agriculture. Diversification aims to provide the alternative avenues available for enhancing the income in a sustainable way. India is dominated by small holders who constitute 86% of farm households and own around 44% of operated area but their output exceeds 50% production. The holding sizes of marginal farms have decreased to 0.38 ha in 2010-11 and likely to reduce to the level of 0.32 ha with in this decade. The small holder farms in India have the typical characteristics of diversification such as multiple cropping, livestock and related activities besides off farm employment. Crop intensity has remained higher with marginal holders but declined with the increase in size of holding. Crop and livestock is the pre-dominant farming system and livelihood of 117 million marginal and small farm holdings. 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 a powerful tool; it holds the key for ensuring income, employment, livelihood and nutritional security in a sustainable mode for small and marginal farmers. IFS aims to meet with these 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 income from various enterprises of the system. Further, interventions indicated that profitability can be enhanced to as high as 137% within one year of low and no cost interventions. Farm level self-sufficiency in water and nutrient is possible through modern technological interventions such as rain water harvesting and recycling, nutrient. Multiple uses of water for household, irrigation, dairy, poultry, duckery and fish rearing is the best example. Small and medium size water bodies can be brought under multi-component production systems using in and around areas which will ultimately lead to improved income, nutrition and livelihood of small farm holdings. Organic or green farming is a holistic way of agriculture, which tries to bridge the widening gap between man and nature. Diversification of existing farming systems with change in cropping systems, addition and improvement of livestock components, inclusion of horticulture, kitchen garden, primary and secondary processing and boundary plantations are essential to improve the on-farm income of small holders. This will also meet with household demand for balanced food, and improve recycling of nutrients and water besides increasing the on-farm employment for family. Diversification of existing farming systems clearly demonstrated 2-3 folds productivity gains and 3-5 folds increase in net returns, 40 to 50% resource saving besides enhancing the income of household to Rs 400-500/day and employment generation to 70-80%. Improved diversified systems also ensure household nutritional security.

Key words: Integrated farming systems, diversification, strategies, sustainability

Introduction

Availability of sufficient man power within the family, capable of hard work, and full time devotion for farming

are considered to be the strength of small farms in India. However, the fragmented holdings, low level of literacy and low risk bearing ability due to poverty are often

their weaknesses that expose them to vagaries of farming. The opportunities available are the availability of low interest loan and subsidies from government agencies, presence of more than one enterprise and also easy addition of livestock through family labour. The threat will be the unpredictable weather changes. A diversification of small farms is essential to reduce risks associated with biotic and abiotic stresses, market price fluctuations and high input costs and meet with requirement of family and market (food, fodder, fuel, fibre and fertilizer). Such a change may help to sustain and improve income, employment and standard of living besides providing diversified products to the market. The integrated farming systems (IFS) approach is considered to be the most powerful tool to enhance the profitability of farming systems, especially for small and marginal farm-holders. Past experience has clearly demonstrated that the income from cropping alone is hardly sufficient to sustain the farmers' needs. With enhanced consumerism in rural areas, farmers' requirement for cash has also increased due to their rising standard of living, especially with small and marginal farmers. Therefore, farmers' income and food requirement must be augmented and supplemented by adoption of efficient secondary or tertiary enterprises like animal husbandry, horticulture (vegetables/ fruits/ flowers/ medicinal and aromatic plants), apiary, mushroom cultivation, fisheries etc. However, these IFS 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 to exploit synergies through adoption of close cycles. These systems are also to be socially acceptable, environment friendly and economically viable.

Integrated Farming System Approach and its Principles

Definition: IFS approach is defined as a "A judicious mix of two or more components while minimizing competition and maximizing complementarities with advanced agronomic management tools aimed at sustainable and environment friendly improvement of farm income and family nutrition". Preservation of bio-diversity, diversification of cropping or farming system and maximum recycling of residues ensure the success of this farming systems approach.

In general, farming system approach is based on several objectives that include sustainable improvement of farmhouse hold systems involving rural communities, enhanced input efficiency in farm production, satisfy the basic needs of farm families, improve their nutrition and raise family income through optimum use of resources and proper recycling of residues within the system. This is achieved by following essential 5-steps:

- Classification - identification of homogenous groups of farmers with similar natural and socio-economic characteristics is the first step and it forms the basis for the setting of priorities and for targeting of research and extension to particular farm types;
- Diagnosis is to identify the limiting factors, constraints and development opportunities of particular target farm types;
- Experimentation either on-farm or on-research station or at both sites and recommendation is made from the knowledge clearly gathered;
- Implementation of farming systems programs through a direct support to the extension agencies; and
- Evaluation is an important component that will lead to acceptance or modifications on farming systems for a wider adoption.

Diversification and Its Practice in Farming Systems

Desirable change is to tilt the existing system towards a more balanced cropping or farming system to meet ever increasing demand of food, feed, fibre, fuel and fertilizer while maintaining agro-ecosystem. Diversification is considered to be a good alternative to improve system yield with enhanced profitability. Further, the farming systems approach is highly location specific involving appropriate combinations of complimentary farm enterprises *viz.*, cropping systems, livestock, fisheries, forests and poultry utilizing the available resources of farmers to raise their income. Two approaches of farming systems such as holistic and innovative are considered to be powerful tools to increase the income and employment opportunities of 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 introduction of new components. The sequential stages of farming systems approach of research are classification, diagnosis, experimentation, recommendation, implementation and evaluation. The classification part involves Identifying homogenous groups of farmers for targeting research, extension and development while diagnosis looks to identify constraints, needs and priorities of target group. Similarly, various options available to address constraints are investigated through on-station or on-farm participatory research programs. Large scale results are analyzed and recommendations are synthesized. These recommendations are then demonstrated on a large scale using cluster participatory approach. Impact of large scale demonstrations are evaluated and selected for wider adoption.

Need for Coordinated Effort

Coordinated research in farming system is essential to investigate on the options available to overcome constraints in various regions in the country and develop resource centric models. It will also help to identify the successful model of one region and aid to spread to other region. Further, ICAR is also considering the farming systems approach for delivering technologies to the farmer door steps. All the time tested technologies generated by commodity based research institutions will be brought under the umbrella of farming systems and delivered to the farmers through All-India Coordinated Research Project (AICRP) on IFS. IFSR is therefore implementing IFS research from April 2010 at 75 centres. Thirty-two centres work on the farming systems model development for small holders mainly for experiential learning, demonstration and modeling the resource flow. Thirty one on-farm centres located in the districts work directly with the farmers through module based interventions in farmer participatory mode. In each location, 30 marginal holders and 6 small holders are covered for farming system model development. Twelve sub centres work additionally on cropping or farming systems. A network project on organic farming is also evaluated at 20 centres.

Pre-dominant Farming Systems in Various Regions

The quick survey conducted as a part of characterization of existing farming systems throughout the country indicated existence of 19 pre-dominant farming systems in India (ICAR 2013). Crop and livestock system is dominate (85%) in the country. Based on the contribution of more than 50% of net income, the systems are classified as crop, horticulture, livestock or fisheries - dominant system. Crop dominant farming systems are found in Andhra Pradesh, Bihar, Chattisgarh, Goa, Haryana, Jammu and Kashmir, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Punjab, Tamil Nadu, Uttar Pradesh, Uttarakhand and north-eastern states. Livestock dominant systems are present in Rajasthan and parts of Gujarat. West Bengal, parts of Odisha and Assam have fisheries as a major source of income in farming systems. There is a vast scope for promotion of horticulture (fruit) based systems exists in Jammu and Kashmir, Himachal Pradesh, Maharashtra, parts of Uttar Pradesh and in Sikkim. Plantation dominant systems can be promoted in Andaman and Nicobar Islands and Kerala. In some states (e.g. West Bengal) and locations (e.g. South 24 Paragnas district), highly diversified systems are prevalent where no single component dominates. Though, various farming systems exist in the country, integration of input and output within the system is either completely lacking or is 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 for use as household fuel. Sustainable farming systems aim for long term productivity, profitability, recycling of resources and employment generation. The monetary returns in 10 farming systems practiced in different parts of the country are given in Fig 1. Among the various existing systems in the country, coconut, banana, cocoa, pineapple and nutmeg (FS9) produced a 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 and dairy farming systems.

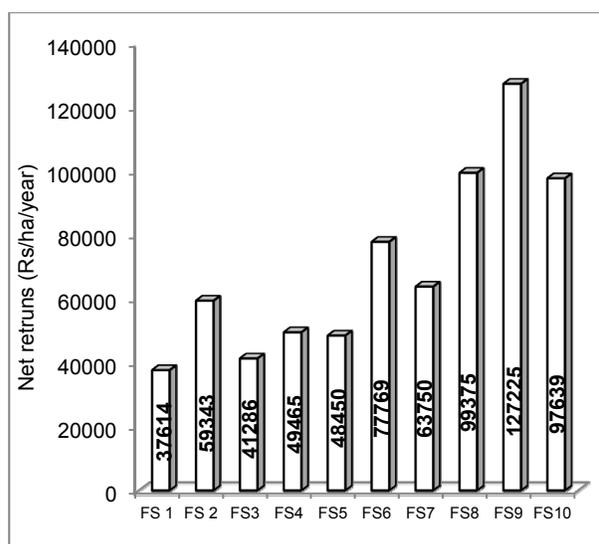


Figure 1: Value of net production of farming systems in the country.

FS 1 = Crops and dairy; FS6 = Crops, dairy, horticulture, poultry and fish; FS 2 = Crops, dairy and horticulture; FS7 = Rice and fish; FS3 = Crops, dairy and poultry; FS8 = Coconut and banana; FS4 = Crops, dairy and goat; FS9 = Coconut, banana, cocoa, pineapple and nutmeg; FS5 = Crops, fishery, dairy and poultry; FS10 = Crop, dairy, horticulture, apiary and fish

Farming System Typology

In India, crop and livestock farming system is dominant. Although, a natural integration of components exists, it lacks much needed recycling of residues within the farm to reduce the external dependence on market. The performance of existing farming systems in 732 marginal households in the country was investigated in 30 districts across 20 states. Results clearly revealed on the existence of 35 types of farming systems with involvement of as many as five components. In the sub group of crop and livestock system, crop and dairy is the major system practiced by 48% of marginal holders.

Table 1. Presence of farming system components in the marginal households

Component	Households with component (%)
Crop	100
Dairy	86
Goat	24
Poultry	21

Crop, dairy and goat (11%) were the next major system. In the livestock use, dairy is practiced by 86% of marginal holders while goat and poultry are owned by 24 and 21% households, respectively. Other components such as fish, fruits, apiary, sheep etc were in location specific use (Table 1).

Further analysis indicated the number of enterprises with farm households in different farming systems across country also vary: 52% with two (example crop and dairy), 28% with three (example crop, dairy and goat) and 11% with four (example crop, dairy, goat and fish) and the remaining with single enterprise (either crop or dairy alone). The contribution of crop and livestock to gross income of marginal households in various zones indicated that in majority of households, crop component contributed to > 50% while in a few districts of Samba (Jammu), Aurangabad (Maharashtra) and Mehsana and Panchmahal (Gujarat), livestock component contributed either equally or more than crop component. Marginal households possessed 3 to 4 persons for effective field work as the family size was 5-7. Even when a bare minimum of 3 persons / household is considered for field work, 1095 man/women days (8 hours/day) are available per household which is sufficient to take up the farming in the tiny holdings. Hence, marginal farms offer greater scope for agricultural diversification.

Approaches of Farming System Diversification

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 two or more crops of synergistic nature at a time in the same piece of land. This type of system offers scope to improve resource use efficiency of water and nutrients besides ensuring natural management of weeds, pests and diseases. Ten bio-intensive complimentary cropping systems were evaluated for higher productivity and profitability. The bio-intensive system of raising maize (for cobs) and cowpea (vegetable) in 1:1 ratio on broad beds (BB) and *Sesbania* in furrows during kharif;

mustard in furrows and 3-rows of lentil on broad beds in rabi and 3- rows of green gram on beds in summer was found to be remarkably better than others. This system produced the highest yield of 24 t/ha as rice equivalent with productively of 50.2 kg grains/ha/day and profitability of Rs.500/ha/day (Gangwar and Ravisankar 2013a). The complimentary effects could be exploited in broad bed and furrow (BBF) system as the furrows served as drainage channels during heavy rains in kharif and 35 t/ha green foliage was incorporated for in-situ green manuring 45 days after sowing. This 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 several crop components (rice-pea-okra and sorghum-berseem-maize), dairy, poultry and fishery was the most suitable and efficient system. This diversified system 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 program and to get more income and employment for small farmers of Odisha. Nearly nine per cent higher net return (Rs 58367) was realized from investment (Rs 49286) in 1.25 ha area which also generated 573 man days of employment. A resource use efficiency of Rs 2.18 per rupee invested ensured better 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 were higher in crop-fish system in rainfed lowlands in comparison to the sole system of any of these two independent components (Sinhababu 1996). Integrated farming system components comprising field crops, vegetables, floriculture, poultry, fishery and cattle in the low-lying valley areas gave higher net returns (Rs 2.11 lakhs/ha) and B:C ratio of 2.5 besides ensuring additional employment generation of 221 man days (Ravisankar et al 2006).

Diversified farming system models: Farming system models can be synthesized using the primary (collected directly from farm households on basic characteristics), secondary data (available from agricultural and livestock census) and research results from on-station and on-farm experiments to improve the productivity and profitability. The cropping systems were modified to include pulses, oilseeds, vegetables and fruits to meet the family demand. The area

allocation to each of the component was also made accordingly. The synthesized cropping system included sugarcane (spring) and onion-ratoon (12% area, 0.12 ha), rice-potato-wheat or marigold (0.15 ha) and dhaincha (26% area, 0.30 ha), maize (cob) and arhar-wheat (11% area, 0.13 ha), and sorghum-rice-mustard (0.21 ha) and oat (0.07 ha) and berseem (0.07 ha) (28% area, 0.35 ha). Arhar and mustard were added mainly to produce adequate pulses and oilseeds for the family. The livestock component of 2-buffalo and 1-cattle was kept as such but provision for producing sufficient green fodder was made by including oat and berseem in the cropping system. To enhance the income and recycle resource, complementary enterprises such as apiary, vermicompost (0.7% area, 100 m²) and karonda (*Carissa carandus*), citrus, jackfruit, beal (*Aegle marmelos*) and subabul (*Leucaena leucocephala*) as boundary plantation were incorporated. Karonda serves as the live fence and produces fruits which can be used to make pickles. Further, it can also protect the farm from blue bull or stray animals.

Mixed plantation of fruits including mango, guava, peach and pear- intercropped with seasonal vegetables like brinjal and 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 requires cereals (1550 kg), pulses (200 kg), oilseeds (130 kg), vegetables (900 kg), fruits (200 kg), milk (1120 litres) and fish (154 kg) per annum as per ICMR standards to provide its 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 this 7-member family. Apart from this, the system also generates marketable surplus of cereals (3585 kg),

oilseeds (106 kg), vegetables (3200 kg), fruits (2218 kg), milk (5001 litres) and fish (276 kg) and thus ensures sufficient income for the family besides improving the availability of these products in the market. The fodder requirement of 2 buffalos and 1 cattle is around 27 t of green fodder and 5.5 t of dry fodder per annum but existing system produced only 21 t of green fodder. In the improved farming system, it increased to 36 t green and 6.4 t dry fodder per annum which is the main reason for additional production of milk. The total production in terms of sugarcane equivalent yield in the improved system was found to be 108 t per annum compared to 56 t per annum only in the existing system (Fig 2). The net profit increased by 88% while the cost of the new system increased by 35%. Internal supply of nutrients was found to be 204 kg N, 136 kg P₂O₅ and 186 kg K₂O per ha as against only 100 kg N, 40 kg P₂O₅ and 100 kg K₂O per ha in the existing system. In the improved system, it is estimated that 65, 85 and 100% of N, P₂O₅ and K₂O requirement can be met within the farm. Further, the recycled resources are expected to supply sufficient level of micronutrients. Employment for the family increased from 360 to 625 man days. The farming system models synthesized for south Bihar alluvial plain zone indicated a profitability of Rs 698/ha/day which was 3.2 times higher than existing system (Table 2).

Profitability can be increased by 10 times in Central and north eastern plateau zone in Jharkhand by diversification of existing farming systems. The diversified systems not only increased the profitability, but also improved the balanced nutrition for family and livestock, recycling of nutrients, water productivity and employment for the farm households.

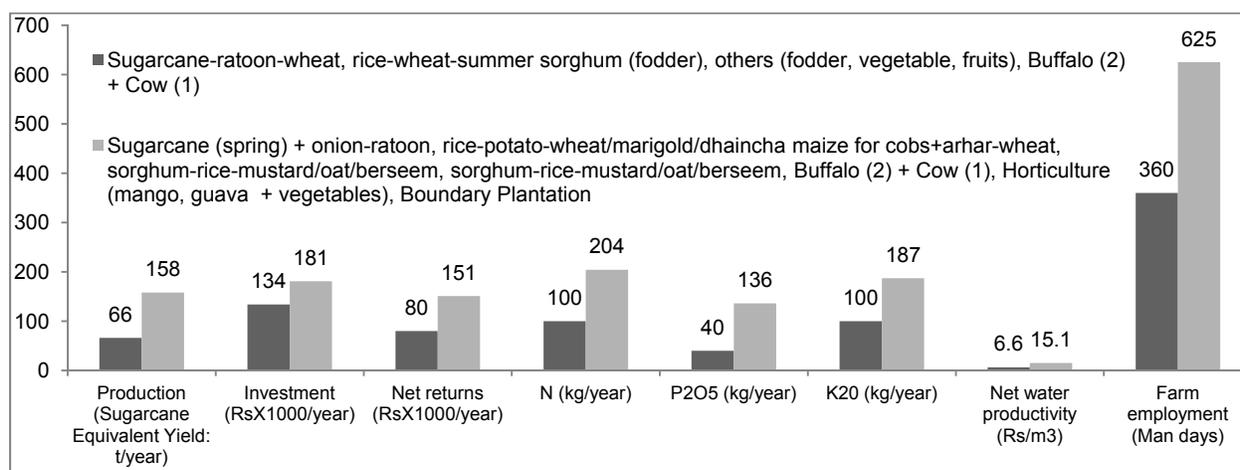


Figure 2. Production, cost, returns, recycling and employment of existing and diversified system in Western Plain Zone of Uttar Pradesh

Table 2. Diversified farming systems and its expected output at various locations

Parameters	Existing system	Synthesized diversified IFS model
South Bihar Alluvial Plain zone (Bhagalpur district of Bihar)		
Holding size (ha)	0.80 ha	0.80 ha
Family size (No's)	7 (Adult: 5, Child:2)	7 (Adult: 5, Child:2)
Dominant system	Crop, livestock and horticulture	Diversified crop(s), livestock, fisheries and horticulture
Model components		
Crop (0.60 ha)	Rice-wheat, rice-maize Maize-maize, rice-lentil	Rice or berseem – wheat or maize or mustard or lentil or Mpchari or cowpea or vegetables
Livestock	Cow (2) and buffalo (1)	Cow (2), fish (0.1 ha) and duckery (35)
Horticulture	Mango, guava, banana	Guava, banana, lemon, papaya Vermicompost, Boundary plantation (Subabul)
Production (Rice equivalent yield : t/year)	8.7	31.3
Investment (Rs in lakhs/year)	0.53	2.18
Net returns (Rs in lakhs/year)	0.64	2.04
Profitability (Rs/ha/day)	219	698
Production of balanced nutrition for family and livestock with in farm (% of total requirement)	55	100
Internal supply of nutrients (kg)	N : 48 P ₂ O ₅ : 32 K ₂ O : 16	N : 75 P ₂ O ₅ : 96 K ₂ O : 38
Net water productivity (Rs/m ³)	9.4	11.6
Farm employment (man days)	136	484
Central and North Eastern Plateau zone (Dhanbad district in Jharkhand)		
Holding size (ha)	1 ha	1 ha
Family size (No's)	6 (Adult: 4, Child:2)	6 (Adult: 4, Child:2)
Dominant system	Crop and livestock	Diversified crop(s), livestock, fisheries and horticulture
Model components		
Crop (0.80 ha)	Rice-fallow-fallow Rice-wheat-fallow	Rice or maize and black gram or pigeonpea or maize (fodder) and cowpea – wheat/ black gram or mustard or berseem
Livestock	Cow (2)	Cow (2), Fish (0.08 ha) Guava, banana, papaya Vermicompost
Production (Rice equivalent yield: t/year)	7.3	36.0
Investment (Rs in lakhs/year)	0.47	1.34
Net returns (Rs in lakhs/year)	0.18	1.95
Profitability (Rs/ha/day)	49	534
Production of balanced nutrition for family and livestock within farm (% of total requirement)	22	100
Internal supply of nutrients (kg)	N : 32.4 P ₂ O ₅ : 21.6 K ₂ O : 10.8	N : 90 P ₂ O ₅ : 35 K ₂ O : 30
Farm employment (man days)	115	392

Family Farming Model for Nutrition and Income

A one hectare area with 5-member family, farming model comprising of 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 of subabul (225 plants) and moringa (50 plants) was developed for the south Bihar alluvial plain zone in middle Gangetic plain region. This model provided round the year income (from Rs 13,160 (September) to 51,950 (April)/ha/month (Fig 3). The diversified cropping systems [rice - wheat - green gram (grain and residue incorporation), rice - maize and potato - cowpea (fodder), rice - mustard - maize (grain) and cowpea (fodder), sorghum and rice bean – berseem or oat-

maize and cowpea (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 cereals (1100 kg), pulses (95 kg), oilseeds (125 kg), fruits (guava and papaya) (185 kg) and vegetables (640 kg) and livestock requirement of green (29.5 t) and dry fodder (6.6 t) per year.

The model also provides for milk (550 litres), egg (900 no's) and fish requirement (120 kg). Besides satisfying the family and livestock requirement, the model produced marketable surplus of cereals (4810 kg), vegetables (986 kg) and fruits (35 kg), milk (4243 litres), egg (950 no's) and fish (124 kg) which resulted in steady income.



Figure 3. Crop, horticulture, dairy, goat, fish, duck and boundary plantation family farming model at Sabour, Bihar

The model had also ensured fuel wood availability of (4 t/year) for the family and could add enriched vermicompost (4 t) and manure (2.3 t) to improve the soil health. The value of recycled products and by-products of the model is 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 was Rs 3.15 lakhs which is 3.2 times higher than existing pre-dominant crop and dairy system of the zone (DARE, 2015).

Figure 4. Round the year net income (Rs/ha; based on prices of 2014-15) for the family
 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 and moringa) farming system model at Sabour, Bihar.

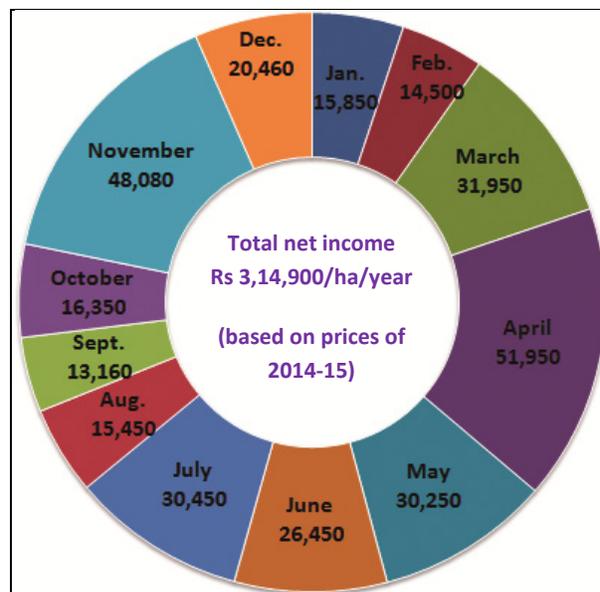


Table 3. Increase in net returns of various farming systems due to on-farm interventions in farming systems

Location	Area (ha)	Farming system components and allied enterprises	Net returns (Rs)		Increase (%)
			Before	After	
Kangra (Himachal Pradesh)	0.31	Crop, dairy, primary processing and kitchen garden	39942	61084	53
Kakdwip (West Bengal)	0.61	Crop, dairy, poultry, fisheries and secondary processing	36344	55969	54
Kabirdham (Chhatisgarh)	0.98	Crop, dairy, secondary processing, fruits and mushroom	68843	103618	51
Angul (Odisha)	0.98	Crop, dairy, goat, secondary processing, kitchen garden, backyard poultry and mushroom	63754	122407	92
Pune (Maharashtra)	0.90	Crop, dairy, primary and secondary processing and fruits	48624	82724	70
Kendrapara (Odisha)	0.91	Crop, dairy, goat, primary and secondary processing, backyard poultry, mushroom and fisheries	21074	34800	65
Chettinad (Tamil Nadu)	0.85	Crop, dairy, primary processing, kitchen garden and backyard poultry	57333	85369	49

(Gangwar and Ravisankar 2013b)

On-farm farmer participatory refinement of farming systems: On-farm interventions were made in farming systems at various locations of the country. Through on-farm centres of AICRP-IFS, documented that the profitability can be enhanced to as high as 137% within one year of introduction of low and no cost interventions (Table 3).

Rice, Vegetable and Fodder and Fish Systems for High Rainfall Areas

Raised and Sunken Bed (RSB) system (Fig. 8) can serve as a 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 increase cropping intensity to 300% in the beds and 200% in the furrows of the BBF system besides reducing the salinity problem. Net return increased by 235% over existing system with B:C ratio of 1.8 from one ha area (Ravisankar et al 2010).

Multiple Use of Resources in Farming Systems

Knowledge generated for management of natural resources is to be integrated in the system mode for an effective resource recycling. Multiple use of the resource such as land and water are essential to enhance the system productivity and profitability. Farm level

self-sufficiency in water and nutrient is possible through modern technological interventions such as rain water harvesting and recycling with nutrient and energy based input-output relationships. Multiple uses of water for household, irrigation, dairy, poultry, duckery and fish rearing is the best example. Small and medium size water bodies can be brought under multi-component production systems using in and around areas which will ultimately lead to improved income, nutrition and livelihood of small farm holdings. It is estimated that water productivity increases by 12 times (1.8 kg/m³ in okra and 2.6 kg/m³ in French bean to 40 kg/m³) in pond based integration of crop, fish, poultry and duckery in humid areas.

Similarly, integration of proper waste resource recycling in the small and marginal farmers holding will pave way for reduced fertilizer usage which in turn will have positive effect on national exchequer in the form of reduced fertilizer subsidy for production and transportation of fertilizers. For example, the egg laying khaki Campbell duck produces more than 60 kg of manure per bird on wet basis. The duck droppings provide essential nutrients such as carbon, nitrogen and phosphorus in the aquatic environment which serve as natural food for fish. From 10 to 20% of feed (23 to 30 g/day) are lost in the normal circumstances of feeding ducks. In the farming systems mode, feed given to ducks were also partially utilized by fish while washing the shed.



Figure 7. IFS model for marginal farm in western Uttar Pradesh

Table 4. Diversified FS models for sustainable livelihood

Zone (Location)	Prevailing FS	Improved Farming System Model*	Net returns Rs/ha/year (% increase over prevailing FS)
TGP (Ludhiana)	Crops and livestock	Crops (0.64 ha), horticulture (0.20 ha), livestock (2 cows) and fish pond (0.1 ha)	2,08,719 (132)
MGP Varanasi Patna	Crops and livestock	Crops (0.81 ha), horticulture (0.06 ha), livestock (6 cows), fish (0.10 ha), poultry (200) and mushroom	2,59,673 (81)
UGP (Modipuram)	Crops and livestock	Crops (0.50 ha), horticulture (0.10 ha), livestock (2 cows), fish (0.10 ha), goat (20:1), poultry (100) and duckery (30:5)	3,03,508 (348)
SPH (Coimbatore)	Crops, horticulture and livestock	Crops (1.2 ha), horticulture (0.16 ha), livestock (2 cows) and goat (10:1)	2,05,000 (122)
			2,38,192 (115)

Improved IFS models were tested at 32 centres in 23 states. By 1,116 farm households in 31 districts farmer participatory refinement of farming system modules were made and accepted after critical evaluation. Overall mean improvement of livelihood through

increased by 80 % in the net income/year following farming system interventions. Bio-intensive complimentary cropping systems produced more with less resources and profitability of Rs 527/ha/day.

Raised and Sunken Bed (RSB) Based Farming System

Raised and sunken bed (RSB) based farming system was suggested for adoption in coastal, high and scarce rain areas. RSB in farming system can serve as climate proof technology withstanding the adversities of rising sea level in coastal areas, high and scarce, intermittent drought and water logging events. Land configuration to grow vegetables, fish and fodder is done right in the midst of lowland areas. Length of beds and furrows can be according to the length of field. In one ha area of flat lowland field, 10 beds of 4 m x 100 m x 1 m and 10 furrows of 6 m x 100 m x 1 m can be made. Fish shelter can be made on the downside slope of furrows. With such modifications, net return of Rs 1.2 lakhs/year can be obtained from one ha area.

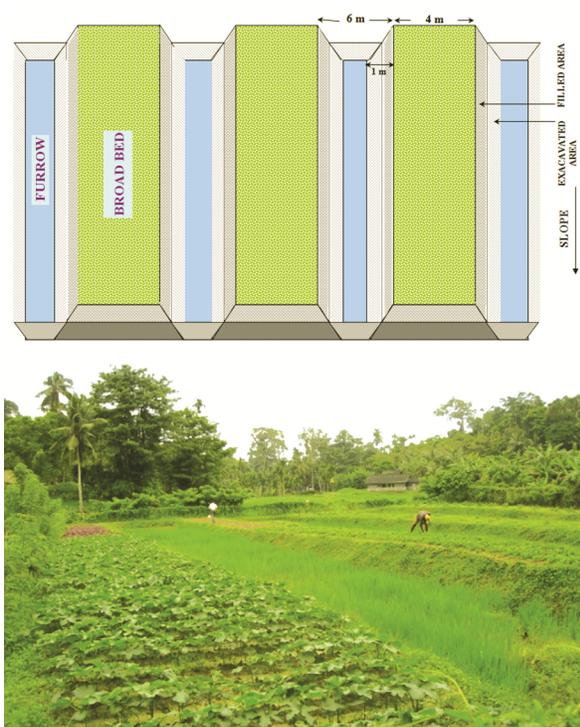


Figure 8. Raised and sunken bed (RSB) based farming system using ridges and furrows

IFS model of 1 ha developed for Vindhyan zone in Eastern Himalayan region comprises of components of diversified cropping systems (0.81 ha), horticulture (0.06 ha), dairy (6 cows), poultry (200 numbers in 6 batches) and fishery (0.10 ha). The diversified cropping systems (rice-wheat-green gram, rice-barley-green gram, rice-mustard-black gram, bottle gourd-cabbage-sponge gourd, Sudan chari-berseem and mustard-Sudan chari and pigeonpea and pearl millet-Sudan chari) were planned to efficiently recycle products and supply 100%

requirement of food and fodder. Boundary plantation of karonda (200 plants) and banana (50 plants), production button mushroom during winter and vermicompost were included in these systems as income supplementing activities. Recycling of products and by-products were estimated to be Rs 1.92 lakhs that reduced the cost of the model by 39%. Flow of input and output is given in Fig 4. The value of marketable surplus after meeting with the household needs of 7-member family was Rs 1.97 lakhs/annum. A net return of Rs 2.59 lakhs/ha/year can be obtained from the model by re-cycling the wastes as input in to components. The model recorded 3.2 times higher net income than the prevailing farming system (crop and dairy) of the region (DARE 2015).

Green Farming Systems

Organic or green farming is a holistic way of agriculture, which tries to bridge the widening gap between man and nature. The concepts and principles of organic farming differ on many accounts with conventional or modern farming. Organic production systems aim at achieving optimal ecosystem management which is socially, ecologically and economically sustainable. Although organic agriculture practices cannot ensure that products are 'completely free' of harmful residues, as residues may possibly trespass into the organic production systems through general environmental pollution. Yet, the major aims of organic farming are to minimize pollution of air, soil, water and farm products. The spread of organic farming on 1-5% area in the high productive zone and large spread in the hill states would help to strengthen the organic movement. It will further strengthen our export-oriented program under WTO regime. However, to make organic farming economically viable, issues like improving the productivity, reducing production costs, ensuring competitive price of organic produce to the grower in domestic and international markets and area approach of process certification are to be addressed at national level. The results of agro-climatic zone wise-analysis of organic farming system indicated that a sizeable increase in the net return can be obtained. The profit margins were directly linked with the number and kind of enterprises. The net profit was (Rs.143625/ha/annum) observed with coconut, banana, vegetable, horticulture, crops and dairy, and Rs.118225/ha/year with crops, dairy and fishery. Ten other farming systems gave net returns in the range of Rs.0.5 to Rs.1.5 lakh/ha/annum.

Organic Farming System Model in 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 and livestock especially seeds, water, nutrients, pest and disease, green and dry fodder within the farm. Mean nutrient and pesticide consumption in Meghalaya was 18 kg of NPK/ha which was far below the national consumption (144 kg/ha). An organic farming system model (0.43 ha) comprising of cereals (rice and maize),

pulses (soybean, lentil and pea) and oilseeds, vegetable crops (French bean, tomato, carrot, okra, brinjal, cabbage, potato, broccoli, cauliflower, chilli and coriander), fodder, fruits (Assam lemon and papaya), dairy (1 cow and 1 calf) and a farm pond of 0.04 ha with depth of 1.5 m for life saving irrigation and fisheries was developed for improving the productivity and livelihood.



Figure 9. Organic Farming System model under NPOF at Umiam, Meghalaya

Table 5. Development of integrated organic farming system models for enhanced income

Location	Components	Area (ha)	Total cost (Rs/year)	Net returns (Rs/year)				Existing system (Rs)
				Crop	Livestock	Others	Total	
Coimbatore	Crop (okra, cotton, desmanthus), dairy (1 milch animal, 1 Heifer and 1 bull calf), vermiculture and biogas plant	0.40	1,10,109	64,500 (87 %)	8,216 (11 %)	1,600 (2 %)	74,316	-
Umiam	Crops (cereals, pulses, vegetables, fruits, fodder), dairy (1 cow and 1 calf), fishery and vermiculture	0.43	68,255	33,531 (57 %)	13,252 (22 %)	11,538 (21 %)	58,321	8,618

FYM (6 t) and vermicompost (2 t) generated could supply 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 of rice-fallow and dairy (1 cow). Crop component contributed to 57% of net income while the remaining dairy and fisheries contributed equally.

Success Story: On-farm IFS, Kendrapara District, Odisha

The income of marginal household was doubled through low cost interventions in farming system (Table 6).

Table 6. Success of low cost interventions in farming system

Feature	Details
Holding size	0.70 ha
Family size	6 No's
Annual rainfall (mm)	1500
Predominant system	
Rice-fallow, cow and small ponds	
Net income (Rs /year)	17600
Interventions	
High yielding varieties, IPM, balanced fertilizer application, artificial insemination for animals, <i>Azolla</i> for poultry, milk frother, mushroom, improved fish culture	
Cost of interventions (Rs/year)	8700
Net income after interventions (Rs/year)	33900
Additional employment man days)	43

Conclusion

It can be concluded that diversification of existing farming systems with changes, addition or improvement of crop and livestock components and inclusion of horticulture, kitchen garden, primary and secondary processing, boundary plantations are essential to improve the on-farm income of small holders in India.



Figure 10. Integration of vermicompost in on-farm farming system



Figure 11. Pond created on farm to raise *Azolla* for use as fertilizer to crop.

This also paves way for meeting with the household demand of balanced food, improves 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 demonstrated that productivity gain is often 2 to 3- times and increase in net return is 3 to 5- times 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.

Way-forward for farming system diversification

Focus should be given mainly on family and market-oriented diversification and livelihood improvement by considering the options of alternative cropping, novel livestock systems and adding of value to primary (raw) products. Market-family driven diversification options can be achieved through the following initiatives.



Figure 12. Mushroom production using crop residues

- Capacity building of stake holders supplemented with physical and technology inputs
- Crop and forage rotation: includes crops, forages and high value crop options like vegetables, fruit trees, medicinal and aromatic plants
- Including perception based small ruminants (goats), poultry birds with component technologies
- Improving/ ensuring monthly income flow through product diversification both in terms of process and physical change.

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