



Integrated farming system in India: Current status, scope and future prospects in changing agricultural scenario

SANJEEV KUMAR¹, B P BHATT², A DEY³, SHIVANI⁴, UJJWAL KUMAR⁵, MD IDRIS⁶, J S MISHRA⁷ and SANTOSH KUMAR⁸

ICAR Research Complex for Eastern Region, Patna, Bihar 800 014

Received: 14 January 2016; Accepted: 22 June 2018

ABSTRACT

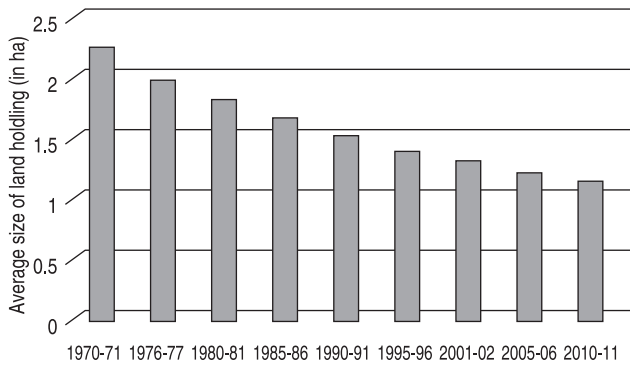
Small and marginal farmers are the core of the Indian rural economy constituting 85% of the total farming community but possessing only 44% of the total operational land. Indian agriculture is labour oriented and requires lot of man-power and energy but even after this hard work farmers are not in a position to earn their livelihood, especially small farmers because there is very little left after they pay for all inputs (seeds, livestock breeds, fertilizers, pesticides, energy, feed, labour, etc.). To fulfill basic needs of these farm families including food (cereal, pulses, oilseeds, milk, fruit, honey, meat etc.), feed fodder, fibre and fuel warrant an attention about integrated farming system (IFS). The emergence of IFS has enabled us to develop a framework for an alternative development model to improve the feasibility of small sized farming operations in relation to larger ones. IFS refer to agricultural systems that integrate livestock and crop production or integrate fish and livestock and may sometimes be known as integrated bio systems. In this system, an inter-related set of enterprises are used so that the waste from one component becomes an input for other enterprises of the system, which reduces cost and improves production and thereby income. Integrated farming systems seem to be the possible solution to the continuous increase of demand for food and nutrition, income stability and livelihood upliftment particularly for small and marginal farmers with little resources. Based on the research works conducted all over the country, it is clear that crop cultivation alone can't fulfill the demand of food and nutritional requirement and we have to focus on multi-component farming as it is the only way of efficient resource recycling within the system with increased economic profitability, economic stability, enhanced soil sustainability, and preserving environmental quality and maintaining biological diversity and ecological stability.

Key words: Farming system, Livelihood improvement, Productivity, Recycling

Indian economy is mainly agriculture oriented. Small and marginal farmers are the core of the Indian rural economy constituting 85% of the total farming community but possessing only 44% of the total operational land (GoI 2014). The average size of operational land holdings has reduced by half from 2.28 ha in 1970-71 to 1.16 ha in 2010-11 (Fig. 1). The operational farm holding in India is still declining. In Bihar and Kerala, the average size of holding fell by more than three times during the last four decades, whereas in Andhra Pradesh, Karnataka, Madhya Pradesh and Maharashtra, it has reduced by more than two times due to immense population pressure on the limited land resource available for cultivation (NABARD 2014). The declining trend of per capita land availability poses a serious challenge to the sustainability and profitability of farming (Siddeswaran *et al.* 2012). Due to ever increasing population and shrinking land resources in the country, practically there is hardly any scope for horizontal expansion of land for food production. Only vertical expansion is

possible by integrating appropriate farming components that require lesser space and time to ensure reasonable periodic income to farm families (Gill *et al.* 2009). From the Green Revolution onwards, farmers are mostly concentrating on single enterprise based agricultural systems that lead to deterioration of soil health, increased risk of crop failure and downward trends in productivity (Rahman and Sarkar 2012). Rapid population growth, urbanization and income growth in developing countries like India, the demand for food of animal origin is increasing, while also aggravating the competition between crops and livestock (increasing cropping areas and reducing rangelands). A system approach is the need of the hour for fulfilling the demand of ever increasing population without disturbing the ecological balance. Integrated farming system seems to be the possible solution to the continuous increase of demand for food production, stability of income and nutritional security particularly for the small and marginal farmers with limited resources. It is not only a reliable way of obtaining a fairly high productivity with substantial fertilizer economy but also a concept of ecological soundness, leading to sustainable agriculture. Further, the modest increments in

¹e mail: shiv_sanjeev@yahoo.co.in



Source: Agricultural Census, various rounds, GOI

Fig 1 Average size of operational holdings as per different agriculture census- All India (in ha)

land productivity are no longer sufficient for the resource-poor farmers. Hence, intelligent management of available resources, including optimum allocation of resources, is important to alleviate the risk related to land sustainability. The Ministry of Agriculture and Farmers' Welfare, GoI has also given major emphasis on Integrated Farming System (IFS) while planning for doubling farmers' income by 2022. However, planning and implementation of different enterprises in integrated farming system in our country lacks scientific and systemic approach. Moreover, proper understanding of interactions and linkages between the components would improve food security.

Challenges ahead

Food insecurity and poverty are the major challenges for the two-third of the world's hungry and poor people which is exacerbated by the soaring food and fuel prices, global economic downturn, volatile markets and climate change. The problem has further increased due to rise in the cost of food and energy, depleting water resources, shrinking farm size, diversion of human capital from agriculture sector, soil degradation, imbalanced use of fertilizer, excess use of pesticides and herbicides and vulnerability to climate change (Paroda 2012).

The marginal farmers with small land holdings concentrate only on crop production, mainly cereals with high risks of flood and drought. Due to failure of monsoon and small size of holdings, they hardly get sufficient income to sustain their family (Kumar *et al.* 2013). Moreover, Indian agriculture is labour oriented and requires lot of man-power and energy but even after this hard work farmers are not in position to earn their livelihood, especially small farmers because there is very little left after they pay for all inputs (seeds, livestock breeds, fertilizers, pesticides, energy, feed, labour, etc.).

To solve the problems of small resource poor farmers, diverse and risk prone environment has led to the development of a more holistic, resource based, client oriented and interacting approach, popularly known as Integrated Farming System. Biswas and Singh (2003) defined integrated farming as the integration of two or more

enterprises for each farm according to the availability of resources to sustain and satisfy as many necessities of the owner as it is possible which leads to increase productivity per unit area, efficient recycling of farm wastes, better utilization of resources, generate employment, reduce the risks and ensure sustainability. The integration is to be made in such a way that by-product of one component should be the input for other enterprises with high degree of complimentary effects on each other (Gill *et al.* 2009).

The challenges can be mitigated by improving efficiency and resilience of agriculture around the IFS. It means an IFS is to upgrade in terms of technological and social disciplines on a continuous basis and further to integrate these disciplines to suit the region and the farm families in a manner that will ensure increased production with stability, ecological sustainability and equitability (Varughese and Mathew 2009). In other words, technologies and management schemes that can enhance productivity need to be developed. At the same time, ways need to be found to preserve the natural resource base. Within this framework, an integrated crop-livestock farming system represents a key solution for enhancing livestock production and safeguarding the environment through prudent and efficient resource use. The increasing pressure on land and the growing demand for livestock products makes it more and more important to ensure the effective use of feed resources, including crop residues. An integrated farming system consists of a range of resource-saving practices that aim to achieve acceptable profits and high and sustained production levels, while minimizing the negative effects of intensive farming and preserving the environment.

Rationale of integrated farming

The rationale behind integrated farming is to minimize wastes from the various subsystems on the farm. Wastes or by-products from each subsystem are used as inputs to other subsystems to improve the productivity and lower the cost of production of the outputs of the various subsystems (Edwards *et al.* 1988, Gill *et al.* 2009). IFS seems to be the possible solution with the changing agrarian scenario of India. Land fragmentation, scarcity of agricultural inputs and changing climatic scenario of the country necessitates the follow up of the holistic perspective in agricultural use. Integrated farming system provides an opportunity to increase the economic yield per unit area per unit time by virtue of intensification and diversification of crops and integration of allied enterprises. It also offers enough scope to nutrient recycling within the system to economize and sustain the system and minimizes the dependence on chemical fertilizers for crop production to earn more profit (Rangaswami *et al.* 1999, Ganesan *et al.* 1999). This may also generate more employment for the family members throughout the year (Kumar *et al.* 2015). Recycling of waste products as input/resources in agricultural production, diversification with different crops and enterprises bringing in stability, meeting the diversified needs of the farm family offer of an insurance against crop/ market risk and overall

sustainability of soil have proven advantages over the monocropped situation (Manjunath and Singh 2012). IFS is an attempt to reconcile agricultural methods with the principles of sustainable development by balancing, in the words of 'FARRE', food production, profitability, safety, animal welfare, social responsibility and environmental care (Singh and Rai 2006). Overall an integrated farming system fulfill the multiple objective of making farmers self-sufficient by ensuring the family members a balance diet, improving the standard of living through maximizing the total net returns and provide more employment, minimizing the risk and uncertainties and keeping harmony with environment (Mali *et al.* 2014). Simultaneous production of fish in ponds, with pigs, duck or chicken rearing in pens, beside or over the ponds constitutes a continuous organic fertilization of the pond by the livestock. This practice increases the efficiency and rentability of both livestock farming and fish culture through the profitable utilization of animal and feed wastes (Vincke 1988, Gill *et al.* 2005).

Concepts and components

Integrated farming system is based on the concept that there is no waste, and waste is only a misplaced resource which can become a valuable material for another product (Edwards *et al.* 1986). This approach is not only a reliable way of obtaining fairly high productivity with substantial fertilizer economy but also deriving maximum compatibility and replenishment of organic matter by way of effective recycling of organic residues/wastes obtained through integration of various land-based enterprises (Jayanti *et al.* 2003). IFS combine livestock, aquaculture, agriculture and agro-industry in an expanded symbiotic or synergistic system, so that the wastes of one process become the input for other processes, with or without treatment to provide the means of production, such as energy, fertilizer, and feed for optimum productivity at minimum costs. The concepts associated with IFS are practiced by numerous farmers throughout the globe. A common characteristic of these systems is that they have a combination of crop and livestock enterprises and in some cases may include combinations of aquaculture and trees. The suitable tree-crop combinations can find the place in integrated farming systems (Bhatt *et al.* 2004a). It is a component of farming systems which takes into account the concepts of minimizing risk, increasing total production and profits by lowering external inputs through recycling and improving the utilization of organic wastes and crop residues. In this respect integration usually occurs when outputs (usually by-products) of one enterprise are used as inputs by another within the context of the farming systems. The difference between mixed farming and integrated farming is that enterprises in the integrated farming systems interact eco-biologically, in space and time, are mutually supportive and depend on each other. Examples include:

- Pig tractor systems where the animals are confined in crop fields well prior to planting and plough the field by digging for roots.

- Chicken tractor poultry used in orchards or vineyards after harvest to clear rotten fruit and weeds while fertilizing the soil.
- Cattle or other livestock allowed to graze cover crop between crops on farms that contain both cropland and pasture.
- Water-based agricultural systems that provide way for effective and efficient recycling of farm nutrients producing fuel, fertilizer and a compost tea/mineralized irrigation water in the process.
- Construction of animal houses over a pond so that animal waste fell directly into the pond on which fish feed.

Goals of IFS

The goals of integrated farming systems (IFS) are to:

- To provide a steady and stable income and rejuvenation/amelioration of the system's productivity.
- To achieve agro-ecological equilibrium through the reduction in the build-up of pests and diseases, through natural cropping system management and the reduction in the use of chemicals (in-organic fertilizers and pesticides).
- To provide environmentally sustainable and economically viable technology that encompasses rational utilization of available resources of the region.
- To conserve natural resource base, protect the environment and enhance prosperity for a longer period of time.

Advantages of IFS

IFS is a multidisciplinary whole farm approach and very effective in solving the problems of small and marginal farmers. The approach aims at increasing income and employment from small-holding by integrating various farm enterprises and recycling crop residues and by products within the farm itself (Behra and Mahapatra 1999, Singh *et al.* 2006). Increased productivity, profitability and sustainability are ensured with protective food and environmental safety. Recycling of waste material, income round the year, saving energy, meeting fodder crisis, employment generation and ultimately increasing the standard of living of the farmers are other major benefits of integrated farming system (Faroda 2014). It is advantageous over cropping system as it is an intensive farming and creates job opportunities to the small and marginal farmers throughout the year, one enterprise may act as insurance to other in case of crop failure, by-product of one enterprise may be used in other and also improves soil health and fertility in long run by increasing the nutritional value of soil (Olele *et al.* 1999, Ugwumba *et al.* 2010). Integration of livestock with crop component has been found beneficial as it improves soil physical and chemical properties in terms of N, P, K and other mineral nutrients (Kumar *et al.* 2012b). The application of livestock manure increases soil organic matter content, and this leads to improved water infiltration and water holding capacity as well as an increased cation exchange capacity, mainly

because of biological aeration. Manure and urine raise the pH level and accelerate the decomposition of organic matter and microbial activity (Brouwer and Powell 1995, 1998). It helps to improve and conserve the productive capacities of soils, with physical, chemical and biological soil recuperation.

Ever increasing concentration of greenhouse gases in the atmosphere resulting in global warming is likely to have serious repercussions for human beings, animals, plants, microbes and environment. As per NSSO, 40% farmers want to quit agriculture and the young generation is no more interested in farming profession. Diversification into farming system mode of agriculture on small land holding can provide proofing for predicted climate change related risk in agriculture. This can also help in obtaining food and nutritional security at farm level and can also generate rural employment, thus preventing excessive migration to urban areas, which is a common problem in developing economies (Singh 2012).

Some other advantages of IFS are summarized below as:

- It improves space utilization and increase productivity per unit area.
- It provides diversified products.
- Improves soil fertility and soil physical structure from appropriate crop rotation and using cover crop and organic compost.
- Reduce weeds, insect pests and diseases from appropriate crop rotation.
- Utilization of crop residues and livestock wastes.
- Less reliance to outside inputs – fertilizers, agrochemicals, feeds, energy etc
- Increase profits by reducing production costs. Poor farmers can use fertilizer from livestock operations, especially when rising petroleum prices make chemical fertilizers unaffordable.
- Higher net returns to land and labour resources of the farming family. It provides diversified income sources, guaranteeing a buffer against trade, price and climate fluctuations (Kumar *et al.* 2015).

Scope for IFS

An IFS consists of a range of resource-saving practices that aim to achieve acceptable profits and high and sustained production levels, while minimizing the negative effects of intensive farming and preserving the environment (Lal and Miller 1990, Gupta *et al.* 2012). IFS gives greater importance for sound management of farm resources to enhance the farm productivity and reduce the environmental degradation, improve the living standard of resource poor farmers and maintain sustainability (Kumar *et al.* 2013). Integrated farming is a system which tries to imitate the nature's principle, where not only crops but, varied types of plants, animals, birds, fish and other aquatic flora and fauna are utilized for production throughout the year (Kumar *et al.* 2015). Farming enterprises include crop, livestock, poultry, fish, tree crops, plantation crops, etc. A combination of one or more enterprises with cropping, when carefully

chosen, planned and executed, gives greater dividends than a single enterprise, especially for small and marginal farmers. Farm as a unit is to be considered and planned for effective integration of the enterprises to be combined with crop production activity. Integration of farm enterprises to be combined on many factors such as:

1. Soil and climatic features of the selected area.
2. Availability of resources, land, labour and capital.
3. Present level of utilization of resources.
4. Economics of proposed integrated farming system.
5. Managerial skill of the farmer

In the context of India, there are a number of situations and conditions that can be alleviated by an IFS. The following situations are ideal for the introduction of IFS:

- The farmer wishes to improve the soil quality.
- The farm household is struggling to buy food or below the poverty line.
- Water is stored on-farm in ponds or river-charged overflow areas.
- Fertilizers are expensive or the recommended blend is unavailable.
- Soil salinity has increased as a result of inorganic fertilizer use.
- The farmer is seeking to maximize profits on existing holding.
- The farm is being eroded by wind or water.
- The farmer is looking to reduce chemical control methods.
- The farmer wants to reduce pollution or waste disposal costs.

Integration of enterprises

Since IFS is an interrelated complex matrix of soil, water, plant, animal and environment and their interaction with each other it enable the system to be more viable and profitable over arable farming system and leads to production of the quality food. The income obtained from crops is hardly sufficient to sustain the farm family throughout the year. Assured regular cash flow is possible when the crop is combined with other enterprises. Judicious combination of enterprises, keeping in view of the environmental conditions of a locality will pay greater dividends. At the same time, it will also promote effective recycling of residues/wastes (Kumar *et al.* 2012a).

To strengthen the food chain, it is essential to eliminate nutritional disorder which has been realized on account of appearing deficiencies of mineral nutrients and vitamins in food being consumed. Horticultural and vegetable crops can provide 2-3 times more energy production than cereal crops on the same piece of land and will also ensure the nutritional security and income sustainability in the existing system (Gill *et al.* 2009). Similarly, inclusion of bee-keeping, fishery, mushroom cultivation, bird rearing, goatry, livestock on account of space conservation also provide additional high energy without affecting production of food grains. Integration of these enterprises helps the production, consumption and decomposition in a realistic

manner in an ecosystem. It is pre-requisite in farming system to ensure the efficient recycling of resources particularly crop residues and animal wastes, because 70-80% of the micronutrients remain in the biomass and animal wastes (Inman *et al.* 2005).

IFS can be practiced in different way with variable intensity depending on socio-economic structure, characteristics of soil, choice of the farmers and most importantly the resource availability of the farmers (Rahman and Sarkar 2012). It would be wise to select the enterprises by keeping the location specificity in mind, means on the basis of environmental condition of the area, land topography, soil and ecosystem, market and processing facility, socio-economical condition, risk bearing capacity, knowledge about the selected enterprise and investment capacity of the individual as farming models are highly location specific and it varies from place to place and even farmer to farmer in the same area. The integration is to be made in such a way that product of one enterprise should be the input for other enterprises with high degree of complimentary effects on each other (Gill *et al.* 2009). Hence, proper attention is required while selecting an enterprise to integrate into the system so that the farming model would be profitable and sustainable in all respect. A study conducted in Uttara Kannada district of Karnataka with an overall objective of identifying and analysing the optimality under different situations for different farming systems and it was concluded that, with the introduction of integrated farming system with suitable enterprises, the net farm return would increase in the range of 25 to 150% over existing plan. Further, with the availability of additional resources for inclusion of new technologies, the net farm return would enhance by 40 to 170% (Naik 1998).

Efficient nutrient recycling

Efficient nutrient recycling within the system is an integral part of any farming system research. In an integrated system, crops and livestock interact to create a synergy, with recycling allowing the maximum use of available resources. Crop residues can be used for animal feed, while livestock and livestock by-product production and processing can enhance agricultural productivity by intensifying nutrients that improve soil fertility, reducing the use of chemical fertilizers. For agricultural use, animal excreta can be used for fertilizer, feed and fuel. Excreta can be dried, composted, or liquid-composted for the production of biogas and energy for household use (e. g. cooking, lightning) or for rural industries (e.g. powering mills and water pumps). Fuel in the form

of biogas or dung cakes can replace charcoal and wood. It can be methane-fermented, directly combusted, or made into solid fuel. Furthermore, biomass production of feed is possible; the excreta is treated to be used as feed again (Moriya and Kitagawa 2007, Matsumoto and Matsuyama 1995). In crop based integrated farming system, crop residues are recycled. 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. A pictorial presentation of efficient nutrient recycling /input-output flow diagram under IFS is illustrated in Fig 3 (Kumar *et al.* 2011).

Bhatt and Bujarbaruah (2005) investigated that crop residue/weed biomass could be recycled for vermicomposting in intensive integrated farming system. On an average, 24.3 q of vermicompost could be obtained from 70.2 q of biomass (dry weight basis). Removal from the nutrient pool includes primarily uptake by the trees and crops which becomes either locked up in the vegetative parts or exported through harvested produce. Nutrient removal through harvested produce is compensated by nutrient input through manures, fertilizers, recycled crop residues and tree nutrient cycling processes. The tree components by virtue of their deep roots intercept absorb and recycle nutrients that would have been otherwise lost by leaching. A dynamic equilibrium can be expected with respect of organic matter and plant nutrients in the soil due to continuous addition of leaf litter, other plant residues and animal wastes and its continuous removal through decomposition (Varughese and Thomas 2009). An ideal nutrient interaction expected in an integrated farming system from the nutrient pool is depicted in Fig 2.

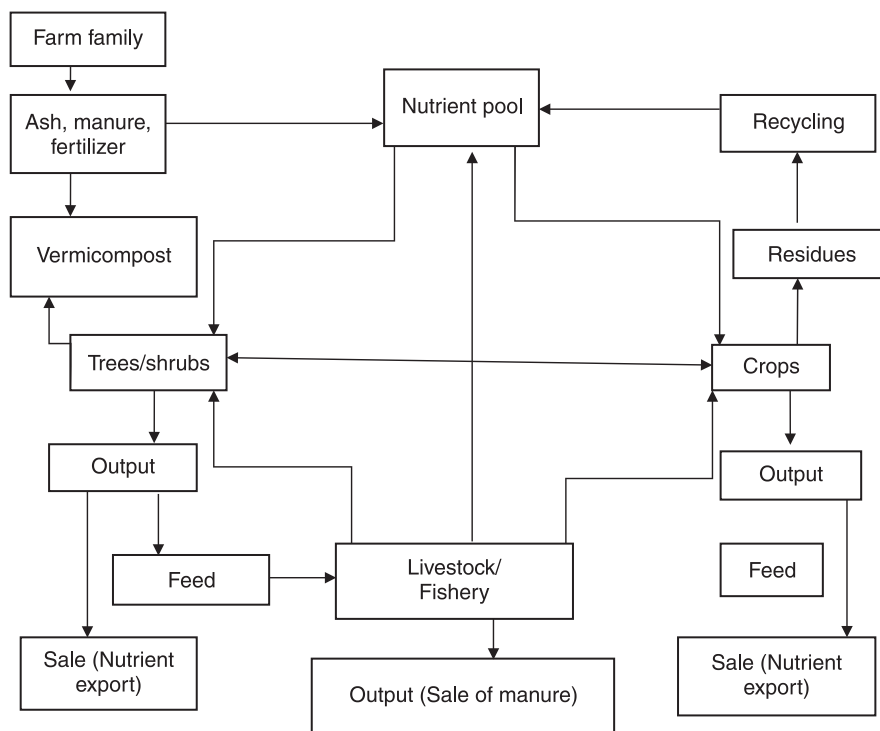


Fig 2 Nutrient flow diagram for an integrated farming system model

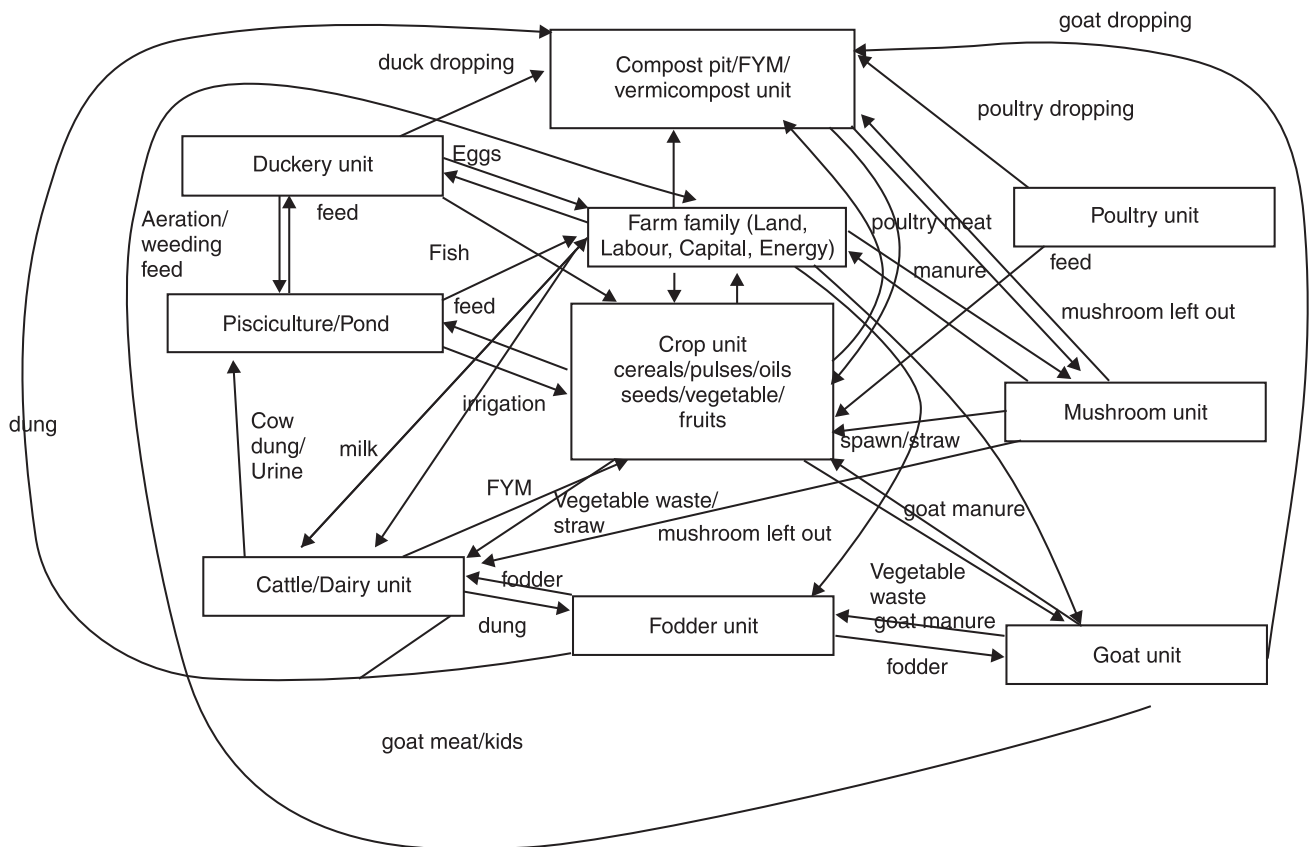


Fig 3 Input-output flow diagram existing under the developed IFS module.

Research outcomes

Crop-livestock farming system: In integrated crop livestock farming system, crop residues can be used for animal feed, while manure from livestock can enhance agricultural productivity by intensifying nutrients that improve soil fertility as well as reducing the use of chemical fertilizers (Gupta *et al.* 2012). Animal excreta contain several nutrients (including nitrogen, phosphorus and potassium) and organic matter, which are important for maintaining the soil structure and fertility. Bhatt and Bujarbaruah, (2005) analyzed different sources of manure available in Intensive integrated farming system developed in Umiam and found higher NPK, Ca and Mg in poultry manure, farmyard manure, goat manure, vermi-compost, pig manure, liquid manure, cow dung, duck droppings, *Azolla pinnata* in the range of N (%): 0.65- 5.20, P (%): 0.35- 1.46, K (%): 0.18- 3.60, Ca (%)- 0.75-4.15, Mg (%)- 0.07-3.96 which were recycled within the system.

Kumar *et al.* (2011) emphasized that the wastes/by-products of crop/animals used as input for another component has increased the nutrient efficiency at the farm level through nutrient recycling. The input-output flow diagram is depicted in Fig 3. Addition of organic residues into the system in the form of recycled animal and plant wastes could also help in improving the soil-health and thereby productivity over a longer period of time with lesser environmental hazards (Gill *et al.* 2009b, Kumar *et al.* 2017). Integration of crop sequences with animal

component improved the system profitability in totality even on small farm of 0.50 ha having 32% slope (converted into terraces) at Umiam, Meghalaya, which contributed more than 55% of the total farm income and made the system more remunerative (Panwar 2014). The inclusion of animal component in the system set a positive link on sustainability by generating cash income, improving family nutrition and recycling crop residues and livestock refuse into valuable nutrient source for crops (Saxena *et al.* 2003). Integration of livestock with crops on watershed and individual holding basis has been reported to improve the traditional farming system on sustainable and eco-friendly basis (Dhiman *et al.* 2003). In North Telangana zone, farming system with agriculture and dairy generated more than 200% additional employment over agriculture alone. The net returns were higher in agriculture and dairy followed by agriculture and poultry and agriculture and sheep (Reddy 2005).

In the pilot area of model Watershed, Rendhar, Jalaun, Uttar Pradesh, among the tested integrated farming systems, the maximum net income (₹ 65819/ha) was obtained from sesame-lentil + mustard + one Murrah buffalo and was closely followed by sesame-lentil + linseed (₹ 64004/ha) in ravines degraded soils of Bundelkhand (Singh *et al.* 2010a). Bohra *et al.* (2014) also found that the model comprising crop (1.15 ha) + vegetables (0.25 ha) + dairy (3 cows) developed for small farm household of Mirzapur with assured irrigation ensured higher household income of ₹ 157737/year. Sharma *et al.* (2014) conducted on-farm

field experiments on different farming system modules in five villages (Kochariya, Mandpiya, Rooppura, Dariba and Salampura) of district Bhilwara in Rajasthan. The increase in net return was 2 to 5 times higher to that of conventional cropping systems. The benefit cost ratio was high (2.01) in micro-farming system compared to 1.49 in conventional system.

In Haryana, Sheokand *et al.* (2000) conducted studies of various farming systems on 1 ha of irrigated and 1.5 ha of unirrigated land and found that under irrigated conditions of mixed farming with crossbred cows yielded the highest net profit (₹ 20581) followed by mixed farming with buffaloes (₹ 6218) and lowest in arable farming (₹ 4615). In another study conducted with 240 farmers of Rohtak (wheat-sugarcane), Hisar (wheat-cotton) and Bhiwani (chickpea-pearl millet) districts in Haryana which represented zones of different crop rotations revealed that maximum returns of ₹ 12593, 6746 and 2317/ha was obtained from 1 ha with buffaloes in Rohtak, Hisar and Bhiwani, respectively. The highest net returns from Rohtak was attributed to the existence of a better soil fertility type and of irrigation facilities coupled with better control measures compared to other zones. In terms of total man days, Rohtak had the highest employment potential followed by Hisar and Bhiwani. The employment potential under mixed farming conditions was predominantly from livestock rather than crop production. (Singh *et al.* 1999). Livestock also constitutes "living bank" providing flexible financial reserve in times of emergency and serve as "insurance" against crop failure for survival (Ramrao *et al.* 2005).

Crop-aquaculture farming system: This system of farming is most prevalent in Japan, China, Indonesia, India, Thailand and Philippines. Many reports suggest that integrated rice-fish farming is ecologically sound because fish improve soil fertility by increasing the availability of nitrogen and phosphorus (Giap *et al.* 2005, Dugan *et al.* 2006). On the other hand, rice fields provide fish with planktonic, periphytic and benthic food (Mustow 2002). Varughese and Mathew (2009) reported from Kerala that integrated farming involving aquaculture has great relevance to the coastal rice lands such as Kuttanad, Kole and Pokkali/Kaippad. In lowland rice, the entire food chain and vast amount of fertilized water can be fully utilized by integrating rice and fish. The rice-based farming involving fish will not only reverse the present trend of non-utilizing and underutilization of rice field but also make rice farming more attractive, consequent of such a farming system, it can sustain food security. This system of farming could trigger a process of change whereby the income and economic prosperity of people living in these areas will increase leading to economic resurgence.

Balusamy *et al.* (2003) explained that rice + *Azolla*-cum-fish culture is one of the economical option in the area. Monoculture system rely mainly on external inputs while in integrated system, recycling of nutrients takes place that help in reducing the cost of production for economic yield. The fish in rice field utilized the untapped aquatic productivity

of rice ecosystem as the rice bottom is highly fertilized on account of the production of zoo and phytoplankton and these resources are fully utilized by the fish. The gross income obtained in rice + *Azolla* + fish was 25.7% more over the rice crop and 6.9% more over the rice + fish. The net income followed the same trend. Thus rice + *Azolla* + fish on an average gave ₹ 8817/ha more over the rice monoculture and ₹ 3219/ha over the rice + fish. This model was proposed for extensive scale adoption in Tamil Nadu.

Bisht (2011) worked on participatory approach at farmer's field in Indian Central Himalaya on integrated fish farming and reported that beside protein rich food for household consumption, an average net gain of ₹ 36823 was obtained annually from integrated fish farming with investment of ₹ 11925 by the farmer. Economic analysis of technology clearly showed advantage over conventional system of cropping under rainfed conditions. A net profit of about 200% of the total cost indicates the economic viability of the technology. It has considerable potential to provide food security, nutritional benefits, employment generation and providing additional income to resource poor small farmers.

Crop-poultry farming system: With rice-based IFS in Kerala, major returns by 79% from coconut-banana intercropping in the dykes and field bunds (Mathew and Varughese 2007). The intervention of green manure husk burial (percent profit- 24.1 and net income: ₹ 32600/ha) and vermicompost with banana pseudo stem (percent profit- 55.3 and net income: ₹ 75000/ha) provided a major share of nutrients (NPK) in the farm over rice crop with recommended doses of fertilizers. Duck droppings also resulted in enhanced profit percentage by 20.5 with net income of ₹ 27800/ha. The above amendments have also enhanced the physical properties of soil like bulk density, porosity, aggregates, infiltration rate etc.

Crop-fish-poultry farming system: Channabasavanna *et al.* (2002) observed from integrated farming system studies at Sirupura that rice-fish-poultry combinations gave highest net income (> ₹ 157000/ha) with an improvement in soil health. Channabasavanna and Biradar (2007) reported that nutritional status of soil NPK show increased trend from 187 kg/ha to 262 kg/ha (40%), 29.3 kg/ha to 33.6 kg/ha (14.6%) and 503kg/ha to 530 kg /ha (5.4%), respectively in rice-fish poultry system over conventional system (rice-rice). The increase was to the tune of 11.5% over conventional systems. Similarly, P and K content showed increased trend with IFS.

Crop-livestock-poultry farming system: Ramrao *et al.* (2006) studied crop-livestock integrated farming system for the marginal farmers in rainfed regions of Chhattisgarh in Central India to find out a sustainable mixed farming model which is economically viable integrating the different component like crop, livestock, poultry and duck on 1.5-acre land holding. A model having 2 bullocks + 1 cow + 1 buffaloes + 10 goats + 10 poultry + 10 ducks along with crop cultivation was the best with a net income of ₹ 33076 per year against arable farming (crop farming)

alone (7843 per year) with a cost returns of 1:2.238 and employment generation of 316 days. Korikanthimath and Manjunath (2009) found that FYM and poultry manure influenced the soil to improve its fertility after successive rotation of different cropping systems (1.35%) as compared to no manure recycling. Recycling of paddy straw with mushroom substrate had an impact in retaining carbon status of soil (1.33%). Singh *et al.* (2014) developed two integrated farming system models in Goa, one each for upland (plantation crop based) and lowland (rice based) with the feasible cropping systems and their integration with allied agri-enterprises. In the upland model, Cashew (Variety Bhaskara) + Pine apple (Variety Giant Kew) system in the upper elevation; local coconut cultivar intercropped with elephant foot yam/papaya (local selection) as well as noni (*Citrus morinifolia*) in middle elevation and high-yielding arecanut variety Mangala with intercrop of tissue cultured banana in lowlying areas integrated with poultry, piggery and vermi composting were found productive. Solaiappan *et al.* (2007) examined different farming system models along with conventional cropping and found that model having poultry (20) + goat (4) + sheep (6) + dairy (1) recorded maximum organic carbon (0.35%), available soil N (134 kg/ha), soil P (8.5 kg/ha) and soil K (378 kg/ha) at the end of study. Kumara *et al.* (2015) found that integration of agriculture + dairy + banana + vegetables + sheeprearing + poultry + vermicomposting + foragecrop + banana was found beneficial on the basis of B:C ratio combination of complementary enterprises. The profit margin varied (from ₹ 15000 to ₹ 150000/ha/annum) with the ecosystem (rainfed/irrigated), management skill, and socio-economic conditions. Resource recycling improves fertility led to 5 to 10 q/ha crop yield increase, generate 50-75 man-days/family/year and reduce the cost of production by ₹ 500-1000/ha. Simultaneously it takes care of the food and nutritional security of the farming family.

Crop-livestock-fish-poultry farming system: IFS also play an important role in improving the soil health by increasing the nutritional value of soil. The benefits of the use of livestock manure in crop production are improvements in soil physical properties and the provision of N, P, K and other mineral nutrients. The application of livestock manure increases soil organic matter content, and this leads to improved water infiltration and water holding capacity as well as an increased cation exchange capacity. Manure and urine raise the pH level and accelerate the decomposition of organic matter and termite activity (Brouwer and Powell 1995, 1998).

Kumar *et al.* (2012b) developed seven IFS models in three districts of Bihar namely Patna, Vaishali and Munger districts, to sustain productivity, profitability, employment generation and nutrient recycling for lowland situations. Among the tested models, crop + fish + cattle model recorded higher rice grain equivalent yield (18.76 t/ha) than any other combinations but in terms of economics, the crop + fish + goat model supersedes over all other combinations by fetching highest average net returns of ₹

164810 (USD 2655/year), maximum sustainability for net returns (73.1%) apart from addition of appreciable quantity of N, P₂O₅ and K₂O into the system in form of recycled animal and plant wastes.

In Tungabhadra project area of Karnataka, integration of crop with fish, poultry and goat resulted 26.3 and 32.3% higher productivity and profitability, respectively over conventional rice-rice system. Among the components evaluated, the highest net returns were obtained from crop (63.8%), followed by goat (30.9%), fish (4.0%) and poultry (1.3%), respectively (Channabasavanna *et al.* 2009). Kulkarni *et al.* (2014) conducted IFS in farmers' field of Raichur in Karnataka and found that integration of various components improved farm income in a sustainable manner besides reduction in cost of cultivation by adopting low cost and ecofriendly technologies. Pearl millet followed by groundnut was common cropping practice followed by the farmer. By adoption and integration of various components like vegetable (tomato, brinjal, chilli, bottlegourd, ridgegourd, coriander, *menthi*, etc), cow, poultry birds, fishery, vermicomposting, Panchagavya, Jeevamruth etc., there was sustainable increase in net returns, *i.e.* 243.3% over pearl millet– groundnut cropping system (₹ 23450). There was also drastic reduction in cost of cultivation besides generating more employment, *i.e.* 245-man days in IFS demonstration as against 80-man days in normal practice.

Singh *et al.* (2006) developed sustainable integrated farming system models for irrigated agro-ecosystem of eastern Uttar Pradesh of north-eastern plain zone which revealed that rice-pea-okra was the most remunerative cropping sequence with highest rice equivalent yield of 17.88 t/ha and net returns than the conventional rice-wheat sequence. The rice based integrated farming system comprising crop components, dairy, poultry and fishery was the most suitable and efficient farming system model giving the highest system productivity and ensured the multiple uses of water. This model generated significantly higher levels of employment than rice-wheat system. Jayanti *et al.* (2004), based on field experimentation at Coimbatore on farming in lowlands reported that integration of cropping with fish, poultry, pigeon and goat resulted in three-fold higher productivity per unit of land over cropping alone as use of manures from the linked allied enterprises helped in increasing productivity of crops.

Kumar *et al.* (2012) studied different IFS models at Patna and identified crop + fish + duck + goat as the best integrated farming system in terms of productivity and employment generation (752 man-days/year) due to better involvement of farm family labours throughout the year. Integration of enterprises created the employment opportunities where in comparison to 512 mandays/year generated in cropping alone system, cropping with fish, duck and goat created additional 240 mandays/annum (Fig 4).

Singh *et al.* (2012) had undertaken integrated farming (IFS) comprising the components like crop, dairy, fishery, horticulture and apiary rearing at Modipuram, Meerut,

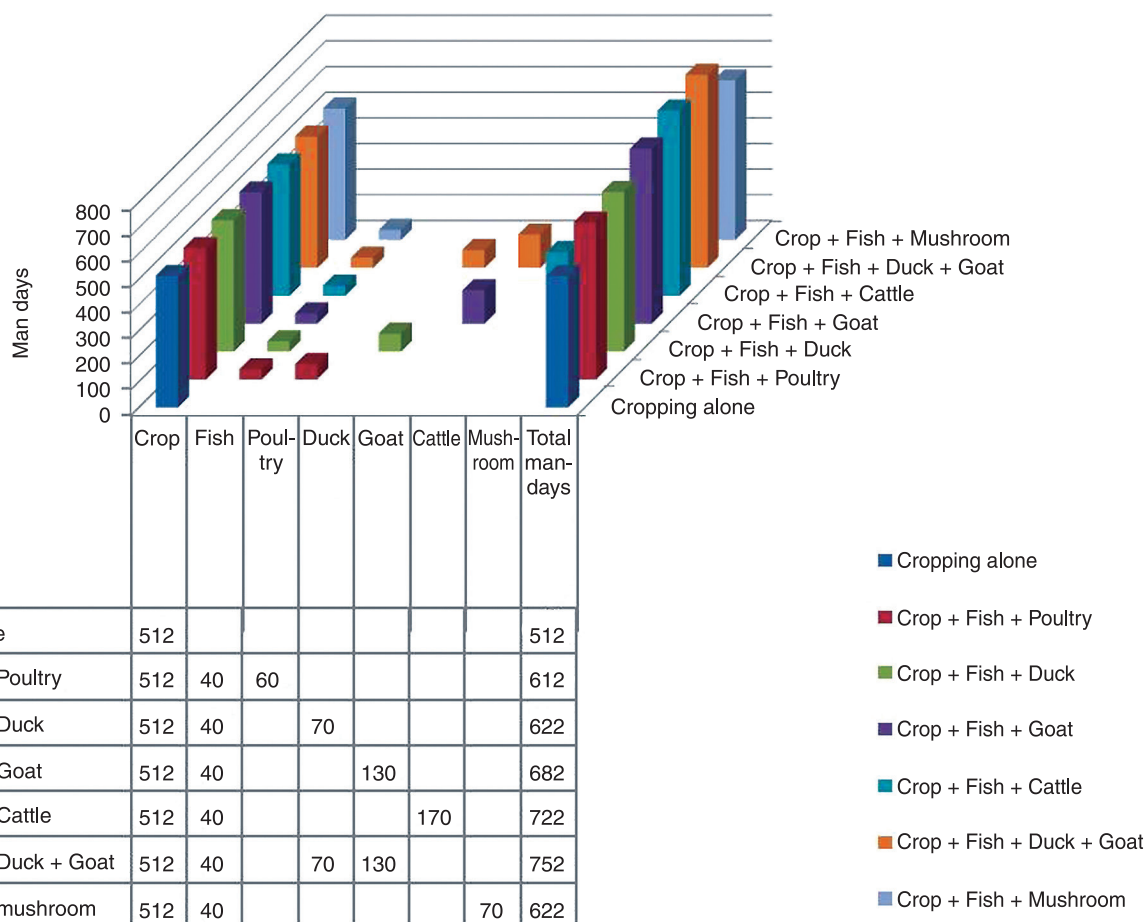


Fig 4 Man-days requirement under different IFS combinations at Patna district.

Uttar Pradesh. The relative share of different component in the order of merit were from dairy (48%), crop (41%), horticulture (6%) followed by fish (3.0%) and apiary (2%). The net returns obtained from different components were ₹ 87029, ₹ 74435, ₹ 10263, ₹ 4947, ₹ 4204, respectively of which total return from IFS unit per year (1.4 ha) was ₹ 135826. Efficient nutrient recycling made the model sustainable and eco-friendly.

In traditional Chinese system, the animal houses were constructed over a pond so that animal waste fell directly into the water fueling the pond ecosystem, which the fish could then feast on for food. Not only were the fish harvested but the pond water, now with extra nutrients was used for irrigation in crops. The maximum return (₹ 79064/ha) was earned from fisheries + piggery + poultry as compared to ₹ 533221 from the rice-wheat system and registered 48.6% gain. This also generated additional employment of about 500-man days/ha/annum (Sutradhar 2016).

Energy budgeting

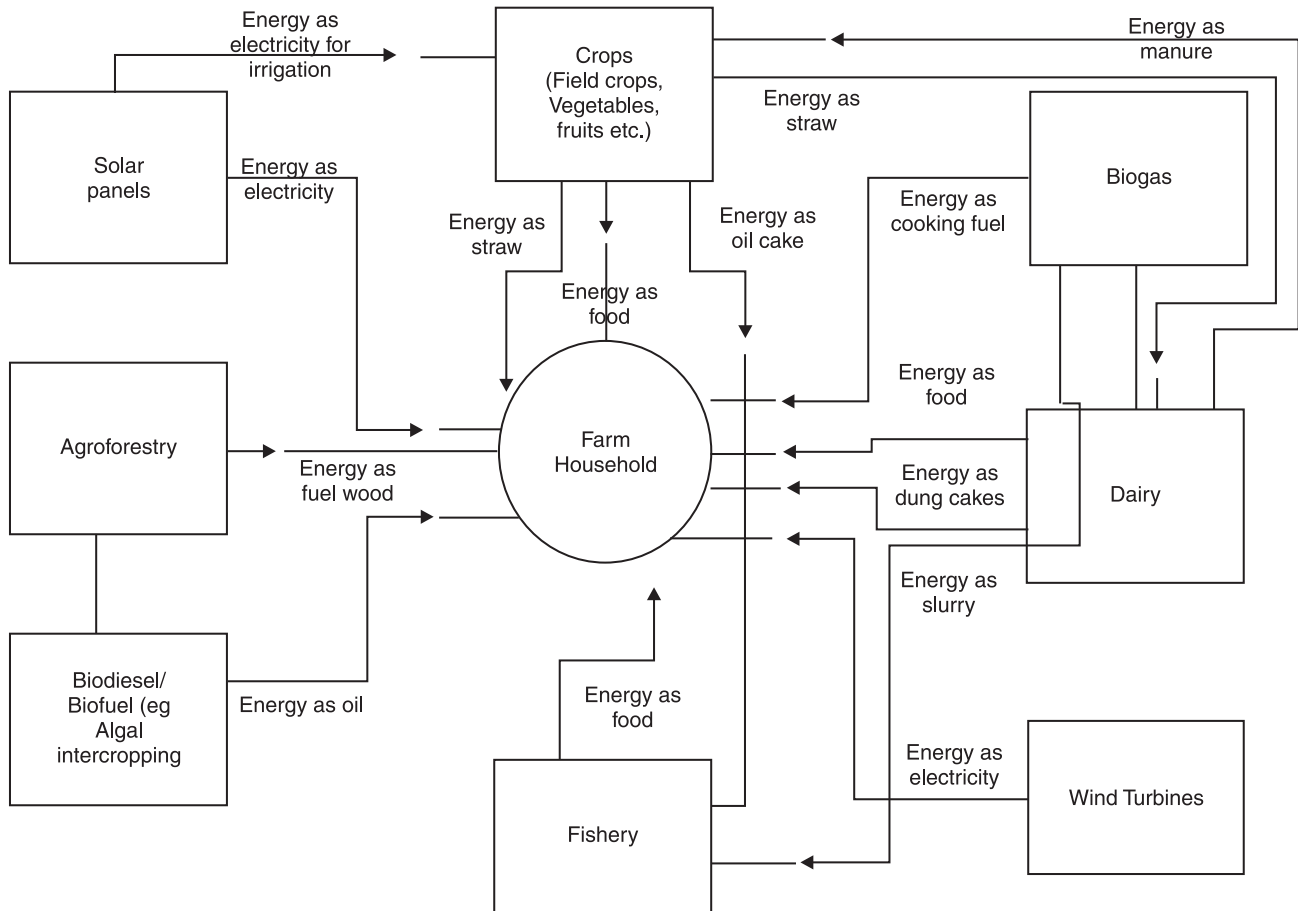
Farming system is a resource management strategy to avail maximum efficiency of a particular system. Studies conducted at Goa revealed the higher energy use efficiency of IFS with rice. Integration of poultry and mushroom enterprises with rice-brinjal system required highest energy input whereas rice cropping alone recorded

the least requirement of energy. The energy output was maximum under rice-brinjal + mushroom + poultry. The output of multi-rice-based enterprise was reasonably good varying from 1.91 to 10.5 lakh MJ/ha. It is thus evident that efficient utilization of scarce and costly resource is the need of the hour and can be accrued by following the concept of IFS through supplementation of allied agro-enterprises (Korikanthimath and Manjunath 2009).

Behera *et al.* (2014) undertook a case study in a small farm (1.25 ha) in eastern India involving IFS (crop-livestock-fishery-agroforestry) and presented a concept of energy self-sufficient integrated farming system. The total energy requirement involving farming and household was 314.597 MJ and there was net deficit of 62.743 MJ (5259 KWH). These energy requirements can be met by exploring renewable energy production from biogas, solar panel and windmill. The integration of modern energy sources with conventional wisdom of integrated farming as suggested by the concept is presented in graphical form (Fig 5). Its whole idea is to produce modern form of energy at the farm itself by linking various interdependent enterprises in order to bridge the energy deficit and future energy demands and offset emissions.

Crop based farming system for hilly areas

A micro-watershed based agro-pastoral system in a



Source: Behra *et al.* 2014

Fig 5 Energy flow among different components of the proposed E-IFS.

hilly slope holds promise for small and marginal farmers for sustaining their family and soil fertility on low input basis (Bhatt and Bujarbaruah 2005). Makdoh *et al.* (2014) also reported from Umiam, Meghalaya that due to adoption of multiple cropping sequences in a farming system approach, very high maize equivalent yield of 6.78 t (18.79 t/ha) was realized from an area of 0.36 ha in sloping land. The same land area if kept under maize monocropping would have given a maximum productivity of 3.85 t/ha under optimum management practices. Thus, a farmer can realize almost five times enhancement in productivity if the farming system concept with appropriate cropping sequences are adopted.

Sustainability through IFS

Sustainable development in agriculture must include integrated farming system (IFS) with efficient soil, water crop and pest management practices, which are environmentally friendly, and cost effective (Walia and Kaur 2013). Nutrient recycling within the system advocates the self-sustainability of the system and which will not only reduce the dependency on the external inputs viz, seed/ fertilizers etc. but also provide the balanced and rich nutrition to the farm family with reduced cost of cultivation and increased profit margin on the same piece of land which is key factor for taking care of sustainability. On any farm,

four natural ecosystem processes like energy flow, water cycle, mineral cycle and ecosystem dynamics work (Sullivan 2003). These four ecosystems processes function together, complementing each other as sustainable agriculture requires system approach (Singh *et al.* 2009) and system implies a set of agricultural activities organized while preserving land productivity and environmental quality and maintaining a desired level of biological diversity and ecological stability. A number of successful IFS models (size 4000m²) have been developed for different part of our country and by adopting those models' farmer's income can be increased many folds as well as sustainability and economic viability of small and marginal farmers can be maintained (Table 1).

Conclusion

Addition of organic residues in the form of animal and plant wastes help in improving the soil health and thereby productivity over a longer period of time with lesser environmental hazards with increased profit margin. IFS model comprising of crop components, dairy, poultry and fishery is the most suitable and efficient farming system model giving the highest system productivity for irrigated agro-ecosystem of north eastern plain zone while suitable IFS model for Indian Central Himalaya region is fishery + poultry + vegetable farming which has considerable potential

Table 1 Economic viability of Integrated Farming System Research models developed in different states of the country

State	Prevailing system	Net return	Integrated Farming System	Net returns	References
Tamil Nadu	Rice-rice-blackgram	8,312	Rice-rice-cotton + maize	15,009	Shanmugasundaram <i>et al.</i> (1995) Shanmugasundaram and Balusamy (1993)
			Rice-rice-cotton + maize + poultry /fish	17,209	
	Rice-rice	15,299	Rice-rice-Azolla/Calotropis + Fish	17,488	Balusamy (2003)
	Rice-rice-rice-fallow-pulses	13,790	Rice-rice-rice-fallow-cotton + maize + duck cum fish	24,117	Ganeshan <i>et al.</i> (1990)
	Cropping alone	36,190	Cropping + fish + poultry	97,731	Jayanthi <i>et al.</i> (2001)
Cropping + fish + pigeon			98,778		
Cropping + fish + goat			13,1118		
Rice	22,971	Rice + fish	28,569	Balusamy (2003)	
		Rice + Azolla + fish	31,788		
Goa	Cashew	36,330	Coconut + forage + dairy	32,335	Manjunath and Itnal (2003)
			Rice-brinjal (0.5 ha) + Rice-cowpea (0.5 ha) + mushroom + poultry	75,360	
Madhya Pradesh	Arable farming	24,093	Mixed farming + 2 cow	37,668	Tiwari <i>et al.</i> (1999)
			Dairy (2 cows) + 15 goats + 10 poultry + 10 duck + fish	44,913	
Maharashtra	Cotton (K) + Groundnut (S)	(-) 92	Blackgram(K) - Onion (R)- Maize + cowpea	1,304	Shelke <i>et al.</i> (2001)
			Crop + dairy + sericulture	3,524	
			Crop + dairy	5,121	
Punjab	Crops (rice-wheat)	81,200 (gross)	Crops (rice-wheat) + dairy	15,4000	Gill (2004)
			Fish + piggery	(gross) 113,200 (Gross)	
Uttar Pradesh	Crops (Sugarcane-wheat)	41,017	Crops (sugarcane+wheat)+dairy	47,737	Singh (2004) Singh <i>et al.</i> (2006)
			Crop + Dairy	103,615	
	Crops alone	66,371	Crop + Dairy + Horticulture	107,467	
			Crop + Dairy + Apiary	134,382	
			Crop + Dairy + Vermicomposting	139,472	
Karnataka	rice-rice system	21,599	Rice-fish (pit at the center of the field) – poultry (reared separately)	62,977	Chnnabasavanna and Biradar (2007)
			Rice-fish (pit at one side of the field) – poultry (shed on fish pit)	49,303	
Bihar	Rice-wheat	22,234	Cropping + poultry + goatry + mushroom	89413	Kumar <i>et al.</i> (2017).

to provide food security, nutritional benefits, employment generation and providing additional income to resource poor small farmers. In general, IFS enable the agricultural production system sustainable, profitable (3-6 fold) and productive on long term. About 90-95% of nutritional requirement is self-sustained through resource recycling which curtails the cost of cultivation and increases profit margins and employment. Therefore, it is imperative to state that to sustain food and nutritional security, IFS approach is promising and will conserve the resource base through efficient recycling of residues and wastes within the system.

The IFS models developed for different ecological

ecosystems and sub systems can be tuned through farmers' participatory trials with multilevel interventions itself on the farmers' fields. Undoubtedly, this approach is a location specific, technically skill based, play multidimensional role in fulfilling the domestic requirement, employment avenues, rational use of resources, sustaining productivity, invest ability and economic ability of the systems. Undoubtedly, integrated farming system enhances the net return, generates employment, conserves natural resources, reduces the cost of production and increases the overall income by minimizing risk. Hence, in the present scenario of agriculture sector, integrated farming system is the only approach that can

enable the Indian farmers self-sufficient and competitive in the global market by producing quality edible products on account of recycling the by-products of different enterprises.

Future thrust

- Creation of database on IFS throughout the country in relation to type and size of integrated farming systems, enterprise selected and their way of allocation, infrastructure, economics, economic sustainability of the system etc. under different ecological situations.
- Development of ecologically stable, environmentally sound and location specific low cost viable IFS modules for different holding sizes which are socially acceptable is required.
- On –farm testing and refinement of the developed modules according to the farmers' need and requirement as it is a continuous process i.e. addition of profitable components and replacement of less profitable components with time, choice of the farmers and availability of market.
- Need to study the sustainability of the developed or identified farming systems under different agro-climatic situations in the long run including high value crops.
- Need to study the nutrient dynamics of soil, accumulation of carbon and carbon sequestration with continuous cropping and recycling of organic resources in form of plant or animal wastes with different systems over time.
- Need to identify the constraints in adoption of identified integrated farming systems for particular area or locality.
- Documentation of ITKs of IFS in the farming community and its scientific validation.
- Need to prepare a strong policy draft for the consideration of planners for its promotion and creating awareness at large scale with some pity financial assistance either through loans or subsidy.

REFERENCES

- Balusamy M, Shanmugham P M and Baskaran R. 2003. Mixed farming an ideal farming. *Intensive Agriculture* **41** (11–12): 20–5.
- Behera U K and Mahapatra I C. 1999. Income and employment generation of small and marginal farmers through integrated farming systems. *Indian Journal of Agronomy* **44**(3): 431–9.
- Behera U K, Babu Amjath, Kasechele Harald and France J. 2014. Energy self-sufficient sustainable integrated farming systems for livelihood security under changing climate scenario. (In) *Proceedings of National Symposium on Agricultural Diversification for Sustainable livelihood and Environmental Security*, held during 18–20 November 2014 at Ludhiana, Punjab, p 576.
- Bhatt B P and Bujarbaruah K M. 2004. Characteristics of some Indian mountain firewood trees and shrubs in the North Eastern Himalayan region. *Renewable Energy* **29**: 1401–5.
- Bhatt B P and Bujarbaruah K M. 2005. Intensive integrated farming system: A sustainable approach of land use in eastern Himalayas. Technical Bulletin No, 46, ICAR Research Complex for NEH Region, Umiam, Meghalaya, pp 1–43.
- Bhatt B P, Bujarbaruah K M, Patnayak A, Mandal B K, Vinod K, Venkatesh M S, Rajkhowa C, Kumaresan A, Santosh A and Dutta M. 2005. Rice based integrated farming system in the North East. *Agroforestry in North East India: Opportunities and Challenges*, pp 575–87. Bhatt B P and Bujarbaruah K M (Eds). ICAR Research Complex for NEH Region, Umiam, Meghalaya.
- Bisht Deepa. 2011. Integrated fish farming for food, nutritional security and economic efficiency in mid hills of Indian Central Himalaya. *Research Journal of Fisheries and Hydrobiology* **18**: 1–6.
- Biswas C and Singh R. 2003. Integrated farming system: An intensive approach. *Intensive Agriculture* **41**(7–8): 22–3.
- Bohra J S, Kushwaha S, Sing S R, Singh Ravi Pratap, Singh S K, Singh Shobhit, Mishra Pankaj, Tripathi A K, Singh Neeraj and Singh Anupam. 2014. Watershed based integrated farming system modules for livelihood security of small and marginal farmers of Vindhyan region. (In) *Proceedings of National Symposium on Agricultural Diversification for Sustainable Livelihood and Environmental Security*, held during 18–20 November 2014 at Ludhiana, Punjab, pp 547–8
- Brouwer J and Powell J M. 1995. Soil aspects of nutrient cycling in a manure experiment in Niger. *Livestock and Sustainable Nutrient Cycling in Mixed Farming Systems of Sub-Saharan Africa. Vol II: Technical papers*. Powel J M, Fernandez-Rivera S, Williams T O and Renard C (Eds). *Proceedings of an International Conference* held during 22–26 November 1993 in Addis Ababa, Ethiopia, pp 349–60.
- Brouwer J and Powell J M. 1998. Micro-topography, water balance, millet yield and nutrient leaching in a manuring experiment on sandy soil in south-west Niger. (In) *Soil Fertility Management in West African Land Use Systems*. Renard G, Neef A, Becker K and Von Oppen M (Eds).. *Proceedings of a workshop* held during 4 - 8 March 1997 in Niamey, Margraf, Weikersheim, pp 349–60.
- Channabasavanna A S, Itnal C J and Patil S G. 2002. Productivity, economics analysis and changes in physico-chemical properties as influenced by integrated rice-based farming system. *Indian Journal of Agronomy* **46**(1): 1–5.
- Chnnabasavanna A S and Biradar D P. 2007. Relative performance of different rice-fish-poultry integrated farming system models with respect to system productivity and economics. *Karnataka Journal of Agricultural Sciences* **20**(4): 706–9.
- Channabasavanna A S, Biradar D P, Prabhudev K N and Hegde M. 2009. Development of profitable integrated farming system model for small and medium farmers of Tungabhadra project area of Karnataka. *Karnataka Journal of Agricultural Sciences* **22**(1): 25–7.
- Dhiman K R, Bujarbaruah K M and Satapathy K K. 2003. Integrated farming system for sustainable development of rainfed agriculture in North Eastern region. (In) *Proceedings of International Conference on World Perspective on Short Rotation Forestry for Industrial and Rural Development*, held during 7–13 September 2003 at Solan, Himachal Pradesh, p 154.
- Dugan P, Dey M M and Sugunan V V. 2006. Fisheries and water productivity in tropical river basins: enhancing food security and livelihoods by managing water for fish. *Agricultural Water Management* **80**: 262–75.
- Edwards P, Kaewpaitoon K, McCoy E W and Chantachaeng C. 1986. Pilot small scale crop/livestock/fish integrated farm, AIT Research Report 184, pp.131 Bangkok, Thailand, p 131.
- Edwards P, Pullin R S V and Gartner J A. 1988. Research and

- education for the development of integrated crop-livestock-fish farming systems in the tropics. *ICLARM Studies and Reviews* 16, Manila, Philippines.
- Faroda A S. 2014. Integrated farming system for livelihood and environmental security under rainfed conditions. (In) *Souvenir of National Symposium on Agricultural Diversification for Sustainable Livelihood and Environmental Security*, held during 18-20 November 2014 at Ludhiana, Punjab, pp 31-5.
- Ganesan G, Chinnasamy K N, Bala Subramanian A and Manickasundaram P. 1990. Studies on rice-based farming system with duck cum fish culture in deltaic region of Thanjavur district, Tamil Nadu. *Farming Systems Newsletter* 1(2) : 14.
- Ganesan S, Chinnaswamy K N, Balasubramaniam A and Manicksundaram P. 1999. Studies on rice-based farming systems with duck-cum fish culture in deltaic region in Thanjavur district of Tamil Nadu. *Farming Systems News Letter* 1(2): 15.
- Giap D H, Yi Y and Lin C K. 2005. Effects of different fertilization and feeding regimes on the production of integrated farming of rice and prawn *Macrobrachium rosenbergii*. *Aquaculture Research* 36: 292–9.
- Gill M S. 2004. Methodologies for farming system approach-A case study. (In) *Proceedings of National Symposium on Alternative Farming Systems*, held during 16-18 September 2004 at PDCSR, Modipuram, Meerut, pp 1-29.
- Gill M S, Singh J P and Gangwar K S. 2009. Integrated farming System and agriculture sustainability. *Indian Journal of Agronomy* 54(2): 128–39.
- Gill M S, Samra J S and Singh Gurbachan. 2005. Integrated farming system for realizing high productivity under shallow water-table conditions. Research Bulletins, Department of Agronomy, PAU, Ludhiana, pp 1-29.
- Gill M S, Singh J P, Gangwar B and Sarkar A. 2009b. Farming System approach towards income enhancement. (In) PDFSR Bulletin no.2009-1 Modipuram, Meerut, pp 1-92.
- GoI. 2014. *Agricultural statistics at a glance*, Directorate of Economics and Statistics, Govt. of India, New Delhi.
- Gupta V, Rai P K and Risam K S. 2012. Integrated crop-livestock farming systems: A strategy for resource conservation and environmental sustainability. *Indian Research Journal of Extension Education*, 2: 49–54.
- Inman D, Khosla R, Westfall D G and Reich R. 2005. Nitrogen uptake across site- specific management zones in irrigated corn production systems. *Agronomy Journal* 97: 169–76.
- Jayanthi C, Rangasamy A, Mythili S, Balusamy M, Chinnusamy C and Sankaran N. 2001. Sustainable productivity and profitability to integrated farming systems in low land farms. *Extended Summaries, National Symposium on Farming System Research on New Millennium*. Singh A K, Gangwar B, Pankaj and Pandey P S (Eds). PDCSR, Modipuram, Meerut, pp 79-81.
- Jayanthi C, Balusamy M, Chinnusamy C and Mythili S. 2003. Integrated nutrient supply system of linked components in lowland integrated farming system. *Indian Journal of Agronomy* 48: 241–6.
- Jayanti C, Sakthivel N, Marimuthu S, Vivek G and Kandaswamy O S. 2004. Efficient integrated farming system for increasing the farm productivity of resource poor farmers. Singh A K, Gangwar B, Sharma G C and Pandey P S (Eds). Farming System Research and Development Association, Modipuram.
- Korikanthimath V S and Manjunath B L. 2005. Resource use efficiency in integrated farming systems. (In) *Proceedings of Symposium on Alternative Farming Systems: Enhanced income and employment generation options for small and marginal farmers*. PDCSR, Modipuram, pp 109-18.
- Korikanthimath V S and Manjunath B L. 2009. Integrated farming systems for sustainability in agricultural production. *Indian Journal of Agronomy* 54(2):140–8.
- Kulkarni Shyam Rao, Upperi S N, Hurali Sujay, Ahmmed Zaheer and Goudar S B. 2014. Sustainable livelihood improvement of farmer through integrated farming system. *Proceedings of National Symposium on Agricultural Diversification for Sustainable Livelihood and Environmental Security*, held during 18-20 November 2014 at Ludhiana, Punjab, p 574.
- Kumar Sanjeev, Singh S S, Shivani and Dey A. 2011. Integrated farming system for eastern India. *Indian Journal of Agronomy* 56(4): 297–304.
- Kumar Sanjeev, Singh S S, Meena M K, Shivani and Dey A. 2012a. Resource recycling and their management under integrated farming system for lowlands of Bihar. *Indian Journal of Agricultural Sciences* 82(6): 504-10.
- Kumar Sanjeev, Subhash N, Shivani, Singh S S and Dey A. 2012b. Evaluation of different components under Integrated Farming System (IFS) for small and marginal farmers under semi-humid climatic environment. *Experimental Agriculture* 48 (3): 399-413.
- Kumar Sanjeev, Singh S S, Kumar Ujjwal, Dey A and Shivani. 2013. Sustainability of integrated farming systems in the eastern region. *Natural Resource Conservation- Emerging Issues and Future Challenges*, pp. 455-64. Madhu M, Jakhar Praveen, Adhikarry P P, Gowda Hombe, Sharda V N, Mishra P K and Khan M K (Eds).
- Kumar Sanjeev, Bhatt B P, Dwivedi S K and Shivani. 2015. Family farming- A mechanism to contribute towards global food security. *Indian Farming* 64(12): 13-8.
- Kumar Sanjeev, Shivani, Samal S K, Dwivedi S K and Manibhushan. 2017. Enhancement in productivity and income sustainability through integrated farming system approaches for small and marginal farmers of Eastern India. *Journal of AgriSearch* 4(2): 85–91.
- Lal R and Miller F P. 1990. Sustainable farming for tropics. *Sustainable Agriculture: Issues and Prospective*, Vol 1 pp 69-89. Singh R P (Ed). Indian Society of Agronomy, IARI, New Delhi.
- Makdoh Badapmain, Das Anup, Ramkrushna G I, Daunisuting Jayantalayek, Lyngdoh M, Panwar A S and Ngachan S V. 2014. Farming system approach for organic food production in Hills: A land-use model for sloping land of Meghalaya. *Proceeding of National Symposium on Agricultural Diversification for Sustainable Livelihood and Environmental Security*, held during 18-20 November 2014 at Ludhiana, Punjab, pp 542-3.
- Mali Hansram, Kumar Amit and Katara Pawan. 2014. Integrated farming system for irrigated and rainfed conditions. (In) *Proceedings of National Symposium on Agricultural Diversification for Sustainable Livelihood and Environmental Security*, held during 18-20 November 2014 at Ludhiana, Punjab, p 546.
- Manjunath B L and Itnal C J. 2003. Farming system options for small and marginal holdings in different topographies of Goa. *Indian Journal of Agronomy* 48(1): 4–8.
- Manjunath B L and Singh M P. 2012. Farming system options for different topographical situations of west coast region. *Extended Summaries Vol 3: 3rd International Agronomy Congress*, held during 26-30 November 2012 at New Delhi, pp 988-90.
- Mathew T and Varughese K. 2007. Nutrient flow and economics of integrated farming system practiced in the coastal region

- of Kerala. (In) *National Symposium on Integrated Farming Systems and its Role towards Livelihood Improvement under Indian Context*, held during 26-28 October 2007 at RARS, Durgapura (Jaipur) RAU, Farming System Research and Development Association, Modipuram.
- Matsumoto H and Matsuyama S. 1995. *Livestock Hygiene*. Japan Agricultural Development and Extension Association, Japan.
- Moriya K and Kitagawa M. 2007. Old and new near-future style agricultural production. (In) *New challenges in Livestock Production*, pp 217-44. Imai H (Ed.). Kyoto University Press.
- Mustow S E. 2002. The effects of shading on phytoplankton photosynthesis in rice-fish fields in Bangladesh. *Agriculture, Ecosystems and Environment* **90**: 89-96.
- NABARD Rural Pulse 2014. Agricultural land holdings in India Issue-I:1-4
- Olele N F, Nweke F U and Agbogidi O M. 1999. Role of integrated farming system in agricultural development in the delta region of Nigeria. *Delta Agriculture* **6**: 128-34.
- Naik B K. 1998. 'Farming systems in Uttara Kannada –An econometric analysis'. PhD (Agri.) Thesis, University of Agricultural Sciences, Dharwad.
- Panwar A S. 2014. Livestock based farming system for small and marginal farmers of north-eastern hill region. (In) *Proceedings of National Symposium on Agricultural Diversification for Sustainable Livelihood and Environmental Security*, pp 531-32, held during 18-20 November at Ludhiana, Punjab.
- ParodaRaj. 2012. Climate smart agriculture for improving livelihoods of small holder farmers. *Extended Summaries Vol I: 3rd International Agronomy Congress*, pp. 01-04, held during 26-30 November 2012 at New Delhi, pp 01-04.
- Rahman F H and Sarkar S. 2012. Efficient resource utilization through integrated farming system approach in the farmers' field at Burdwan district of West Bengal. *Extended Summaries Vol 3: 3rd International Agronomy Congress*, held during 26-30 November 2012 at New Delhi, pp 997-8.
- Ramrao W Y, Tiwari S P and Singh P. 2005. Crop-livestock integrated farming system for augmenting socio-economic status of smallholder tribal of Chhattisgarh in central India. *Livestock Research for Rural Development*, Vol **17**, Article#90. <http://www.lrrd.org/lrrd17/8/ramr17090.htm>
- Ramrao W Y, Tiwari S P and Singh P. 2006. Crop-livestock integrated farming system for the marginal farmers in rainfed regions of Chhattisgarh in central India. *Livestock Research for Rural development*. **18**(7): Article # 102. <http://www.lrrd.org/lrrd18/7/ramr18102.htm>
- Rangaswami A, Manicksundaram P and Vidhya G. 1999. Integrated farming system: a variable approach. *Farming Systems News Letter* **1**(2): 11-3.
- Reddy M D. 2005. Predominant farming systems and alternatives in Andhra Pradesh. *Journal of Farming Systems Research Development* **11**: 217-27.
- Saxena D C, Singh N P, Satapathy K K, Panwar A S and Singh J L. 2003. Sustainable farming systems for hill agriculture. (In) *Proceeding of National Seminar 'Approaches for Increasing Agricultural Productivity in Hill and Mountain Ecosystem'*, held during 18-20 October, 2001 at Barapani, pp 73-85.
- Sharma S K, Sharma R K, Jajoria Dinesh and Kumar Ashok. 2014. Enhancing income and resource conservation through micro farming systems. (In) *Proceedings of National Symposium on Agricultural Diversification for Sustainable Livelihood and Environmental Security*, held during 18-20 November 2014 at Ludhiana, Punjab, pp 561-2.
- Shanmugasundaram V S and Balusamy M. 1993. Rice-fish- *Azolla*- An Integrated Farming System in low land wetlands. *Farming Systems* **9**: 105-7.
- Shanmugasundaram V S, Balusamy M and Rangaswamy A. 1995. Integrated farming system research in Tamil Nadu. *Journal of Farming Systems Research and Development* **1**(1 and 2): 1-9.
- Shelke V B, Kulkarni S N, Waghmore D B and Chavan A. 2001. Study on integrated farming system in Marathwada. *Extended Summaries: 1st National Symposium on Farming System Research in New Millennium*, held during 15-17 October, 2001 at PDCSR, Modipuram, pp 99-100.
- Sheokand R S, Narinder S and Sheoran O P. 2000. Comparative economics of different farming systems under paddy-wheat farming sequence in rice-belt of Haryana. *Haryana Agricultural University Research Journal* **30**(1/2): 49-53.
- Siddeswaran K, Sangetha S P and Shanmugam P M. 2012. Integrated farming system for the small irrigated upland farmers of Tamil Nadu. *Extended Summaries Vol 3: 3rd International Agronomy Congress*, held during 26-30 November 2012 at New Delhi, pp 992-3.
- Singh Gurbachan. 2004. Farming systems options in sustainable management of national resources. (In) *Proceedings of National Symposium on Alternative Farming Systems*, held during 16 to 18 September 2004 at PDCSR, Modipuram, Meerut, pp 80-94.
- Singh Gurbachan. 2012. Integrated farming systems: option for diversification to manage climate change related risk and livelihood security. (In) *lead papers Vol -I Third International Agronomy Congress*, held during 26-30 November at New Delhi, pp 93-4.
- Singh J P, Gangwar B, Kochewad S A and Pandey D K. 2012. Integrated farming system for improving livelihood of small farmers of western plain zone of Uttar Pradesh, India. *SAARC Journal of Agriculture* **10**(1): 45-53.
- Singh K, Bohra J S, Singh Y and Singh J P. 2006. Development of farming system models for the north-eastern plain zone of U.P. *Indian Farming* **56**(2): 5-11.
- Singh N P, Manjunath B L, Mahajan Gopal, Devi Priya, Desai A R, Das S K, Chakurkar E B and Swain B K. 2014. Development of integrated farming system models for west coast region, profitability and livelihood security in Garhwal region. (In) *Proceedings of National Symposium on Agricultural Diversification for Sustainable Livelihood and Environmental Security*, held during 18-20 November 2014 at Ludhiana, Punjab, pp 554-5.
- Singh R A, Singh D and Khan K. 2010. Integrated farming for rural prosperity and livelihood security based on watershed technology in Bundelkhand. *Range Management and Agroforestry* **31**(2): 130-2.
- Singh Rajender, Singh Narinder, Phogat S B, Sharma U K, Singh R and Singh N. 1999. Income and employment potential of different farming system. *Haryana Agricultural University Journal of Research* **29**(3-4): 143-5
- Singh S P, Gangwar B and Singh M P. 2009. Economics of farming systems in Uttar Pradesh. *Agricultural Economics Research Review* **22** (January-June): 129-38.
- Singh V P and Rai S C. 2006. Integrated Farming System. *World Food Day*: 31-6.
- Solaiappan U, Subramanian V and Maruthi Sankar G R. 2007. Selection of suitable integrated farming system model for rainfed semi-arid vertic Inceptisols in Tamil Nadu. *Indian Journal of Agronomy* **52**(3): 194-7.

- Sullivan P. 2003. Applying the Principles of Sustainable Farming: Fundamentals of Sustainable Agriculture. ATTRNA- National Sustainable Agricultural Information Service, Fayetteville, USA.
- Sutradhar P. 2016. Improved farming system technology inclusion into existing farming system for sustainable agriculture. *Ph D Thesis*, Assam Agricultural University, Jorhat, pp 1-120.
- Tiwari S P, Ravi R, Nandeha K L, Vardia H K, Sharma R B and Rajgopal S. 1999. Augmentation of economic status of Bastar tribals through integrated (crop, livestock, poultry, duck, fish) farming system. *Indian Journal of Animal Sciences* **69**(6): 448–52.
- Ugwumba C A O, Okah R N, Ike P C, Nnabuiife E L C and Orji E C. 2010. Integrated farming system and its effect on farm cash income in Awka South Agricultural zone of Anambra state, Nigeria, *Am. Euras Journal of Agriculture and Environment Science* **8**(1): 1–6.
- Varughese K and Mathew T. 2009. Integrated farming systems for sustainability in coastal ecosystem. *Indian Journal of Agronomy* **54** (2): 120–7.
- Vincke M. 1988. La rizipisciculture et les elevageassociesenAfrique. *CIFA Technical Paper (4) Suppl 1*: 659–707.